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GEOLOGISKA FÖRENINGENS

I

STOCKHOLM

FÖRHANDLINGAR

TRETTIONDEANDRA BANDET

(ÅRGÅNGEN 1910)

DEL 3

MED 20 TAFLOR OCH TALRIKA FIGURER I TEXTEN

STOCKHOLM
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
1911
[100170]

Innehållsförteckning.

Anm.	F.	efter	en	titel	utmärker	ett hållet *föredrag.*
	R.F.	»	»	»	»	*referat* af ett hållet *föredrag.*
	M.	»	»	»	»	ett lämnadt *meddelande.*
	R.M.	»	»	»	»	*referat* af ett lämnadt *meddelande.*
	R.	»	»	»	»	*refereradt arbete.*
	U.	»	»	»	»	en *uppsats.*

Författarna äro ensamma ansvariga för sina uppsatsers innehåll.

Sid.

Förteckning på taflorna.

Rättelser och tillägg till Band 32, Del 3.

(Corrections and additions to Vol. 32, Part 3.)

G. DE GEER, Quaternary Sea-bottons in Western Sweden:
Page 1158, line 1 from below, is printed 18.0, read 18.6.
» 1158, » 3 » » » » 27.1, » 26,1.

In the tables are the following errors to be corrected with regard to the sums:

Table	A	Pelecypoda	total:	col. 5	from the end, is printed	165.6,	read 166.6.
»	»	Balanidæ	» :	» 13	» » » » »	60.7,	» 420.7.
»	B	»	» :	» 2	» » » » »	584,	» 564.
»	»	Gastropoda	» :	» 2	» » » » »	50,	» 60.
»	C	Balanidæ	» :	» 5	» » » » »	233.5,	» 133.5.

H. MUNTHE, Studies in the Late-Quaternary history of South Sweden:
Page 1205, line 9 from above, researches is to be added after which.
» » » 17 » , is printed those instead of that.

Page 1208, Line 2 from below, is printed BRÖGGER instead of BRÖGGER'S
» 1212, » 12 from above, average annual is to be added next before temperature.
» 1216, » 12 » » , in southern and is to be added after oses.
» 1223, » 12—13 from below, is printed had — — the character of, read is — — represented by.
» 1230, » 8 from above, » » ice-border, read *ice*.
» 1255, » 8 from below, » » commons lopes, read common slopes.
» 1261, » 5 from above, is a comma to be taken away after was.
» 1268, » 5 » » is printed as, read a.
» 1269, » 7 from below, » » wa, » we.
» » » 6 » » , » » vallay, read valley.
» 1271, » 3 from above, » » S. » N.
» 1279, » 10 » » , » » giviny, » giving.
» 1282, » 13 » » , » » upparmost, read uppermost.

On the map, Pl. 47, the hypothetic terminal line Fd+e N. of Bråviken has by mistake become signed by coarse points instead of fine ones. — In the NE. corner of the same map a *C* is to be added, marking a northern branch of the terminal line in question. — Finally, it may be pointed out, *inter alia*. that the blue colour, or that for the *sea*, partly continues also within the areas of the Wetter ice-lake and the Baltic ice-lake, and that the designations for both of these ice-lakes are to be found between Hjo and Billingen as well as somewhat above the marine district within the southern part of lake Wettern (S. of Hjo etc.). These designations are, namely, not evident enough from the explanation to the map.

H. MUNTHE: On the Sequence of Strata within Southern Gotland:
Page 1397, Line 2 from above, is printed naturalist, read naturalists.
» 1398, » 12 from below, is printed all, read different.
» 1403, » 7 » above, » agress, » agrees.
» 1404, » 6 » » » 1897, » 1907.
» 1405, » 15 » » » interresting, » interesting.
» » » » » » » compe-(tely), » comple-(tely).
» 1407, » 7 » » » tubulaled, » tabulated.
» 1409, » 12—13 » » » *Chonetes* cfr. *minima*, read *Chonetes striatella* (a small var.)
» » » 21 » » » above, read under
» » » 4 » below, » send, » sent
» 1411, » 9 » » » SW., » S.
» 1413, » 7 » above, is and to be taken away.
» 1417, » 4—5 » » , is printed all forms, read most of them
» 1418, » 8 » » » *limbata*, » *limata*
» 1422, the table, — — is omitted before *Atrypa marginalis* var. *5-costata* in the columns Crinoidal limestone and Ascoceras limestone.
» 1425, line 7 fr. below and some other places, is printed *Strophomena* cfr. *Fletcherii*, read *Strophomena* cfr *Orbignyi*.

Page 1426, line 19 fr. below, is have to be taken away.
» 1430, » 3 » » is printed thought was, read was thought.

On the fig. 27, facing p. 1433 is S. l. (to the left) to be removed downwards near G. l.

Page 1433, the lowest line, is printed form, read forms
» 1435, line 16 fr. below, is printed DAME's read DAMES'
» 1435 » 9 » » many, » may
» 1437 » 5 » » occurs, » occur

Page 1440, line 15 fr. below, is printed a of, read of a
» 1446 » 14 » » the bed 5, » the lowest part of the bed 5
» 1452 » 18 fr. above, » Bd 23, » Bd. 43,

H. HEDSTRÖM, The stratigraphy of the Silurian strata of the Visby district:

Page 1457, line 5 from below, is printed fortsetz, read fortsetzt.
» 1462, in the scheme, part III, is printed but is, read but reefs are
» 1465, line 2 from above, » » » *Comphoceras*, read *Gomphoceras*
» 1474, » 20 » after sections is to be added (fig. 3)
» 1478, the explanation to fig. 4, line 2 from below, is printed white, read black
» 1483, line 17 from below, is printed *caronatum*, read *coronatum*.

Pl. 58, is printed Photo by G. HOLM, read Photo by the author.

GEOLOGISKA FÖRENINGENS

I STOCKHOLM

FÖRHANDLINGAR.

BAND 32. Häftet 5. Maj 1910. N:o 271.

Motet den 4 maj 1910.

Antal närvarande: 34.

Ordföranden, hr HÖGBOM, meddelade, att Föreningens Ledamot f. rektorn vid Tekniska skolan i Örebro, E. B. FERNQVIST, aflidit.

På Styrelsens förslag beslöt Föreningen, att, om så ansågs behöfligt, anordna extra Föreningsmöten dels i slutet af maj och dels omedelbart före Geologkongressen.

Härefter föredrogs *revisionsberättelsen* öfver Styrelsens och Skattmästarens förvaltning för år 1909 och beviljades af revisorerna tillstyrkt ansvarsfrihet.

Ur revisionsberättelsen framgår bland annat, att Föreningens *inkomster* under året utgjort sammanlagdt kr. 10,180.87, hvaraf behållning från år 1908 kr. 1,347.51, ledamotsafgifter kr. 4,000, statsanslag kr. 750, Jernkontorets bidrag (inlösen af 750 exemplar af tidskriften) kr. 750, försäljning af Förhandlingarna kr. 307,73, räntevinst kr. 435.86, annonsbilaga och diverse kr. 175.87 samt ersättning af Geologkongressen för Guide-tryck kr. 2,413.90. — *Utgifterna* hafva varit: omkostnader för tryckning af tidskriften kr. 7,963.52, för tidskriftens distribution kr. 701.74, arfvoden kr. 700, omkostnader för mötena, brandförsäkring m. m. kr. 212.05, afsättning till reservfonden kr. 500 och till registerfonden kr. 103.94. Vid årsskiftet fanns en brist å kr. 0.08.

Under förutsättning att K. Maj:t beviljade Föreningen begärdt anslag (750 kr.) såsom bidrag till fortsatt utgifvande under år 1910 af Föreningens Förhandlingar, beslöt Föreningen, att fullmakt skulle utfärdas åt Skattmästaren, prof. G. HOLM, att å Föreningens vägnar lyfta och utkvittera beloppet, samt att protokollsutdrag härom skulle meddelas prof. HOLM att såsom fullmakt gälla.

Hr QUENSEL höll ett af kartor, stuffer och fotografier belyst föredrag *om grunddragen af de patagoniska Andernas byggnad.*

I anslutning till föredraget yttrade sig hrr SVEDMARK, HEDSTRÖM, JOHANSSON, HÖGBOM och *föredraganden.*

Hr HOLMQUIST höll, under förevisning af kartor, profiler stuffer och fotografier, föredrag *om de tektoniska förhållandena vid Torneträsk.* (Jämför föredrag:s uppsats: Die Hochgebirgsbildungen am Torneträsk in Lappland i föregående häfte af Förhandlingarna.)

Med anledning af föredraget yttrade sig hrr HÖGBOM, HAMBERG och *föredraganden.*

Vid mötet utdelades N:r 268 af Föreningens Förhandlingar.

Extra möte den 31 maj 1910.

Ordföranden, hr HÖGBOM, meddelade, att Styrelsen till Ledamöter af Föreningen invalt:

Fil. kand. BENGT ESKOLA, Helsingfors,
på förslag af hrr Borgström och Ramsay;
Amanuensen, fil. stud. OLOF BAECKSTRÖM, Upsala,
på förslag af hrr A. G. Högbom och Quensel;
Herr JUSTUS CEDERQUIST, Stockholm,
på förslag af hr Holm;
Fil. kand. GRETA PHILIP, Upsala,
på förslag af hr Högbom, samt
Direktör AUG. REINHOLD,
på förslag af hr Holm.

Cederquists Graf. A.-B., Sthlm.

Fig. 1. Der Kalktuff bei Skultorp von Westen gesehen. (Aus *Hulth* 1899).

Die Entwicklung der Molluskenfauna in dem Kalktuffe bei Skultorp in Wästergötland.

Von

NILS ODHNER.

Einleitung.

Mit Unterstützung von »Sveriges Geologiska Undersökning» (Schwedische Geologische Landesanstalt) unternahm ich im Mai dieses Jahres eine Reise nach Skultorp am Fusse des Billingen in Wästergötland, um hier eine Einsammlung von Mollusken aus der bekannten Kalktuffablagerung vorzunehmen. Meine Absicht war, die von HULTH (1899) schon vorgenommenen Untersuchungen über die Molluskenfauna zu ergänzen um auf diese Weise zu versuchen sowohl die geologische Entwicklung der Fauna zu verfolgen als auch die klimatischen Epochen der postglazialen Zeit zu konstatieren. Der vorliegende Aufsatz enthält die Resultate dieser Untersuchung.

HULTH, welcher den Tuff hauptsächlich in botanischer Hinsicht studiert und die Einwanderung der Flora ermittelt hat, führt folgende Schichten an, wozu noch SERNANDER (1902) und MUNTHE (1905) einige neue Angaben gefügt haben.

a.	*Wiesenkalk* mit Moosen und *Kalktuff* mit Blättern	0,3 —0,5 *m*
b.	*Humusstreifen*	0,05—0,2 »
c.	*Kalktuff* mit etwas *Wiesenkalk;* der Tuff untenan in Blöcke zerfallen	ca 2,5 »

d.	*Humusstreifen* mit *Tuff*	0,05—0,1	*m*
	Kalktuff, porös, gelblichweiss	0,1 —0,25	»
	Humusstreifen mit *Tuff*	0,05—0,1	»
e.	*Wiesenkalk* mit *Tuffstückchen*	0,6 —0,1	»
f.	*Tuff* mit Moosen (hauptsächlich *Amblystegium*)	0,1 —0,5	»
g.	*Schwemmsand* von wechselnder Mächtigkeit		
h.	*Kies mit Sand* gemischt, am Ufer des Eisstausees Wettern abgesetzt[1]	0,2 —0,3	»
(*k.*	Moräne	3—4	»
l.	Alaunschiefer).		

Da gerade die Pflanzen gute Auskünfte über die Klimaschwankungen geben, habe ich die von HULTH angetroffenen Arten in der folgenden Tabelle zusammengestellt, um zum Vergleich mit der Molluskenfauna zu dienen.

	f	d_2	*c*	*a*
Acer platanoides L.	.	.	+	+
Amblystegium glaucum LAM.	.	.	+	.
» **falcatum* (BRID.)	+	.	.	.
Betula alba L.	.	+	+	.
Corylus avellana L.	.	.	+	+
Equisetum hiemale L.	.	+	.	.
Marchantia polymorpha L.	.	+	.	.
Peltigera canina L.	.	+	.	.
Pinus silvestris L.	.	.	+	.
» » var. *lapponica* FR.	.	+	.	.
Populus tremula L.	.	+	+	+
Quercus robur L.	.	.	+	.
Salix caprea L.	.	+	+	+
» *cinerea* L.	.	+	+	.
» *glauca* L.	+	.	.	.
» *lanata* L.	+	.	.	.
» *reticulata* L.	+	.	.	.
Sorbus aucuparia L.	.	.	+	.
Tilia europaea L.	.	.	+	+
Ulmus montana SM.	.	.	+	+

[1] Nach MUNTHE 1905. Das Lager wurde zuerst von SERNANDER (1902) entdeckt, aber als eine Uferbildung der *Yoldiasee* aufgefasst.

Nach Hulth und Munthe (1905) ist die geologische Entwicklungsgeschichte des Lokales etwa die folgende. Als das Landeis geschmolzen war, dehnte sich über die Gegend der Eisstausee Wettern aus. Dieser wurde bald abgelassen und das Land kam dadurch über den Seespiegel zu liegen. Nun setzte sich der Schwemmsand (*g*) ab und wurde mit einem Teppich von *Amblystegium *falcatum* bedeckt. Nach einiger Zeit begannen die Quellen Kalk abzusetzen, und ausser *Amblystegium* wurden darin Blätter von *arktischen Salix*-Arten eingebettet (Schicht *f*). Danach folgte die Absetzung des Wiesenkalkes (*e*), worin Moose eingebettet vorkommen. Es trat nun eine Zeit ein, wo die Quellen eintrockneten oder das Wasser in anderer Richtung abfloss, und so wurde der Humusstreifen (d_3) gebildet. Die Tuffabsetzung beginnt dann wieder (Schicht d_2). Die *Birke*, die *Kiefer* (*Pinus silvestris* var. *lapponica*), die *Espe* und einige *Weiden* bildeten jetzt die hauptsächliche Vegetation des Lokales. Diese Zeit war die *Espen-Birken*-Periode. Der folgende Zeitabschnitt, wo die Kiefer auftrat, zeichnet sich durch Austrocknen der Quellen aus; viele Landschnecken wandern nun ein (Humusstreifen d_1). Dieser Periode folgte eine andere nach, wo die Quellen wieder reichlich fluteten und das mächtige Tuff- und Wiesenkalklager *c* absetzten. Die *Eiche* war nun eingewandert, und mit ihr zusammen bildeten *Esche*, *Linde*, *Ulme* und *Ahorn* üppige Laubwiesen am Abhang des Billingen. Dies war die *Eichen*-Periode. Auch die Mollusken waren reichlich vertreten. Später trockneten die Quellen wieder (Humusschicht *b*), um darauf noch einmal zu fluten, wodurch die Schicht *a* gebildet wurde. Die Laubbäume waren jetzt dieselben als in *c*, aber nicht so reichlich vorhanden. Schliesslich sind die Quellen ganz ausgetrocknet, wodurch eine neue Humusschicht (die oberflächlichste) sich gebildet hat.

Hulth und Sernander erklären das Alternieren von Tuff und Humusschichten als direkte Folgen von *abwechselnden feuchten und dürren Zeitabschnitten*, so dass sie die *borealen*, *atlantischen, subborealen und subatlantischen Perioden* von Blytt repräsentieren. Munthe hat dagegen die Vermutung ausgesprochen, dass die betreffenden Schichten möglicherweise nur durch lokale Veränderungen des Wasserstandes zu erklären sind. Man könnte sich nämlich vorstellen, dass die Absetzung in einem kleinen Wasserbecken vorsichgegangen ist, und dass zuweilen dessen Dämme erodiert wurden, wodurch das Wasser abfloss und eine Humusschicht abgesetzt wurde.

Seit den Besuchen Hulth's ist der Kalktuff durch Graben sehr vermindert worden, und die Lagerungsverhältnisse zeigen sich daher teilweise anders als die von ihm beschriebenen. Das Profil hat eine westliche steile Hauptfassade, deren nördliches Ende quer abgeschnitten worden ist, so dass hier die Wand nach Nordwesten zu liegt. Im südlichen Teil des Profils findet sich noch ein kleiner Rest des von Hulth erwähnten Ganges, und jenseits dieses folgt noch eine kurze Strecke der Hauptwand. (Vgl. Fig. 1.)

Von etwa 5 Stellen habe ich Probenserien aus den Schichten genommen. Wegen der steilen Wände der westlichen Seite konnten hier nur die untersten Schichten erreicht werden, und nur in den nördlichen und südlichen Ecken konnte daher je eine zusammenhängende Serie von Proben durchsucht werden (Lokale 3 und 4). Von den anderen Lokalen sind nur Proben aus den oberen Schichten eingesammelt worden, da die unteren von Talusbildungen bedeckt waren. Lokal 1 liegt an der nordwestlichen Wand, Lokal 5 in dem südlichsten Teil des Profils und die anderen dazwischen. Die unten gegebene Skizze (Fig. 2) und Tabelle zeigen die Lage und die Lagerungsverhältnisse der Lokale.

Alle die von Hulth besprochenen Schichten konnten identifiziert werden, und ich habe im folgenden seine Bezeichnungen angewandt. Infolge des Weggrabens einer grossen Partie des westlichen Teiles waren ausserdem einige andere von HULTH nicht erwähnte Schichten zum Vorschein gekommen; diese wurden im südlichen Teil des Profils angetroffen. Hier fand ich nämlich (Lokal 4), direkt auf der Moräne, eine dünne Schicht von glazialem Ton, die eine Mächtigkeit von ca 13 *cm* besass und vier horizontale Streifen zeigte. Das Vorkommen dieses Tones beweist, dass der Kalktuff etwas unterhalb der höchsten spätglazialen Meeresgrenze gelegen ist. Die Tonschicht erstreckt sich gegen das nördliche Ende des Profils hin, verdünnt sich aber allmählich und ist schliesslich bei Lokal 2 ganz verschwunden. Eine ähnliche Diskor-

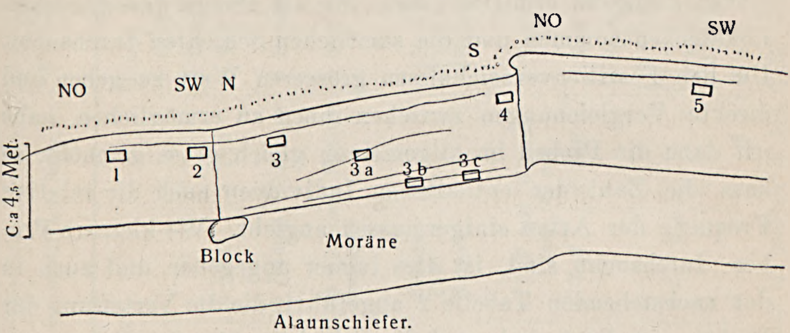

Fig. 2. Das Profil von Westen gesehen. Skizze um die Lage der Lokale 1—5 zu zeigen. Die Humusstreifen sind eingezeichnet.

danz zeigen die nächst überliegenden Lager, wie auch HULTH bemerkt; von dem Lager *d* aber aufwärts folgen die Schichten regelmässig aufeinander, doch mit einer Ausnahme. Sowohl bei Lokal 4 als 5 treten nämlich in dem oberen Teil des Profils zwei neue Schichten hinzu, die an den anderen Stellen nicht vorkommen, und die von HULTH nicht erwähnt werden. Es sind dies eine direkt auf dem Kalktuffe *a* liegende Humusschicht, die ich mit β bezeichnet habe, und ein darüber befindlicher Schwemmsand mit *Pisidien*, im folgendem mit α bezeichnet. Diese beiden verschmelzen wieder gegen die Enden zu, bis sie, wenigstens im nördlichen Ende des Profils, ganz schwinden. Ihrer Lage nach dürften sie dem oberen Teil der Kalktuffschicht *a* der übrigen Lokale entsprechen, denn über dieser folgt, wie auch in den Lokalen 4 und 5 über α, unter allmählichem Übergang, das oberflächliche Humuslager.

Über die Mächtigkeit der Schichten an den verschiedenen Lokalen giebt die nachstehenden Tabelle 1 Auskunft.

Da man nun in diesem Kalktuffe eine lückenlose Serie von Schichten von dem glazialem Ton an bis zu dem rezenten Humus vor sich hat, ist es sehr wahrscheinlich, dass auch die in dem Tuffe enthaltenen Fossilien einen kontinuierlichen Entwicklungsverlauf der Fauna während der postglazialen Zeit abspiegeln. Um in möglichst vollständiger Weise diese Entwicklung zu ermitteln, habe ich die Proben verschiedenen Lokalen entnommen und die sämtlichen Schichten durchsucht. Um den Fossilienverzeichnissen grösseren Wert zu geben und direkte Vergleichungen zwischen ihnen zu ermöglichen, habe ich dazu die Proben im allgemeinen gleich gross gemacht, so dass die Zahl der enthaltenen Individuen auch die relative Frequenz der Arten einigermassen angiebt. Wo kleinere Proben durchsucht sind, ist dies immer angegeben und auch in der nachstehenden Tabelle 2 angeführt, die die Verteilung der Proben auf die Lokale und die Schichten übersichtlich veranschaulicht.

Die Entwicklungsstufen der Molluskenfauna spiegeln oft sehr treu die klimatischen Perioden ab. Auch habe ich im folgenden stets versucht, das Klima der Absetzungszeit jeder Schicht nach der Fauna wenn möglich zu bestimmen. Jede der einzelnen Schichten ist zuerst in chronologischer Ordnung behandelt; danach wird eine tabellarische Übersicht über das ganze faunistische Material gegeben, und dann folgen einige allgemeine Bemerkungen über die gewonnenen Resultate nebst Vergleichungen mit anderen Kalktufffaunen in Schweden.

Schliesslich habe ich eine tabellarische Übersicht sämtlicher Mollusken, die bisher in den quartären Ablagerungen von Schweden angetroffen sind, als Anhang beigefügt, um dadurch den fühlbaren Mangel eines kurzen Resumees der schon bekannten Tatsachen über die Einwanderung und die

I. Tabellarische Übersicht der Schichtenfolge.

Lokal	1	2	3	3 a	3 b	3 c	4	5
Lage	N. Seite, östlich.	N. Seite, westlich.	N. Ende der westlichen Seite.	Mitte der westlichen Seite.			S. Ende der westlichen Seite.	Südlichster Teil des Profils.
Schichtenfolge	Humus		Humus				Humus	
							α Schwemmsand ca 20 *cm*	α Schwemmsand } 40 *cm*
							β Humus ca 10 *cm*	
	a Tuff ca 14 *cm*	*a* Tuff ca 50 *cm*	*a* Tuff	*a* Tuff	*a* Tuff	*a* Tuff	*a* Tuff ca 18 *cm*	*a* Tuff
	b Humus ca 10 *cm*	*b* Humus ca 10 *cm*	*b* Humus	*b* Humus	*b* Humus	*b* Humus	*b* Humus ca 10 *cm*	*b* Humus ca 10 *cm*
	c Tuff ?	*c* Tuff ca 245 *cm*	*c* Tuff	*c* Tuff, mitten mit einem Humusstreifen [2]			*c* Tuff ca 210 *cm*	*c* Tuff ca 90 *cm*
	d ?	*d*[1] {Humus 3 *cm*, Tuff ca 35 *cm*, Humus ca 10 *cm*}	*d* {Humus, Tuff, Humus}	*d* {Humus, Tuff, Humus}			*d* {Humus ca 5 *cm*, Tuff, Humus} 23 *cm*	*d* {Humus, ?}
	?		*e* Tuff	*e* Tuff	*e* Tuff mit Wiesenkalk 55 *cm*		*e* Tuff und Wiesenkalk 36 *cm*	?
				f Tuff	*f* Tuff	*f* Tuff	*f* Tuff 19 *cm*	
							g Schwemmsand 15 *cm*	
				Glazialer Ton			{»Mjäla»-Schicht, Graue » 5—7 *cm*, Braune » 3—3,5 *cm*, »Mjäla»-Schicht 1—2 *cm*}	
	Moräne		Moräne				Moräne	Moräne

[1] 12 *cm* oberhalb des oberen Humusstreifens findet sich ein anderer in dem Tuffe; südwärts steigt dieser aufwärts und geht in den Humusstreifen der Lokale 3 a, b und c über.

[2] Der Humusstreifen hat hier eine Mächtigkeit von 10 *cm* und befindet sich 170 *cm* aufwärts in dem Tuffe.

2. Tabellarische Übersicht der Lage der Proben.

Lokal	1	2	3	3 a	3 b	3 c	4	5
Lage der Proben	Humus 1 Probe	Humus 1 Probe in der Grenze zu dem Tuffe					Humus 1 Probe	
							α Schwemmsand 1 Probe	α Schwemmsand 1 Probe
							β Humus 1 Probe	
	a Tuff 1 Probe	*a* Tuff	*a* Tuff				*a* Tuff 1 Probe	
	b Humus 2 Proben	*b* Humus 2 Proben	*b* Humus 1 Probe				*b* Humus 1 Probe	
	c Tuff { 1 obere Probe	*c* Tuff { 1 Probe 215 *cm* ob. d. Grundes; 1 Probe 135 *cm*; 1 Probe 50 *cm*; 1 Probe am Grunde		*c* Tuff { 1/3 Probe 170 *cm* ob. d. Grundes; 1/3 Probe 80 *cm* ob. d. Grundes			*c* Tuff { 1 Probe 170 *cm* ob. d Grundes; 1 Probe 85 *cm*; 1 Probe am Grunde	*c* { Tuff 1 Probe am Grunde
		d { Humus 1 Probe; Tuff 1 Probe; Humus 1 Probe			*d* { Unterer Humus 1 Probe	*d* { Unterer Humus 1 Probe	*d* { Humus 1 Probe; Tuff 1 Probe; Humus 1 Probe	*d* { Humus 1 Probe
						e Wiesenkalk 2/3 Probe	*e* Wiesenkalk 1 Probe	
							f Tuff 1 Probe	
							g Schwemmsand 1 Probe	

Entwicklungsstufen der skandinavischen Molluskenfauna einigermassen abzuhelfen.

Die Autorennamen habe ich in den Fossilienverzeichnissen, der Kürze wegen, weggelassen und nur in den übersichtlichen Tabellen beibehalten.

I. Die Fauna der einzelnen Schichten.

Die unterste fossilführende Schicht des Profiles ist ***der untere Schwemmsand g,*** der nur in Lokal 4 gut ausgebildet ist. Da er dem unterliegenden glazialen Lehm direkt anlagert und in ihn überzugehen scheint, muss seine Absetzung kurz nach der partiellen Senkung des Eisstausees Wettern begonnen haben;[1] er ist also glazialen Alters. Die wenigen angetroffenen Mollusken stützen auch diese Annahme. Sie sind:

Hyalinia hammonis, 1 Fragment. *Pisidium fossarinum*, 5 Ex.
Pupa arctica, 1 Ex.

Es wurden auch zwei kleine Fragmente von einer grösseren Schnecke gefunden, die jedoch nicht bestimmbar waren.

Hulth hat in dieser Schicht auch *Conulus fulvus*, *Punctum pygmaeum* und eine unbestimmte *Pupa* entdeckt.

Ausserdem wurden einige Teile von Coleopteren hier angetroffen. Nach vorläufiger Bestimmung von Dr. E. Mjöberg gehören diese (ein Kopf, ein Flügel und ein Bein) den Gattungen *Aphodius* und *Cercyon* an.

Unter den Mollusken erregt *Pupa arctica* das grösste Interesse. Diese ist nämlich eine ausgesprochen arktische Spezies, die ihre Heimat nur in den nördlichsten Teilen von Skandinavien und Finnland, in Tirol und in den höchsten Regionen des Riesengebirges hat. Sie kommt in Schweden jedoch weit nach Süden hin vor, nämlich bis Uppland und Södermanland (wo ich sie bis Nyköping angetroffen habe) und ausserdem noch in Småland. In den letzteren Gegenden

[1] Siehe H. Munthe, Studies in the Late-Quaternary history of Southern Sweden. G. F. F. **32**, 1910.

ist sie als ein echtes glaziales Relikt zu betrachten; dass sie eigentlich mehr nördlich zu Hause ist, zeigt der Umstand, dass sie erst dort ihre Maximallänge erreicht, wie aus den nachstehenden Massangaben ersichtlich ist:

Grösstes Ex. aus	Små-land.	Stock-holm.	Gestrik-land.	Da-larne.	Härje-dalen.	Jämt-land.	Lapp-land.
Länge in *mm* . .	2.1	2.2	2.3	2.3	2.4	2.5	2.5
	(1 Ex. aus dem Reichs-museum.)	(1 Ex. von 40 gemes-senen.)	(1 Ex.)	(1 Ex. von 15 gemes-senen.)	(1 Ex.)	(1 Ex. von 3 gemes-senen.)	(1 Ex. nach ODHNER 1908.)

Sämtliche gemessenen Exemplare waren völlig ausgewachsen und hatten die gleiche Zahl von Windungen. Diese Masse zeigen daher deutlich, dass die Art nach Norden hin an Grösse zunimmt, und dass also die südlich lebenden Individuen unter ungünstigeren Bedingungen ihr Dasein führen. [1] Wenn man nun das aus der vorhandenen Schicht herrührende Exemplar mit den obenstehenden der Länge nach vergleicht, findet man eine völlige Übereinstimmung mit den Exemplaren aus Jämtland und Lappland, denn seine Länge beträgt *2.5 mm.* Man kann daraus schliessen, dass die klimatischen Verhältnisse den jetzigen von Lappland oder Jämtland entsprachen, so dass die mittlere Julitemperatur höchstens 13° betrug und das Klima also völlig arktischen Charakter hatte.

Der Fund von *Pupa arctica* in dieser Schicht ist um so mehr von Interesse, als sie in Schweden nicht fossil bekannt gewesen ist.[2] Er zeigt auch, dass sie von Süden her eingewandert ist, was im Gegensatz zu anderen arktischen Formen steht, z. B. *Acanthinula harpa*, die allem Anschein nach vom Norden aus sich südwärts verbreitet hat.

Die übrigen Funde derselben Schicht widersprechen den obigen Schlussfolgerungen nicht, denn die Arten sind alle weitverbreitet und somit auch in der arktischen Region zu Hause. *Pisidium fossarinum*, eine Art, die grosser Variation

[1] LUTHER (1901) hat dieselbe Beobachtung in Finnland gemacht.

[2] Im nördlichen Deutschland ist sie in glazialen Ablagerungen angetroffen worden (MENZEL 1910).

unterworfen ist, zeigt hier auch eine ausserordentliche Ähnlichkeit mit lappländischen Exemplaren derselben Art.

Inwieweit die *Coleopteren* auch auf ein arktisches Klima deuten, muss noch dahinstehen.

In dem ***Kalktuffe f*** wurden keine Mollusken angetroffen, obwohl solche sicherlich, wenn auch selten, vorkommen dürften. HULTH erwähnt auch keine; dagegen hat er Pflanzenreste von Salices gefunden, die ein arktisches Klima beweisen.

Der ***Wiesenkalk e,*** der, wie die vorigen Schichten, nur in dem südlichen Teil des Profils vorhanden ist, wurde an zwei Stellen durchsucht. Die angetroffenen Mollusken waren folgende.

An der ersten Stelle, die etwas nördlicher als Lokal 4 nahe an Lokal 3 c gelegen ist, hatte die Schicht eine Mächtigkeit von 55 *cm* und enthielt in der Mitte eine Sandschicht mit folgenden Arten ($^2/_3$ Probe):

Conulus fulvus, 1 Ex. *Pupa Genesii*, 10 Ex.

An Lokal 4 wurden folgende Schnecken eingesammelt:

Cionella lubrica, 2 Ex. *Helix pulchella*, 2 Ex.
Conulus fulvus, 1 Ex. *Hyalinia petronella*, 4 Ex.

Die Durchsuchung war sehr sorgfältig und da nicht mehr Arten gefunden wurden, muss also die Fauna als sehr artenarm angesehen werden. Die wichtigsten Funde sind die von *Pupa Genesii* und *Helix pulchella*. Die erste muss als eine nördliche Art betrachtet werden (vgl. HÄGG 1910, ODHNER 1910). Sie kommt auch in frühzeitigen quartären Schichten vor, z. B. bei Rangiltorp und in Schonen, tritt zum erstenmal in der subarktischen Periode auf und lebt in Schonen danach bis in die atlantische Zeit weiter. Wahrscheinlich ist die vorhandene Schicht etwas älter als der unterste fossilführende Torf bei Rangiltorp, da ihre Fauna noch sehr spärlich vertreten ist; es ist daher anzunehmen, dass ihre Bildung unter subarktischem Klima stattgefunden hat. Das Vorkommen von *Helix pulchella* in dieser frühen Periode ist aber ganz überraschend, da diese Art heute ihre Nordgrenze in der borealen Region bei etwa 63° n. Br. hat. In Finnland aber lebt sie weit nördlicher, bis Kemi Träsk (etwa 66° 30′ n. Br.). Es ist daher möglich, dass sie während der subarktischen Periode allgemeiner vorkam als man dies auf Grund ihrer gegenwärtigen Verbreitung in Schweden annehmen kann. Doch steht der vorhandene Fund noch vereinzelt da; in der nächsten Periode kommt sie aber schon in Östergötland, Schonen und auf Gottland vor.

Wir begegnen in dieser Schicht noch drei weitverbreiteten Schnecken, die auch allgemein in der arktischen Region vorkommen. In Übereinstimmung mit ihrer geographischen Verbreitung steht die geologische; von dieser Schicht an trifft man sie durch das ganze Profil an.

Die Schicht d zerfällt in drei gut getrennte Zonen, zwei äussere Humusstreifen und einen mittleren Kalktuff. Sie erstreckt sich wie die oben folgenden Ablagerungen durch das ganze Profil und ist deshalb an verschiedenen Lokalen durchsucht worden.

Der unterste Humusstreif enthielt folgende Fossilien:

An Lokal 2:

Carychium minimum, 4 Ex.
Cionella lubrica, 3 Ex.
Conulus fulvus, 3 Ex.
Helix hortensis, Fragmente.
H. pulchella, 7 Ex.
Hyalinia hammonis, 8 Ex.
H. petronella, 1 Ex.
Patula ruderata, 2 Ex.
Punctum pygmaeum, 2 Ex.
Pupa substriata, 1 Ex.
Succinea oblonga, 1 Ex.

Candona candida, 1 Ex.

Weiter unten wurde nur *Helix pulchella* in einer Probe angetroffen.

An Lokal 3 b:

Cionella lubrica, 4 Ex.
Conulus fulvus, 1 Ex.
Helix hortensis, 1 Ex. + Fragm.
H. pulchella, 2 Ex.
Hyalinia hammonis, 1 Ex.
H. petronella, 4 Ex.
Patula ruderata, 3 Ex. + Junge.
Pupa pygmaea, 2 Ex.
Succinea oblonga, 2 Ex.

An Lokal 3 c:

Cionella lubrica, 5 Ex. + Junge.
Conulus fulvus, 7 Ex.
Helix hortensis, 1 junges Ex.
H. pulchella, 10 Ex.
Hyalinia hammonis, viele Ex.
Patula ruderata, 4 Ex. + Fragm.
Punctum pygmaeum, 1 Ex.
Pupa muscorum, 1 junges Ex.
P. pygmaea, 2 Ex.
Succinea oblonga, 1 Ex.

An Lokal 4:

Cionella lubrica, 1 Fragment.
Hyalinia petronella, 6 Ex. + kleine Junge.

Im Gegensatz zu der nächst unterliegenden Schicht ist dieser Humusstreif mit einer ziemlich reichen Fauna ausgestattet. Viele neue Formen treten hinzu. Die meisten von ihnen sind in geographischer und dementsprechend auch geologischer Hinsicht weitverbreitet, einige sind ausgesprochen nördliche Arten, andere aber haben eine mehr südliche Verbreitung. Unter den nördlichen Formen ist in erster Linie *Patula ruderata* zu erwähnen die in ganz Skandinavien vorkommt aber gegen Süden hin allmählich selten wird. Die Repräsentanten des südlichen Zuschusses der Fauna sind *Carychium minimum*, *Helix hortensis*, *Pupa pygmaea* und *P. substriata*, gegenwärtig nicht nördlicher als in Dalarne angetroffen, wenn man das Vorkommen sämtlicher als Relikten in Jämtland ausser Rechnung lässt. Daraus ist zu schliessen, dass das Klima der entsprechenden Periode ungefähr dem jetzigen von Dalarne glich, dass also die mittlere Julitemperatur etwa 15° betrug.

Das Auftreten von *Succinea oblonga* scheint auf den ersten Blick hin dieser Annahme zu widersprechen, da diese Art in der Neuzeit, wenn man von dem relikten Vorkommen in Jämtland und Hälsingland (HÄGG 1908) absieht, nicht nördlicher als in Wästmanland lebt. In Wirklichkeit stützt jedoch auch diese Art die Annahme, denn in geologischen Ablagerungen tritt sie schon früh, in borealer Zeit, auf (Schonen, Östergötland), und ihre rezente Verbreitung muss daher als ein Zeichen allmählichen Absterbens angesehen werden.

Der Kalktuff in d weist wieder eine verminderte Zahl von Arten auf. Nur wenige treten neu hinzu; einige schon eingewanderte sind nicht wiedergefunden worden. Die Fauna hat folgende Zusammensetzung:

An Lokal 2:

Carychium minimum, 10 Ex.	*H. petronella*, 5 Ex.
Cionella lubrica, 4 Ex.	*Limax laevis?*, 1 Ex.
Conulus fulvus, 10 Ex.	*Patula ruderata*, 1 Ex.
Helix fruticum, 1 Ex. + Fragmente.	*Pupa substriata*, 2 Ex.
H. pulchella, viele Ex.	*Succinea oblonga*, 3 Ex.
Hyalinia hammonis, 10 Ex.	*Vitrina pellucida*, 1 Ex.

An Lokal 4:

Cionella lubrica, 1 Fragment.	*Helix hortensis*, Fragmente.
Conulus fulvus, 4 Ex.	*Hyalinia petronella*, 4 Ex.

Von den neu auftretenden Mollusken ist *Vitrina pellucida* eine weit verbreitete Art. In quartären Ablagerungen in Schweden ist sie aber nicht gemein eingetroffen worden, was aus der Zartheit ihrer Schale zu erklären ist. Am frühesten ist sie aus borealer Zeit in Schonen bekannt; ausserdem hat man sie in Närke und Östergötland aus atlantischer bezw. subborealer Zeit angetroffen.

Helix fruticum hat ihre Nordgrenze in Dalarne und Hälsingland, woneben sie als Relikt in Jämtland vorkommt. Man kennt sie nur in Schonen aus der borealen Zeit; aus späteren Perioden ist sie aber von mehreren Orten her bekannt.

Limax laevis ist bis Uppland verbreitet und liegt nur aus atlantischer Zeit von Schonen her vor. Der vorhandene Fund gehört nicht sicherlich dieser Art.

Die neu hinzutretenden Arten geben somit keine sichere Klimaveränderung an.

Das Schwinden der drei schon früher eingewanderten *Punctum pygmaeum*, *Pupa muscorum* und *P. pygmaea* ist nur zufällig, denn sie treten wieder in höheren Schichten auf, und kann auf rein lokalen Verhältnissen beruhen; in klimatischer Hinsicht hat es nichts zu bedeuten. Auch diese Schicht wurde demnach in der borealen Periode abgesetzt.

SERNANDER (1902) ist wie HULTH der Ansicht, dass dieser Kalktuff eher zu der subarktischen als der borealen Periode gehört. Dafür sprechen nach SERNANDER die angetroffenen Reste von Kiefer, die der nördlichen Varietät *lapponica* angehören. In der Molluskenfauna hat man ein Mittel, die Frage nach der Absetzungszeit des Tuffes d_2 in überzeugender Weise zu beantworten. Schon in dem unteren Humusstreifen treten Arten auf, die auf boreales Klima deuten, und schon von dieser Schicht an muss man also die boreale Periode datieren. Dass in dieser Zeit, wo das Klima sich allmählich besserte, Schwankungen der Tuffabsetzung vorsichgegangen sind, deutet darauf, dass dieselben von anderen Umständen als den klimatischen beeinflusst werden können. Vielleicht sind in diesem Fall nur lokale Veränderungen der Quellen eingetreten.

Der obere Humusstreif in d ist in klimatologischer Hinsicht von grossem Interesse, dann hier treten zuerst einige südliche Formen auf, die ein Temperaturerhöhung andeuten. Die in der Schicht enthaltene Fauna umfasst folgende 17 Arten:

An Lokal 2:

Acanthinula aculeata, 1 Fragment.
Buliminus obscurus, 4 Ex.
Carychium minimum, 15 Ex.
Cionella lubrica, 4 Ex.
Conulus fulvus, 10 Ex.
Helix hortensis, 1 Ex. + Fragmente.

H. pulchella, viele Ex.
Hyalinia hammonis, 15 Ex.
H. petronella, 4 Ex.
Limax agrestis, 1 Ex.
Patula ruderata, 5 Ex., Junge, Eier.
Punctum pygmaeum, 10 Ex.

An Lokal 4:

Acanthinula aculeata, 1 Ex.
Cionella lubrica, Fragmente.
Helix hortensis, 1 Fragment.
H. pulchella, viele Ex.
Hyalinia hammonis, 5 Ex.
Limax agrestis, 1 Ex.

An Lokal 5:

Carychium minimum, 1 Fragment.
Helix fruticum, Fragmente + Junge.
H. hispida, 1 Ex.
H. hortensis, Fragmente.
H. pulchella, 2 Junge Ex.
Hyalinia hammonis, 1 Ex.
H. petronella, 1 Ex.
Vitrea crystallina, 3 Ex.

Hulth fand in dieser Schicht dazu *Clausilia laminata*, *Cl.* sp. (= *bidentata!*), *Helix fruticum* und *Succinea oblonga*.

Die interessantesten Konstituenten dieser Fauna sind die nur an humus- und wärmereichen Orten im südlichen Schweden lebenden *Acanthinula aculeata* und *Buliminus obscurus*, die am nördlichsten in den Schären von Stockholm angetroffen worden sind (Odhner 1910). Im Vergleich zu ihrer gegenwärtigen Verbreitung scheint ihr Auftreten in dieser Schicht sehr frühzeitig zu sein. Aus anderen Lokalen (siehe den Anhang) kennt man sie als fossil zuerst aus der atlantischen Zeit oder aus der Eichenzone. Hier aber begegnen sie uns schon vor der atlantischen Periode in einer Schicht, die sich an die boreale am nächsten anschliesst und darum höchstens den Beginn der Eichenzone repräsentieren kann. Erst die folgende Schicht gehört auch, wie unten besprochen werden wird, der atlantischen Periode an.

Vitrea crystallina und *Clausilia laminata* dagegen kommen auch in etwas nördlicher gelegenen Gegenden vor. Ihre Nordgrenze liegt in Dalarne, und *Clausilia laminata* ist noch in Hälsingland angetroffen (sicherlich als Relikt anzusehen, Hägg 1908). Diese beiden Arten treten auch früher in den Ablagerungen auf, indem sie in Schonen bereits in der Kiefernzone vorkommen.

Wenn es nun gilt, die Temperatur der Bildungsepoche zu bestimmen, muss man vor allem die südlichsten Formen berücksichtigen. Da diese nördlichst bei einer Julitemperatur von ca 16° gedeihen, kann man diese Temperatur als ein *Minimum* für die betreffende Zeit betrachten. Auch der Umstand, dass die Fauna ziemlich viele Arten umfasst, macht es wahrscheinlich dass eine grössere Einwanderung durch günstigere klimatische Verhältnisse befördert wurde, und dass also eine Temperaturerhöhung eingetreten war.

Es ist aber nicht möglich aus dem vorliegenden faunistischen Material den sonstigen Charakter des Klimas zu bestimmen.

Der Kalktuff c, die mächtigste Ablagerung des Fundortes ist nach HULTH's Ansicht während der atlantischen Zeit abgesetzt worden, und die Feuchtigkeit dieser Periode hat die grossartige Ausbildung des Lagers ermöglicht. Die Flora ist durch viele neue Arten bereichert, und dieselbe Erscheinung ist in der Molluskenfauna deutlich bemerkbar. In keiner anderen Schicht treten die Mollusken so massenhaft wie hier auf, und dies gilt sowohl für die Arten als für die Individuenzahl. Im ganzen sind 27 Arten vorhanden, aber nur 7 davon sind seit der Absetzung des unterliegenden Humusstreifens eingewandert.

Die angetroffenen Arten sind folgende:

An Lokal 1 (nur eine Probe im obersten Teil des Tuffes):

Acanthinula aculeata, 1 Ex.
Carychium minimum, 1 Ex.
Helix fruticum, 2 Ex.
H. hortensis, 3 Ex.
H. pulchella, 2 Ex.
H. strigella, 2 Ex.
Hyalinia pura, 2 Ex.

An Lokal 2, im untersten Teil des Tuffes, wurde in einer kleinen Probe (1/3) nur *Helix pulchella* spärlich angetroffen.

D:o, im unterem Teil, 6 *dm* oberhalb der vorigen Probe:

Acanthinula aculeata, 1 Ex.
Buliminus obscurus, 12 Ex.
Carychium minimum, 20 Ex.
Cionella lubrica, ca. 30 Ex.
Clausilia bidentata, ca. 20 Ex.
Conulus fulvus, 6 Ex.
Helix hortensis, 2 Ex. + Fragmente und Junge.
H. pulchella, massenhaft.
Hyalinia hammonis, 8 Ex.
Limax laevis, 1 Ex.
Patula ruderata, 4 Ex. (klein).
Pupa angustior, 4 Ex.
P. columella, 1 Ex.
P. Genesii, 1 Ex.
P. pusilla, 2 Ex.

D:o, im mittleren Teil:

Acanthinula aculeata, 6 Ex.
Buliminus obscurus, ca. 10 Ex.
Carychium minimum, 4 Ex.
Cionella lubrica, ca. 10 Ex.
Clausilia bidentata, viele Ex. + Junge.
Conulus fulvus, 1 Ex.
Helix fruticum, Fragmente und Junge.
H. pulchella, massenhaft.
Hyalinia hammonis, viele Ex.
H. petronella, 2 Ex.
Limax agrestis, 1 Ex.
Patula ruderata, 1 Ex.
Punctum pygmaeum, 1 Ex.
Pupa angustior, 1 Ex.
P. Genesii, 12 Ex.
P. minutissima, 1 Ex.
Succinea oblonga, 3 Ex.
Vitrea crystallina, 13 Ex.

D:o, im obersten Teil des Tuffes:

Carychium minimum, 1 Fragment.
Clausilia bidentata, 1 junges Ex.
Conulus fulvus, 1 Ex.
Helix hortensis, Fragmente.
Vitrea crystallina, 1 junges Ex.

An Lokal 3 a, in der unteren Probe (1/3):

Helix pulchella, 10 Ex.
Hyalinia hammonis, 1 Ex.
Succinea oblonga, 1 Ex.

D:o, in der oberen Probe (1/3):

Buliminus obscurus, 2 Ex.
Carychium minimum, 6 Ex.
Cionella lubrica, viele Ex.
Clausilia bidentata, 2 Ex. + Junge.
Conulus fulvus, 8 Ex.
Helix fruticum, 2 Ex.
H. hortensis, 1 Ex. + Fragmente.
H. pulchella, massenhaft.
Hyalinia hammonis, massenhaft.
H. petronella, 3 Ex.
Patula ruderata, 2 Ex.
Punctum pygmaeum, ca. 12 Ex.
Pupa edentula, 2 Ex.
P. pygmaea, 1 Ex.
P. pusilla, 2 Ex.
Succinea oblonga, 7 Ex.

An Lokal 4, in dem untersten Teil direkt auf dem Humusstreifen in d:

Buliminus obscurus, 2 Fragmente.
Carychium minimum, 2 Ex.
Cionella lubrica, 2 Ex.
Clausilia bidentata, Fragmente.
Conulus fulvus, 7 Ex.
Helix hortensis, Fragmente.
H. pulchella, massenhaft.
Hyalinia hammonis, 5 Ex.
H. petronella, 3 Ex.
Patula ruderata, 5 Ex.
Succinea oblonga, 2 Ex.

D:o, im mittleren Teil:

Buliminus obscurus, 1 Fragment.
Carychium minimum, 1 Ex.
Cionella lubrica, 1 Fragment.
Clausilia bidentata, 1 Fragment.
Cl. laminata, 1 Fragment.
Helix fruticum, 1 Ex. + Fragmente.
H. hortensis, 1 Ex. + Fragmente.
H. pulchella, viele Ex.
Hyalinia hammonis, 3 Ex.
Limax agrestis, 1 Ex.
Patula ruderata, 1 Fragment.
Vitrea crystallina, 2 Ex.

D:o, im oberen Teil:

Carychium minimum, 1 Ex.
Helix hortensis, Fragmente.
H. pulchella, viele Ex.
H. strigella, Fragmente,
Hyalinia hammonis, 1 Ex.
Vitrea crystallina, 1 Ex.

An Lokal 5, im unteren Teil des Kalktuffes *c*, wurden nur 1 Fragment von *Helix hortensis* und 1 Ex. von *H. pulchella* angetroffen.

Die obenstehenden Verzeichnisse zeigen, dass in dem Kalktuffe *c* hauptsächlich einige kleine *Pupa*-Arten die neuen Formen repräsentieren. Sie werden hier zum erstenmal in der Schichtenfolge angetroffen. Bemerkenswerterweise sind *Pupa edentula* und *P. columella* erst hier gefunden, obgleich diese eine weite Verbreitung besitzen und sogar in der arktischen Region sehr allgemein vorkommen. Sicherlich kommen sie auch in den unterliegenden Schichten vor.

Eine bisher nicht fossil angetroffene Art ist *Pupa minutissima*. Ihre Verbreitung ist ziemlich beschränkt, denn sie kommt nur bis Närke, Wästmanland und Uppland vor. Auch die übrigen *Pupa*-Arten leben nur in den südlichen Gegenden von Schweden, *P. angustior* bis Stockholm, *P. pygmaea* bis Dalarne;[1] ausserdem sind beide in Jämtland relikt.

Da auch die nur im oberen Teil des Tuffes angetroffenen *Helix strigella* und *Hyalinia pura* ihre nördlichsten Fundorte in Dalarne haben, kann man aus den neu auftretenden Mollusken keinen Schluss auf das Klima ziehen. Nur eine *untere* Grenze der herrschenden Temperatur kann angegeben werden und diese ist schon bei 16° mittleren Julitemperatur anzusetzen, da diese gegenwärtig die charakteristischen Verbreitungsgebiete in Wästmanland auszeichnet.

Ausser dem Auftreten neuer südlicher Arten ist für diesen Tuff eine andere Erscheinung eigentümlich. Hier begegnen uns nämlich zum letztenmal einige schon aus älteren Schichten bekannte Mollusken, die also nach der atlantischen Zeit aus der Fauna von Skultorp verschwinden. Sehr auffallend ist dieser Umstand betreffs *Patula ruderata*. Aus den Zahlen der angetroffenen Exemplare ist direkt ersichtlich, wie diese Schnecke aufwärts mehr selten wird. Nachstehende Tabelle, in der diese Zahlen zusammengestellt sind, erläutert diese Erscheinung:

Zahl der Individuen an Lokal	2	3 a	4
Schicht *c* 1	0	—	0
Schicht *c* 2	1	2	1
Schicht *c* 3	4	—	5
» *d* 1	5 +	—	0
» *d* 2	1	—	0
» *d* 3	2	3 +	0

Während z. B. in Lokal 2 aus dem oberen Humusstreifen d_1 mehr als 5 Exemplare vorliegen, ist die Zahl im unteren Teil des Tuffes (c_3)4, im mittleren Teil nur 1 und darüber 0.

[1] Exemplare aus Leksand und Rättvik, von E. NORDENSKIÖLD eingesammelt, sind im Reichsmuseum vorhanden.

Ausser *Patula ruderata* verschwinden von dieser Schicht an noch *Succinea oblonga* und *Pupa Genesii.* Im mittleren Teil des Tuffes erreicht *Succinea* eine grössere Frequenz, ehe sie im oberen Teil ganz ausbleibt:

Zahl der Individuen an Lokal	2	3 a	4
Schicht *c* 1	0	—	0
Schicht *c* 2	3	7	0
Schicht *c* 3	0	1	2
» *d* 1	0	—	0
» *d* 2	3	—	0
» *d* 3	1	2	0

Das Verschwinden von *Patula ruderata* gegen Ende der atlantischen Zeit steht mit ihrer gegenwärtigen geographischen Verbreitung in voller Übereinstimmung. Nur in den höchsten Gebirgen des mittleren Europas hat sie sich erhalten können, weil die Temperatur dort eine niedrigere und die Regenmenge etwas grösser als in den Ebenen ist. Wenn sie nun von Skultorp verschwunden ist, hat man die Ursache dazu nur darin zu suchen, dass *an diesem Ort* die günstigen Lebensbedingungen verloren gegangen sind. In der nächsten Gegend konnte sie aber solche behalten, und daher kommt es, dass sie noch heute z. B. in der Nähe von Sköfde am Fusse des Billingen fortlebt (Exemplare im Reichsmuseum).

Eine gewisse Feuchtigkeit befördert auch das Gedeihen von *Succinea oblonga*, die freilich sehr starken Sonnenschein und hohe Wärme vertragen kann, wenn nur schliesslich Feuchtigkeit die Dürre ablöst. An ganz trockenen, das Wasser normal entbehrenden Lokalen findet man sie nie. Wenn sie also mitten im Tuffe an Frequenz zunimmt, dürfte das auf einer grösseren Feuchtigkeit beruhen, wenn sie dann plötzlich verschwindet, ist wahrscheinlich eine trockene Periode eingetreten und in dem vorliegenden Fall hat vermutlich eine solche während der Absetzung des oberen Teiles der Tuffschicht geherrscht.

Eine andere Feuchtigkeitsliebende Schnecke, die dieselbe Erscheinung in ihrer Frequenz zeigt, ist *Helix pulchella.* Sie nimmt, wie die folgende Tabelle zeigt, in dem Tuffe *c* bedeutend an Zahl zu. Darin liegt eine Bestätigung der oben ausgesprochenen Annahme.

Zahl der Individuen an Lokal	1	2	3 a	4	5
Schicht *c* 1	2	0	—	viele	—
Schicht *c* 2	—	massenh.	massenh.	»	—
Schicht *c* 3	—	»	10	massenh.	1
» *d* 1	—	viele	—	viele	2
» *d* 2	—	»	—	4	—
» *d* 3	—	7	10	0	—

Das Wiederauftreten von *Pupa Genesii* während der atlantischen Zeit — diese Schnecke ist nicht in den nächst unterliegenden Schichten angetroffen — ist auch eigentümlich; möglicherweise hat sie aber die ganze Zeit, obschon selten, fortgelebt, wie sie in Schonen kontinuierlich von der subarktischen bis zur atlantischen Zeit angetroffen ist. Von da an ist sie aber, wie auch in Schonen, ausgestorben, was möglicherweise auch für diese Art in der zunehmenden Temperatur und Trockenheit des Klimas seine Erklärung findet.

Vorübergehend verschwinden im oberen Teil des Tuffes auch einige andere Formen, wie *Buliminus obscurus*, *Cionella lubrica*, *Hyalinia petronella* und *Limax agrestis*, und die ganze Fauna wird hier sehr arm, nur 11 Arten umfassend, ohne dass man jedoch die Ursache dazu in klimatischen Veränderungen sehen kann; vielleicht haben lokale Verhältnisse diese Schwankung in der Fauna herbeigeführt.

Der obere Humusstreifen b. Oben sind die Gründe auseinandergesetzt worden, die für ein warmes und feuchtes Klima während der atlantischen Zeit und für eine darauf folgende Trockenheit ausschlaggebend sind. Wir finden in der nächst überliegenden Schicht Stützen für diese Annahme, denn sie ist ein Humusstreifen und als solcher während einer dürren Periode gebildet. Die hier enthaltene Fauna ist aus den folgenden 18, meist xerophilen Arten zusammengesetzt:

An Lokal 1, in einer rötlich-grauen Partie:

Carychium minimum, viele Ex.
Cionella lubrica. 2 Ex,
Clausilia laminata, 1 Ex.
Helix hortensis, Fragmente.
H. pulchella, viele Ex.
Hyalinia petronella, viele Ex.

D:o, in einer schwarzen, humusreicheren Partie:

Buliminus obscurus, 1 Ex.
Carychium minimum, 5 Ex.
Cionella lubrica, 4 Ex.
Clausilia bidentata, 1 Ex.
Cl. laminata, 3 Ex.
Helix hispida, 3 Ex.
H. hortensis, 1 Fragment.
H. pulchella, viele Ex.
Hyalinia hammonis, viele Ex.
H. petronella, 1 Ex.

Ausserdem dass hier die Zahl der Individuen eine grössere ist, treten in dieser schwarzen Partie einige humusliebende Arten auf, die sonst in den grauen Partien des Humusstreifens nicht angetroffen wurden.

An Lokal 2:

Acanthinula aculeata, 1 Ex.
Carychium minimum, viele Ex.
Cionella lubrica, 3 Ex.
Clausilia laminata, 1 Fragment.
Helix fruticum, Fragmente.
H. hortensis, Fragmente.
H. pulchella, viele Ex.
H. strigella, 1 Ex. + Fragmente.
Hyalinia petronella, viele Ex.
Succinea putris, 1 junges Ex.
Vitrea crystallina, 2 Ex.

Eine andere Probe von demselben Lokale enthielt dieselben Schnecken mit Ausnahme von *Clausilia* und *Succinea*, aber dazu folgende neue:

Clausilia bidentata, 6 Ex.
Hyalinia hammonis, 1 Ex.
H. pura, 1 Ex.
Pupa muscorum, 1 Ex.

An Lokal 3:

Carychium minimum, 1 Ex.
Clausilia laminata, 1 Ex.
Helix hortensis, Fragmente.
H. pulchella, viele Ex.
H. strigella, 2 Ex. + Fragmente.
Hyalinia hammonis, viele Ex.

An Lokal 4:

Acanthinula aculeata, 1 Ex.
Clausilia bidentata, 1 Ex.
Helix fruticum, 1 Ex. + Fragmente.
H. hortensis, Fragmente.
H. pulchella, 3 Ex.
Limax agrestis, 1 Ex.

Unter diesen Arten treten jetzt zum erstenmal zwei auf: *Helix hispida* und *Succinea putris*.

Helix hispida kommt in dem schwedischen Quartär ganz selten vor. Sie ist am frühesten aus dem schwarzem Humus (boreal) aus Ystad Hafen bekannt und neulich auch von MUNTHE (1910) für sublitorinale Ablagerungen auf Gottland erwähnt. Ausserdem kennt man sie aus jungem Humus bei Kiviks-Esperöd, Schonen (KURCK 1904) und bei Berga, Närke (KJELLMARK 1897), sowie aus supralitorinalen Bildungen auf Gottland (MUNTHE 1910). Ihre Einwanderung in das innere Land scheint somit in relativ später Zeit vorsichgegangen zu sein, und ihre Verbreitung in Schweden ist auch nicht weit; sie geht nördlich bis 60° n. Br. und lebt an schattenreichen, etwas feuchten humusreichen Lokalen unter üppiger Vegetation.

Succinea putris folgt hier der ausgestorbenen *S. oblonga*, ist aber nur in einem jugendlichen Exemplar angetroffen und höher aufwärts nicht wiedergefunden worden. Auch sie liebt nur schattenreiche Lokale; ihre geologische wie geographische Verbreitung in Schweden ist aber eine sehr weite, und es ist auffallend, dass sie nicht schon früher bei Skultorp eingewandert war.

Dass *S. oblonga* nicht infolge des Auftretens dieser Art ausgestorben ist, geht deutlich aus der Beschaffenheit dieses einzelnen Fundes hervor. Ob aber in anderen Lokalen (z. B.

bei Rangiltorp) das schliessliche Verschwinden von *S. oblonga* auf einem Unterliegen in der Konkurrenz mit *S. Pfeifferi* oder *S. putris* beruht, wie Jentzsch (1872) unter gleichen Umständen annimmt, ist noch nicht möglich festzustellen.

Auch *Pupa muscorum* fordert humusreiche oder trockene Lokale als Aufenthalt. In dem ganzen Profile ist sie auch nur in Humusstreifen anzutreffen (vgl. die tabellarische Übersicht).

Aus dieser Fauna Schlüsse auf die Beschaffenheit des Klimas zu ziehen ist nicht angängig, denn keine Art giebt in besonderer Hinsicht darüber Aufschluss; alle sind aber humusliebend und geben somit eine ziemlich trockene Beschaffenheit des Lokales an.

Der oberste Kalktuff a. Die Verminderung der Artanzahl, die seit der atlantischen Schicht zu konstatieren war, ist hier nicht so stark ausgeprägt, denn die Fauna umfasst hier wieder 20 Arten. Diese sind folgende:

An Lokal 1, unmittelbar über dem Humusstreifen:

Acanthinula aculeata, 1 Ex.
Buliminus obscurus, 2 Ex.
Carychium minimum, 1 Ex.
Cionella lubrica, 2 Ex.
Helix hortensis, Fragmente, Junge.
H. pulchella, 1 Ex.
Hyalinia hammonis, 2 Ex.

An Lokal 2, im untersten Teil des Lagers:

Acanthinula aculeata, 1 Ex.
Buliminus obscurus, 1 Fragment.
Carychium minimum, 15 Ex.
Cionella lubrica, 5 Ex.
Clausilia bidentata, 2 Ex.
Conulus fulvus, 2 Ex.
Helix hortensis, Fragmente und Junge.
H. pulchella, 18 Ex.
H. hispida, 1 Ex.
Hyalinia petronella, viele Ex.
Pupa edentula, 1 Ex.

D:o, im mittlerem Teil des Lagers:

Carychium minimum, 1 Ex.
Cionella lubrica, 1 Ex.
Clausilia laminata, 1 Fragment.
Helix hortensis, 1 Ex.
H. pulchella, viele Ex.
Hyalinia hammonis, 4 Ex.
Vitrea crystallina, 2 Ex.

An Lokal 3, im unteren Teil des Lagers:

Clausilia plicatula, 1 Fragment. *Helix hispida*, 1 Ex.
Vitrea crystallina, 1 Ex.

D:o, im oberen Teil des Lagers:

Cionella lubrica, Fragmente. *H. pulchella*, 2 Ex.
Clausilia laminata, 1 Fragment. *Hyalinia petronella*, 1 Ex.
Helix hortensis, Fragmente. *H. pura*, 1 Ex.
Zonitoides nitidus, 1 Ex.

An Lokal 4:

Clausilia laminata, 1 Fragment. *H. hispida*, 3 Ex.
Helix fruticum, 1 Fragment. *H. pulchella*, 1 Ex.
H. strigella, 3 Ex.

Helix hispida wird in dieser Schicht gemeiner und auf die Lokale ziemlich gleichmässig verteilt. Dazu treten noch *Clausilia plicatula* und *Zonitoides nitidus* hinzu. Die letztgenannte Art ist hier von besonderem Interesse, da sie erst jetzt und nur in einem einzigen Exemplar in der Lagerfolge angetroffen ist. *Buliminus obscurus* und *Acanthinula aculeata* sind hier noch vorhanden, aber in wenigen Individuen, und es ist klar, dass ihre günstigste Periode vorüber ist. Diese fiel in den Beginn und den mittleren Teil der Absetzung des Tuffes *c*, denn hier sind die beiden Arten am reichlichsten vertreten, wie die nachstehende Tabelle zeigt:

	Acanthinula aculeata.			*Buliminus obscurus.*			
Zahl der Individuen an Lokal	1	2	4	1	2	3 a	4
Schicht *a*	1	1	0	2	1	—	0
» *b*	0	0	0	0	1	—	1
» *c* 1	1	1	0	0	0	—	0
» *c* 2	—	6	0	—	10	2	1
» *c* 3	—	1	0	—	12	0	2
» *d* 1	—	1	1	—	4	0	0

Sie sind auch nur im *unteren* Teil der Schicht *a* zu finden, weiter oben bleiben sie aus, und auch die Zahl der enthaltenen Arten ist dort eine geringere.

Der Humusstreifen β, der in Lokal 4 angetroffen wurde, aber in Lokal 5 nicht differenziert vorkam, enthielt die folgenden Arten.

An Lokal 4:

Carychium minimum, 1 Ex.
Cionella lubrica, 4 Ex.
Helix fruticum, Fragmente.
H. hortensis, Fragmente.
H. pulchella, massenhaft.
Hyalinia petronella, viele Ex.
Punctum pygmaeum, 2 Ex.
Pupa muscorum, 7 Ex.

Der obere Schwemmsand α wurde nur in dem südlichen Teil des Profils beobachtet; nordwärts verlier er sich allmählich durch Abdünnung. Er bestand aus einem sehr feinkörnigen, gelbroten Sande. Die folgenden Mollusken wurden eingesammelt:

An Lokal 4:

Carychium minimum, 3 Ex.
Helix strigella, Fragmente.
Hyalinia hammonis, 1 Ex.
H. petronella, 1 Ex.
Pisidium fossarinum, viele Ex.
Pupa pusilla, 1 Ex.

Dazu wurden auch viele Exemplare von dem Ostrakode *Candona candida* erhalten.

An Lokal 5:

Helix hortensis? ein kleines Fragment.
Pisidium fossarinum, 1 Ex.

Der Mächtigkeit nach zu urteilen sind die beiden akzessorischen Schichten α und β der Lokale 4 und 5 mit dem oberen Teil des Tuffes *a* gleichzeitig abgesetzt worden. Besonderes Interesse verdient die Schicht α, die als Schwemmsand ausgebildet ist. Die vorhandenen Süsswasserformen *Pisidium* und *Candona* beweisen, dass die betreffenden Lokale eine Versumpfung erlitten haben, und dass eine Wasseransammlung hier entstanden ist. Das Vorkommen von *Zonitoides nitidus* auf Lokal 3 im oberen Kalktuffe *a* steht möglicherweise mit dieser Erscheinung in Zusammenhang. Vielleicht zeigt diese Schnecke dass gerade in der Nähe das Ufer der kleinen Wasseransammlung gelegen war, denn *Z. nitidus* ist eine ausgeprägte Uferform.

Der oben besprochene Kalktuff *a* wird von HULTH als subatlantisch bezeichnet und die jetzt dargelegten Befunde widersprechen dieser Annahme nicht. Nach SERNANDER war diese Periode feucht und kalt, und das Vorkommen des Schwemmsandes mit den Wasserformen scheint in guter Übereinstimmung mit SERNANDERS Ansichten zu stehen. Was die Temperaturverhältnisse betrifft, so können keine positive Stützen für eine Bestimmung derselben dem faunistischen Material entnommen werden, denn die Zahl der Arten ist zu gering. Wenn man aber gerade diese Armut der Fauna berücksichtigt und sie dem Artenreichtum der atlantischen Schicht gegenüberstellt, so wird man geneigt sein, dieses negative Verhältnis als einen Beweis für ungünstigeres Klima zu halten, und da die Ungünstigkeit ersichtlich nicht in Trockenheit liegt, muss sie in einer niedrigeren Temperatur zu suchen sein. Die besonders wärmeliebenden Mollusken (*A. aculeata*, *B. obscurus*, *Clausilia*) verschwinden demgemäss oder werden selten, und die Fauna besteht grösstenteils aus mehr eurythermen Formen. Da diese Schichten sehr sorgfältig und an mehreren Lokalen durchsucht sind, ist die Eventualität ausgeschlossen, dass allzu viele Arten übersehen worden sind.

In der oberflächlichen Humusschicht sinkt die Artenzahl wieder und beträgt nur die Hälfte derjenigen des Tuffes *a*. Die angetroffenen Mollusken sind nur folgende:

An Lokal 1:

Cionella lubrica, 6 Ex.
Helix hortensis, Fragmente und Junge.
H. pulchella, 10 Ex.

An Lokal 2:

Hier wurde die Probe mehr nach unten in der Grenze zu dem Tuffe *a* genommen:

Carychium minimum, 4 Ex.
Cionella lubrica, 1 Junges Ex.
Helix hortensis, Fragmente.
H. pulchella, viele Ex.
Hyalinia hammonis, 1 Ex.

An Lokal 4:

Cionella lubrica, 1 Ex.
Clausilia laminata, 2 Ex. (Junge).
Helix costata, 6 Ex.
H. hispida, 1 Ex. + 1 Junges.
Limax agrestis, 1 Ex.
Pupa muscorum, 6 Ex.

In Lokal 4 tritt nun *Helix costata* auf, die eine xerophile Form ist. An demselben Ort findet sich *Pupa muscorum* sehr reichlich, und diese beiden Arten beweisen, dass der Fundort wieder eine trockene Entwicklungsperiode durchläuft.

II. Tabellarische Übersicht der fossilen Fauna bei Skultorp.

Arten.	Schichten und Klimaperioden.												
	Arktisch.	Subarktisch.	Boreal.			Atlantisch.			Subboreal.	Subatlantisch.			Oberste Humusschicht.
			d			c							
	g	e	3	2	1	3	2	1	b	a	β	α	
Acanthinula aculeata (MÜLLER)	.	.	.	.	2, 4	2	2	1	2, 4	1, 2	.	.	.
Buliminus obscurus (MÜLLER)	.	.	.	.	2*	2, 4	2, 3a, 4	.	1	1, 2	.	.	.
Carychium minimum (MÜLLER)	.	.	2	2	2, 5	2, 4	2, 3a, 4*	1, 2, 4	1, 2, 3	1, 2*	4	4	2
Cionella lubrica (MÜLLER)	.	4	2, 4, 3b, 3c	2, 4	2, 4*	2, 4	2, 3a, 4*	.	1, 2	1, 2, 3	4	.	1, 2, 4
Clausilia bidentata STRÖM	.	.	.	.	*	2, 4	2, 3a, 4	2	1, 2, 4	2	.	.	.
Cl. laminata (MONTAGU)	.	.	.	.	*	.	4	.	1, 2, 3	2, 3, 4	.	.	4
Cl. plicatula DRAPARNAUD	.	.	.	.	.	.	.	.	.	3	.	.	.
Conulus fulvus (MÜLLER)	.	3d, 4	2, 3b, 3c	2, 4*	2	2, 4	2, 3a*	2	.	2	.	.	.
Helix costata MÜLLER	.	.	.	.	.	.	.	.	.	.	.	.	4
H. fruticum MÜLLER	.	.	.	2	*	.	2, 3a, 4	1	2, 4	4*	4	.	.
H. hispida LINNÉ	.	.	.	.	.	.	.	.	1	2, 3, 4	.	.	4
H. hortensis MÜLLER	.	.	2, 3b, 3c	4	2, 4*	2, 4, 5	3a, 4*	1, 2, 4	1, 2, 3, 4	1, 2, 3*	4	5	1, 2
H. pulchella MÜLLER	.	4	2, 3b, 3c	2	2, 4, 5	2, 3a, 4, 5	2, 3a, 4	1, 4	1, 2, 3, 4	1, 2, 3, 4	4	.	1, 2
H. strigella DRAPARNAUD	.	.	.	.	.	.	.	1, 4	2, 3	4*	.	4	.
Hyalinia hammonis (STRÖM)	4	.	2, 3b, 3c	2	2, 4, 5	2, 3a, 4	2, 3a, 4	4	1, 2, 3	1, 2	.	4	2
H. petronella CHARPENTIER	.	4	2, 3b, 4	2, 4	2	4	2, 3a	.	1, 2	2, 3	4	4	.
H. pura ALDER	.	.	.	.	.	.	.	1	2	3	.	.	.
Limax agrestis LINNÉ	.	.	.	.	2, 4	.	2, 4	.	4	.	.	.	4
L. laevis MÜLLER	.	.	.	?2	.	2	.	.	.	.	.	.	.
Patula ruderata (STUDER)	.	.	2, 3b, 3c	2	2*	2, 4	2, 3a, 4*	.	.	.	.	.	.
Pisidium fossarinum CLESSIN	4	.	.	.	.	.	.	.	.	.	.	4, 5	.
Punctum pygmaeum (DRAPARNAUD)	*	.	2, 3c	.	2	2	2, 3a	.	.	.	4	.	.
Pupa angustior (JEFFREYS)	.	.	.	.	.	2	2	.	.	.	.	.	.
P. arctica WALLENBERG	4	.	.	.	.	.	.	.	.	.	.	.	.
P. columella BENZ	.	.	.	.	.	2	.	.	.	.	.	.	.
P. edentula DRAPARNAUD	.	.	.	.	.	.	3a	.	.	2	.	.	.
P. Genesii GREDLER	.	3*d*	.	.	.	2	2	.	.	.	.	.	.
P. minutissima HARTMANN	.	.	.	.	.	.	2	.	.	.	.	.	.
P. muscorum (MÜLLER)	.	.	3c	.	.	.	.	.	2	.	4	.	4
P. pusilla (MÜLLER)	.	.	.	.	.	2	3a	.	.	*	.	4	.
P. pygmaea DRAPARNAUD	.	.	3b, 3c	.	.	.	3a	.	.	.	.	.	.
Pupa substriata (JEFFREYS)	.	.	2	2	.	.	.	.	.	.	.	.	.
Succinea oblonga DRAPARNAUD	.	.	2, 3b, 3c	2	*	3a, 4	2, 3a*	.	.	.	.	.	.
S. putris LINNÉ	.	.	.	.	.	.	.	.	2	.	.	.	.
Vitrea crystallina (MÜLLER)	.	.	.	.	5	2	2, 4	2, 4	2	2, 3	.	.	.
Vitrina pellucida (MÜLLER)	.	.	.	2	.	.	.	.	.	.	.	.	.
Zonitoides nitidus (MÜLLER)	.	.	.	.	.	.	.	.	.	3	.	.	.
Candona candida (MÜLLER)	.	.	2	.	.	.	.	.	.	.	.	4	.
Aphodius	4	.	.	.	.	.	.	.	.	.	.	.	.
Cercyon	4	.	.	.	.	.	.	.	.	.	.	.	.
S:a Molluskenarten	5	5	13	13	17	19	23	11	18	20	8	7	10

Bemerkungen zu der Tabelle.

Die Bezeichnungen der Schichten sind die in dem Text benutzten; in *c* und *d* sind die drei untersuchten Etagen auseinandergehalten. Die Ziffern bezeichnen Lokale die Sternchen (*) die von HULTH erwähnten Funde.

III. Allgemeine Bemerkungen über die Fauna.

Eine besonders auffallende Eigentümlichkeit der oben dargelegten Fauna ist die völlige Abwesenheit von Süsswassermollusken in den Schichten. Es sind nur *Pisidien* in zwei Horizonten angetroffen worden, sonst wird die Süsswasserfauna von keiner einzigen Art repräsentiert. Wenn man aber die Naturverhältnisse des Lokales berücksichtigt, so ist dieser Umstand leicht zu erklären, denn die Lage des Fundortes ist für die Entstehung einer Wasseransammlung sehr ungünstig, da er am Abhang des Billingen sich befindet. Nur während der arktischen Periode, als der Eissee in der unmittelbaren Nähe sich ausdehnte, waren die Bedingungen dafür besser. In der subatlantischen Schicht zeigen die Süsswasserformen auch eine Wasseransammlung an; da es sich aber nur um *Pisidien* handelt, dürfte diese von vorübergehender Beschaffenheit gewesen sein und vielleicht nur eine Erweiterung der Quellen dargestellt haben.

Trotz der Abwesenheit von Wassermollusken, die gewöhnlich den Reichtum der Fauna verursachen, beträgt die Zahl der hier angetroffenen Molluskenarten nicht weniger als 37; dazu kommen noch 1 Ostrakode und 2 Coleopteren. Von den Mollusken sind 2 Schnecken, *Pupa arctica* und *P. minutissima*, zum erstenmal fossil gefunden; andere sind bisher nur selten fossil angetroffen worden wie *Hyalinia pura* und *Limax laevis*. Viele Arten, die auch in geographischer Hinsicht weitverbreitet sind, kehren durch die ganze Lagerfolge hindurch immer wieder; andere sind nur sporadisch angetroffen worden, und noch andere zeigen in ihrem geologischen Auftreten die drei Entwicklungsstufen von Progress, Kulmination und Regress. Alles dies ist aus der obenstehenden Tabelle ersichtlich.

Wie die letzgenannte Artengruppe zeigt auch die ganze Fauna im allgemeinen diese drei Entwicklungsstufen. Wenn man die Artenzahl der verschiedenen Schichten vergleicht, findet man nämlich, wie der Formen- und auch Individuenreichtum, anfangs gering, in subarktischer und borealer Zeit allmählich zunimmt, bis er in der atlantischen Zeit das Maximum erreicht; dann tritt ein Rückgang bis in die Neuzeit ein, so dass in der obersten Humusschicht nur die Hälfte der in dem Tuffe *c* angetroffenen Formen vorhanden ist.

Eigentümlich ist auch der Umstand, dass die Fauna viele Arten entbehrt, die man doch als Konstituenten erwarten könnte. Hulth hebt die Abwesenheit von *Helix arbustorum* hervor; von dieser Art findet man keine Reste, und doch ist sie ziemlich allgemein fossil verbreitet, obschon nicht massenhaft in den Schichten auftretend; man kennt sie aus quartären Ablagerungen von Schonen, Östergötland, Gottland und Jämtland. Dass ihre Abwesenheit in dem Skultorp-Tuffe aber auf ausschliesslich lokalen Ursachen beruht, ist klar, denn in der nächsten Gegend lebt sie gegenwärtig und zwar am Fusse des Billingen bei Sköfde (Exemplare im Reichsmuseum).

Eine andere südliche Form, die man in den Ablagerungen vergebens sucht, obwohl sie dort zu erwarten wäre, ist *Patula rotundata*, die von der atlantischen Zeit an sowohl in Schonen als auf Gottland und in Jämtland fossil vorkommt. In Wästergötland ist diese Art bei Gothenburg und auf dem Kinnekulle angetroffen worden.

Das Vorkommen von *Patula ruderata* nicht weit von Skultorp, obwohl sie in den Tuffen nur bis zu atlantischer Zeit auftritt. wurde schon oben angemerkt.

Auch *Helix nemoralis* fehlt in den Ablagerungen bei Skultorp; diese Schnecke lebt aber gegenwärtig am Billingen.

Von anderen Arten, die man in dem Tuffe bei Skultorp nicht wiederfindet, obwohl sie in anderen quartären Ablagerungen ziemlich allgemein vorkommen, mögen *Pupa antivertigo* und *P. alpestris* erwähnt werden.

Stellen wir schliesslich einen Vergleich zwischen Skultorp und anderen bekannten Kalktuffen hinsichtlich der Fauna an, so sind im ganzen die gleichen Stufen der Entwicklung zu konstatieren. Eine arktische Molluskenfauna ist noch aus keinen anderen Kalktuffen bekannt geworden, aber in Wiesenkalken (z. B. bei Fröjel, Gottland) und Tonen (in Schonen) ist eine solche angetroffen. Dabei handelt es sich jedoch in erster Linie um Süsswassermollusken; von Landschnecken kennt man aus dieser frühen Zeit nur *Pupa muscorum* und *P. Genesii*, sowie *Succinea elegans*, aus einigen Lokalen in Schonen.

Erst während der nächsten Zeit, der subarktischen oder Birkenperiode, findet man einige Landschnecken in den Kalktuffen von Schonen (Kurck), in Torfen und anderen Schichten in Schonen und auf Gottland. Die betreffenden Arten sind *Pupa alpestris*, *P. edentula*, *P. Genesii* und *P. muscorum;* im Skultorp-Tuffe treten nun *Cionella lubrica*, *Conulus fulvus*, *Helix pulchella* und *Hyalinia hammonis* hinzu, alle mit Ausnahme von *H. pulchella*, weitverbreitete, auch in der arktischen Region lebende Arten.

In der borealen Epoche, die mit der Ancyluszeit im ganzen zusammenfällt, nimmt die Zahl der bekannten fossilen Arten beträchtlich zu, so dass man z. B. aus dieser Zeit in den Kalktuffen von Schonen (Kurck) etwa 28 und von Östergötland 15 Landmollusken kennt. In borealen Ablagerungen von Gottland sind 20 Arten bekannt und bei Skultorp ist die Zahl der borealen Arten auch 20. Ohne Zögern kann man sagen, dass die Fauna während dieser Zeit überall einen grossen Zuschuss von Formen erhalten hat. Noch weiter aber geht die Intensität der Einwanderung neuer Formen in der nächstfolgenden, atlantischen oder Litorinazeit. Wie an anderen Orten kann man auch bei Skultorp aus der reichen Entwicklung der Weichtierfauna eine Zunahme der Temperatur und der Feuchtigkeit herauslesen, der Betrag derselben ist aber nicht leicht zu konstatieren. Im Gegensatz zu anderen Gebieten fehlen hier nämlich ganz solche Formen, die auf Extreme in diesen Hinsichten deuten können. In Östergötland tritt z. B. *Pupa moulinsiana* auf, und von Gottland kennt man aus dieser Zeit *Succinea putris* var. *gotlandica*, bei Skultorp aber fehlen alle Gegenstücke. Dieser Umstand ist aber sicherlich daraus zu erklären, dass dem betreffenden Fundort wegen seines grossen Abstandes vom Meere von der Feuchtigkeit weniger zu teil geworden ist. Diese hygrophilen Formen haben sich sicherlich nur längs den Küsten verbreitet, ohne ins Land einzudringen. Vielleicht ist auf diese Weise auch das Fehlen oder die Seltenheit der *Succinea*-Arten (*S. Pfeifferi* und *S. putris*) bei Skultorp zu erklären, da dort nur die mehr xerophile *S. oblonga* diese Gattung vertritt.

Wie in dem Kalktuffe bei Skultorp die Art- und Individuenzahl nach dieser Zeit wieder abnimmt, so ist dies auch in anderen postlitorinalen Ablagerungen bemerkbar, und diese Erscheinung kann demnach nicht auf nur lokalen Verhältnissen beruhen, sondern ist sicherlich durch Klimaschwankungen bedingt. Die über fossile Molluskenfaunen und ihre Entwicklung ausgeführten Untersuchungen sind aber noch zu gering an Zahl und zu unvollständig besonders hinsichtlich der jüngeren Perioden, als dass sichere Schlüsse daraus gezogen werden könnten; es scheint mir jedoch, dass wenigstens die Befunde von Skultorp die Hypothese SERNANDER's bestätigen, wonach in subatlantischer Zeit das Klima durch feuchte und kalte Sommer ausgezeichnet war.

Dass aber die regionale Einteilung nicht notwendigerweise auf abwechselnde Klimaperioden deuten muss, dafür liefert die oben dargelegte Molluskenfauna Beispiele. Man kann nicht schliessen, dass immer eine dürre Periode durch einen Humusstreifen ausgezeichnet ist. In der borealen Zeit wechseln drei Schichten ab, der untere Humusstreifen d_3, der Kalktuff d_2 und der obere Humusstreifen d_1. Die Molluskenfauna zeigt nicht eine Veränderung des Klimas von

d_3 zu d_2 an; eine feuchte Periode kann daher nicht eingebrochen sein. In dergleichen Weise kann man im oberen Teil des Tuffes *c* eine eintretende trockene Zeit spüren, bevor noch der Humusstreifen *b* abgesetzt wurde. Andererseits können lokal Humusschichten auftreten, die natürlich nicht auf dürre Zeitabschnitte deuten, sondern nur auf lokalen Ursachen beruhen, wie z. B. der mittlere Humusstreifen des Lokales 3 *a* und die Schicht β des Lokales 4 lehren.

Um die oben ausführten Darlegungen besser zu illustrieren und auch eine kurze, übersichtliche Rekapitulation der gesamten Einwanderungsgeschichte der schwedischen Molluskenfauna zu geben, habe ich in dem beigefügten Anhang eine tabellarische Übersicht der quartären Molluskenfauna Schwedens zusammengestellt.

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Anhang.

Tabellarische Übersicht der quartären Molluskenfauna Schwedens.

Bemerkungen zu der Tabelle.

Die nachstehende Tabelle veranschaulicht unsere bisherige Kenntnis von der Verbreitung der quartären Molluskenfauna in Schweden. Sie ist unter Benutzung aller bis jetzt vorliegenden Literaturangaben zusammengestellt. Einige Inkonsequenzen sind unvermeidlich gewesen, insbesondere wegen der verschiedenen Zeit- oder Zoneneinteilung der Autoren. Leider können in dieser zusammengedrängten Tabelle keine Hinweise auf die Literatur geliefert werden.

Die benutzten Verkürzungen bedeuten:

Bl.	Blekinge.	S.	Skåne (Schonen).
Bo.	Bohuslän.	Sdm.	Södermanland.
Dal.	Dalarne.	Up.	Uppland.
G.	Gottland.	Wb.	Wästerbotten.
Hall.	Halland.	Wg.	Wästergötland.
J.	Jämtland.	Ög.	Östergötland.
N.	Närke.	Öl.	Öland.

Ein Fragezeichen *vor* einem Buchstaben bezeichnet unsichere Art-, ein solches *darüber* unsichere Zeitbestimmung.

Arten.	Klimaperioden.						
	Prä- oder interglazial.	Arktisch.	Subarktisch.	Boreal.	Atlantisch.	Subboreal.	Subatlantisch oder jünger.
Acanthinula aculeata (Müller)	.	.	.	Wg.	N. S. Wg. Ög	G. Wg.	Wg.
Acme polita Hartmann	.	.	.	.	S.	.	.
Ancylus fluviatilis Müller	.	.	.	G.	S.	.	.
A. lacustris (Linné)	.	.	.	G.	G. S.		Öl.
Anodonta	.	S.	.	Bl. G. Up.	{ G. J. N. S. Up. Wb. }	.	G.
Aplexa hypnorum (Linné)	.	.	.	.	J. S.	J.	S.

Arten.	Prä- oder interglazial.	Arktisch.	Subarktisch.	Boreal.	Atlantisch.	Subboreal.	Subatlantisch oder jünger.
Arion	.	.	.	.	S.	.	.
Balea perversa (Linné)	.	.	.	.	S.	.	.
Buliminus obscurus (Müller)	.	.	.	Wg.	G. S. Wg.	Wg.	G. S. Wg.
Bythinia inflata Hansén	.	.	.	.	? S.	.	.
B. Leachi (Sheppard) = *ventricosa* Gray	.	.	.	G.	G. S.	.	.
B. tentaculata Linné	.	.	G.	G. S. Up.	Dal. G. S. Wg.	Öl.	G. Up. Öl.
Carychium minimum Müller	.	.	.	S. Wg. Ög.	{ G. J. N. S. Wg. Ög.	G. J. N. Wg. Ög.	G. J. N. S. Wg.
Cionella lubrica (Müller)	.	.	Wg.	G. S. Wg. Ög.	{ G. J. N. S. Wg. Ög.	G. J. N. Wg. Ög.	G. J. N. S. Wg.
Clausilia bidentata Ström	.	.	.	Wg.	N. S. Wg.	N. Wg.	N. S.
Cl. biplicata (Montagu)	.	.	.	.	S.	.	.
Cl. laminata (Montagu)	.	.	.	S. Wg.	N. S. Wg. Ög.	N. Wg.	G. N. Wg.
Cl. plicata Draparnaud	.	.	.	.	.		G.
Cl. plicatula Draparnaud	.	.	.	S.	S.	Wg.	N. S.
Cl. sejuncta Westerlund	.	.	.	.	S.	.	N.
Cl. ventricosa Draparnaud	.	.	.	.	S.	.	.
Conulus fulvus (Müller)	.	Wg.	Wg.	S. Wg.	{ G. J. S. Wg. Ög.	J. N. Wg. Ög. }	G. { J. N. Wg.
Helix adela Westerlund	.	.	.	S.	.	.	.
H. arbustorum Linné	.	.	.	S.	J. S. Ög.		G. S.
H. bidens Chemnitz	.	.	.	.	S.	.	.
H. costata Müller	.	.	.	S. Ög.	{ N. J. G. S. Ög. }	N. G.	N. J. G. Wg.
H. fruticum Müller	.	.	.	Wg. S.	{ N. J. S. Wg. Ög.	J. Up. Wg. Ög. }	J. S. Wg.
H. hispida Linné	.	.	.	S.	G.	Wg.	G. N. S. Wg.

Arten.	Klimaperioden.						
	Prä- oder interglazial	Arktisch.	Subarktisch.	Boreal.	Atlantisch.	Subboreal.	Subatlantisch oder jünger.
H. hortensis Müller	.	.	.	G. S. Wg.	G. J. S. Wg. Ög.	S. Up. Wg.	G. N. S. Wg.
H. incarnata Müller	.	.	.	.	S.	.	.
H. lapicida Linné	.	.	.	S.	S.	.	.
H. nemoralis Müller	.	.	.	S.	S.	.	.
H. pulchella Müller	.	.	Wg.	G. S. Wg. Ög.	G. S. Wg. Ög.	Wg. Ög.	G. S. Wg.
H. striata Müller	.	.	.	.	.	.	G.
H. strigella Draparnaud	.	.	.	S.	N. S. Wg.	Wg. Ög.	N. S. Wg.
Hyalinia alliaria (Müller)	.	.	.	.	S. Ög.	.	.
H. cellaria (Müller)	.	.	.	.	G.	.	G. .
H. hammonis (Ström)	.	Wg.	.	S. Wg.	J. N. S. Wg. Ög	J. N. Wg.	G. N. J. S. Wg.
H. nitens Michaud	.	.	.	.	S.	.	.
H. nitidula Draparnaud	.	.	.	? S.	S.	.	S.
H. petronella Charpentier	.	.	Wg.	S. Wg.	J. S. Wg.	J. Wg.	J. N. Wg.
H. pura Alder	.	.	.	.	S. Wg.	Wg.	.
Limax agrestis Linné	.	.	.	S. Wg.	? S. Wg. G.	.	G. Wg.
L. laevis Müller	.	.	.	? Wg.	S. Wg.	.	.
L. marginatus Müller	.	.	.	.	? S.	.	.
L. tenellus Nilsson	.	.	.	.	S.	.	.
Limnaea auricularia (Linné)	? S.	.	.	.	.	.	.
L. lagotis Schrank	.	.	S.	.	S. J.	.	.
L. ovata Draparnaud *f. typica*	.	G. Wg.	G. Hall. S.	N. S. Up.	Bo. G. S. J. Wg. Ög.	Öl.	G. Öl.
L. ovata Draparnaud *f. baltica*	.	.	.	G.	G.	.	G. .
L. palustris (Müller)	.	G.	G. S.	G.	G. S. Ög.	.	G. S. Up.
L. peregra (Müller)	S.	G. S.	G.	G.	G. S. Ög.	.	S.
L. stagnalis (Linné)	.	.	G. S.	G. ? S.	Dal. G. J. S. Wg.	.	.
L. truncatula (Müller)	.	G.	G. S.	G. S. Ög.	G. J. S. Ög.	J. Öl.	G. J. S.
Neritina fluviatilis (Linné)	.	.	.	.	G. S.	.	.
Paludina vivipara (Linné)	.	.	.	.	.	.	Sdm. Up.
Patula rotundata (Müller)	.	.	.	.	G. J. S.	G.	G. S.
P. ruderata (Studer)	.	.	.	N. S. Wg. Ög.	G. J. N. S. Wg. Ög.	N. J.	N. J.
Physa fontinalis (Linné)	.	.	.	G.	G. S. Wg.	? Wg.	Öl.
Pisidium amnicum (Müller)	.	.	S.	G.	G.	.	.
P. fossarinum Clessin	.	G. Wg.	G. S.	G.	G. S. Ög.	.	S. Up. Wg.
P. henslowianum (Sheppard)	.	S.	.	.	.	.	.
P. Lindströmi Clessin	.	.	S.	.	.	.	.
P. Lovéni Clessin	.	G.	G.	.	.	.	.
P. milium Held	.	.	.	G.	G. Ög.	.	G.
P. nitidum Jenyns	.	.	G.	G.	G. Ög.	.	.
P. obtusale Pfeiffer (incl. var.)	.	G.	G. S.	G. J.	G. Wg. Ög.	.	G.
P. pallidum Jeffreys	.	.	.	G.	.	.	.
P. parvulum Clessin	.	.	.	G. N.	G. Ög.	.	G.
P. pulchellum Jenyns	S.	S.	? S.	.	J. S.	.	.

Arten.	Klimaperioden.						
	Prä- oder interglazial.	Arktisch.	Subarktisch.	Boreal.	Atlantisch.	Subboreal.	Subatlantisch oder jünger.
P. pusillum Jenyns	.	S.	.	.	.	.	.
P. Scholtzi Clessin	S	.	.	.	.	.	.
P. subtruncatum Malm	S.	.	.	G.	G.	.	.
Planorbis albus Müller	.	.	.	G.	J. S. Wg.	.	.
Pl. arcticus Beck	.	G.	.	.	.	.	.
Pl. carinatus Müller	.	.	.	G.	G. S. Wg.	.	.
Pl. complanatus (Linné) = *fontanus* Lightfoot	.	.	S.	S.	G. S.	.	.
Pl. contortus (Linné)	.	.	.	G.	G. S. S. Wg.	.	G. J. Up.
Pl. corneus (Linné)	.	.	.	S.	S.	.	Up.
Pl. nautileus (Linné)	.	G.	G.	G.	J.	Öl.	Öl.
Pl. nitidus Müller	.	.	.	.	Bo. Wg.	.	Öl.
Pl. riparius Westerlund	.	.	.	.	G.	.	G. .
Pl. spirorbis (Linné)	.	.	.	.	Bo. S.	.	S.
Pl. umbilicatus Müller	.	.	S.	G.	G. S. ? Wg. Ög. Öl.	? Öl.	G. ? Öl. Up.
Pl. vortex (Linné)	.	.	S.	.	S.	.	.
Pl. vorticulus Troschel	.	.	.	.	? S.	.	.
Punctum pygmaeum (Draparnaud)	.	Wg.	.	S. Wg. Ög.	G. J. N. S. Wg. Ög.	J. N. Ög.	G. J. N. S. Wg.
Pupa alpestris (Alder)	.	.	.	S.	G. N. S. Ög.	.	G. .
P. angustior (Jeffreys)	.	.	.	S.	J. N. S. Wg. Ög.	G.	S.
P. antivertigo Draparnaud	.	.	.	S.	G. J. S. Ög.	.	G. S.
P. arctica Wallenberg	.	Wg.	.	.	.	.	.
P. columella Benz	.	.	.	S. Ög.	S.	.	.
P. costulata Nilsson	.	.	.	.	? S.	.	.
P. cylindracea Da Costa	.	.	.	.	.	.	G. .
P. edentula Draparnaud	.	.	S.	Ög.	G. J. S. Wg.	J. Wg.	G. J. S.
P. Genesii Gredler	.	.	S. Wg.	S. Ög.	J. S. Wg.	J.	J.
P. Lilljeborgi Westerlund	.	.	.	? J.	.	.	.
P. minutissima Hartmann	.	.	.	.	Wg.	.	.
P. moulinsiana Dupuy	.	.	.	.	Ög.	.	G.
P. muscorum (Müller)	S.	Wg.	S.	G. S. Wg. Ög.	J. N. G. S.	G. Wg.	G. J. N. S. Wg.
P. pusilla (Müller)	.	.	.	S.	G. N. S. Wg. Ög.	Wg.	N. Wg.
P. pygmaea Draparnaud	.	.	.	G. Wg. Ög.	G. S. Wg.	.	G. S.
P. Shuttleworthiana Charpentier	.	.	S.	S.	J. S.	.	.
P. substriata (Jeffreys)	.	.	.	Wg. S.	N. J. S. Ög.	G. J.	J. N.
Sphaerium corneum (Linné)	.	.	S.	G. Up.	Bo. G. S.	.	Öl.
Sph. Draparnaldi Clessin	.	.	.	.	? S.	.	.
Sph. mamillanum Westerlund	.	.	S.	G.	G.	.	.
Sph. subsolidum Clessin	.	.	S.	.	.	.	.
Succinea arenaria Bouchard	.	.	.	G.	G.	.	G. .
S. elegans Risso	.	.	S.	.	.	.	S.
S. oblonga Draparnaud	.	.	.	S. Wg. Ög.	J. S. Wg.	.	J.

Arten.	Klimaperioden.						
	Prä- oder interglazial.	Arktisch.	Subarktisch.	Boreal.	Atlantisch.	Subboreal.	Subatlantisch oder jünger.
S. Pfeifferi Rossmässler	.	.	.	G. S. Ög.	G. S. Ög.	.	G. .
S. putris (Linné)	.	.	.	S.	J. S.	J. Wg.	J. Up.
S. putris (Linné) var. *gotlandica*	.	.	.	.	G.	.	G. .
Valvata alpestris Blauner	.	G. Öl.	.	.	.	.	.
V. antiqua Sowerby	.	.	? S.	G.	{ ? S. }	.	.
V. cristata Müller	.	.	Hall. S.	Bo. Dal. G. S.	J. G. S.	.	G. Öl. S.
V. glacialis Westerlund	.	S.	.	.	.	.	.
V. macrostoma Steenbuch	.	.	G. S.	G.	G.	.	.
V. piscinalis (Müller)	.	.	Hall. S.	G. S.	G. S. Wg.	{ ? Öl. }	{ ? Öl. }
Vitrea crystallina (Müller)	.	.	.	S. Wg.	S. Wg. Ög.	Wg. Ög.	G.
Vitrina pellucida (Müller)	.	.	.	S. Wg.	N. S.	Ög.	.
Zonitoides nitidus (Müller)	.	.	.	G. S. Ög.	G. J. S. Ög.	G.	Wg. G.
Summe aller Arten 123	6	20	34	77	105	59	72

Quaternary Sea-bottoms in Western Sweden.

By

Gerard de Geer.

(With Plates 43—45).

Contents.

Introduction.

The west coast of Sweden very nearly coincides with the south-western border of Fennoscandia, the great Archæan plateau of which is here limited by a vast, partly submarine plain, embracing Kattegat, Skagerack, Denmark, and the North

Sea, and being, no doubt, as to by far the greatest part covered by Cretaceous and younger sediments.

The limit of the area of sedimentation has repeatedly shifted place, being situated sometimes outside and sometimes inside the Fennoscandian border. This was also the case at the end of the Quaternary period, when the great ice-covering of the last glaciation gradually melted away, giving place to a new-born land and a new-born sea, forming a real *tabula rasa* for the organic world, which did not delay taking it into possession.

Especially now, when it has proved possible to determine in years the rate of recession of the ice-border, it is, no doubt, of especial interest to study the laws which regulate the immigration of plants and animals into such a new area, gradually forming what may be called a consequent flora and fauna.

The study of the marine fauna of Western Sweden is of special importance, this being the only part of the country where the normal marine fauna is represented, which is suitable for comparison with corresponding faunas in other countries, the interesting but poor faunulas of the Baltic having a too local composition. Furthermore, the late glacial marine fauna in Western Sweden represents the immediate continuation of the fauna which immigrated to the late glacial coasts of Northern Denmark when these were left by the land-ice. The fossil shell-beds in Western Sweden tell the story of the evolution of this fauna as well during the time when Northern Sweden and the whole of Norway were still covered by the land-ice as also during all the succeeding time, until the present development of our still living fauna.

The most salient feature of the coast regions of Western Sweden, and especially of Bohuslän, is the bareness of the extended plateau of bed-rocks, in strong contrast to the flat, fertile valley-bottoms, which are often cultivated close to the steep walls of the innumerable quarters of the dissected plateau. In fact, this border region of Fennoscandia has been crushed up along some very pronounced systems of fissures, one running in the direction of the coast and another crossing it, sometimes at almost right angles. At a great number of places the fissures are densely crowded, representing real zones of fracture, which have afterwards, by running water and land-ice, been partly swept out, so as to form the numerous straight, steep-sided, and often also deep valleys which characterize this region.

The original cause of the fissures, running in the direction of the coast, may be traced back to the great mountain-folding which, in pre-Cambrian time, gave rise to the imposingly uniform arrangement of the secondary foliation within the great gneiss belt of Western Sweden, in the main parallel to the coast. During the Devonian period some extended fissures, the most considerable 70 *km* long, opened in the same direction and just in the continuation of the great fault-line bordering the east side of the not uplifted Christiania region. These fissures were filled by dikes of rhomb-porphyry and augite-porphyry, evidently belonging to the same Devonian period of eruption as the corresponding rocks in Norway and no doubt indicating that the Devonian dislocations determined the Fennoscandian border also in western Sweden.

Still, the recent valley-systems do not show any direct relation to these Devonian dikes, though they are evidently oriented along the same general lines of weakness. On the other hand, the close connection between the valleys and the very numerous zones of fracture younger than the dikes seems to indicate that these fractures, geologically speaking, may be very young or, considering several other circumstances probably of Tertiary age.

The deepest and most important of these valleys run in the direction of the coast and are partly occupied by lakes, as by Stora Le, N. and S. Bullaren, and by the deep, submarine lake-basin E of the Koster—Väderö ridge. These depressions were crossed obliquely, often at great angles, by the glacial land-ice which, evidently, had nothing else to do with their origin than the sweeping out of the crushed material to the extension and depth predestined by the pre-Quaternary act of crushing.

With respect to the valleys which follow other zones of fracture, forming a greater or smaller angle to the coast, it is true that they sometimes also coincide with the striæ, but, as their connection with the rock-fractures in this naked region can be most easily ascertained in a quite conclusive way, it is evident that these valleys have determined the direction of the ice and not *vice versa.*

Especially northern Bohuslän with its uniform granite and its very conspicuous fissure-systems affords a striking example of how ineffective was the power of the glaciation, working during the whole length of the ice-age, of obliterating or essentially changing this fissure-topography, rather modest as to the dimensions, but still exceedingly well developed. Nevertheless, the land-ice has in a very characteristic way, though on a smaller scale, put its stamp on the landscape, by grinding off the proximal ends of the rock-ledges to the well-known ice-worn round-rocks (Sw. *rundhällar*, Germ. *Rundhöcker*). Hereby every rock of the whole region like old JANUS has got two different faces. The original one, facing seawards, is rugged and wrinkled, and the other, facing in the opposite direction, is smooth and polished after the severe treatment received from the land-ice. This gives the whole landscape a different aspect according to the direction from which it is viewed. Many different kinds of striæ, glacial grooves and channels of different sizes are often unusually well exposed in this naked region.

The remarkable lack of morainic material seems often to be original, being almost the same in regions above the hihgest marine limit and in enclosed, sheltered places, from which no marine action could have carried away any ordinary moraine-covering, if it had once really existed. Yet it is quite possible that the lack of morainic material may to some extent be only an appearance, as morainic accumulations may have been caught in and hidden at the bottom of the deep fissure valleys.

But there is also a remarkable lack of glaci-fluvial deposits in Bohuslän, which seems to indicate a corresponding lack of the ordinary morainic raw material, though, of course, even glaci-fluvial deposits may be concealed below the thick clays in the valleys.

Giant-kettles, or the characteristic marks of corrasion by sub-glacial rivers, are found at a great number of places where such currents, pushed forward by a strong hydrostatic pressure, passed over rock-ledges so as to form sub-glacial whirls.

The assumption frequently made that these kettles were formed by water falling down through crevasses is found untenable, at least when applied to the many low-lying kettles which, at the time of their formation, were situated at a considerable depth, even as much as 100—150 *m* below the surface of the sea. In such cases even the crevasses must evidently have been filled to at least the same height by standing water, and it does not seem likely that a water-fall could bore out holes in the bed-rock through such a depth of standing water. Recent giants' kettles, forming in ordinary rapids, show that vertical falls are not at all necessary for their formation, and thus the extraordinarily strong rapids of the sub-glacial rivers were no doubt more than sufficient to produce even giant' kettles of such imposing dimensions as those sometimes found in Bohuslän some 3—6 *m* in diameter. The great number of giant' kettles observed in this province may partly depend upon its broken topography, but partly also upon the rocks being bare of moraine coverings and woods, which in other regions conceal a considerable part of the rock-surface.

A feature of great importance for the deciphering of the Quaternary history of Western Sweden is that the receding ice-border in this region of the country has been stationary at several different lines, a sufficient length of time to leave greater or smaller terminal moraines, indicating the successive limits of the land-ice.

By means of the direction of the glacial striæ and principally by the great Fennoscandian moraines, running from this side of the country to the other, the terminal moraines in Western Sweden can now become approximately correlated with the great chronologic section in eastern Sweden by which the ice-recession has recently been determined.

From this correlation it is evident that the late glacial recession of the ice went on at a much greater speed on the continental than on the oceanic side of Sweden. Thus, the recession of the ice-border through Bohuslän and the adjoining part of the province of Dalsland has taken the same amount of time as the whole recession from the south end of Sweden almost up to the Åland archipelago, that is to say over 3 000 years. As shown by the marginal terraces, the land was at the recession of the ice-border past Bohuslän submerged to the highest marine limit of this region. In the sea, which in the lower parts of the region immediately followed the receding land-ice, was deposited the fine, glacial clay, carried out by the sub-glacial rivers. In this way the late glacial sea at first extended to the northernmost part of Denmark, then to certain parts of Kattegat and Skagerack, further to Halland and Bohuslän, and later on to Central Sweden and to Norway.

The arctic marine fauna, which settled first in Northern Denmark, spread gradually into the new marine areas, left by the receding land-ice, and though the temperature of the air, being able so rapidly to destroy the great ice-cap, must have become considerably milder, several of the arctic forms endured for a long time in the cold water at greater depths, having their last really comfortable period of *renaissance* during the few centuries of low temperature when the ice-border was stationary at the great Fennoscandian moraines.

Changes of level during the late glacial epoch.

By the occurrence in Denmark as well as in Skåne of sub-fossil arctic land-plants at the sea-level in layers resting upon an uplifted arctic sea-bottom, it has been shown that the upheaval of the sea-bottom was accomplished in the region indicated while the climate was still arctic. From investigations of the younger late glacial shell-beds in Western Sweden, described further on in this paper, it appears probable that this wave-like upheaval, which followed the recession of the ice, and its reduction in weight, went on at least as far as the central parts of Western Sweden. By this wave of emergence, which seems to have reached the receding ice-border at about the latitude of the great Fennoscandian moraines, the clay-covered sea-bottom was uplifted, so that shell-deposits with mostly littoral species could accumulate where the water had previously been more than 100 *m* deep. These beds have been found to be covered with shell-layers, sometimes amounting to 12 metres in thickness, showing a gradual decrease of shallow-water forms and at the same time a corresponding increase of forms liking deeper water. These transgressional beds were covered by a sub-arctic clay, evidently marking the maximum of this new depression, and succeeded by sandy shell-deposits still showing a somewhat modified, sub-arctic littoral fauna, marking the emergence from this subsidence and the final regression of the late glacial sea.

After this upheaval followed the known postglacial subsidence, which in the Baltic region was locally characterized by the immigration of *Litorina*.

The time-scale, obtained by the investigation carried out along the western side of the Baltic valley with the purpose of determining the late glacial chronology, seems to indicate that the most natural subdivision of that part of the late glacial epoch, during which the ice-border receded past the region named, is to be made at the most marked break in this recession, indicated by the great Fennoscandian moraines.

Gothi- and finiglacial sub-epochs.

It seems appropriate to designate as *gothiglacial* that part of the late glacial epoch during which the ice-border receded through Götaland — the old Gothia — from Skåne to the great moraines, crossing its northernmost provinces, Dalsland, Västergötland, and Östergötland.

During this time the marine fauna was still arctic, while the land flora was rather subarctic.

The last part of the late glacial epoch, when the ice receded from the great moraines to eastern Jämtland at the point of the first bipartition of the vanishing ice-remnant, may be called the *finiglacial* age. During this time a considerable amelioration of the climate, causing the more and more rapid dissolution of the ice, took place, the land-flora following the receding ice being characterized by the Swedish fir, and the marine fauna in shallow water by an increasing number of boreal forms, while the arctic relicts were more and more confined to the clay-bottom of the deeper water.

Thus, the deposition of the regressional *Yoldia*-clay in Western Sweden south of the moraines was gothiglacial, and likewise its wave-like upheaval, which seems to have extended at least to the region of the moraines, judging from the contemporary emergence at Dal's Ed.

The succeeding wave-trough of subsidence, here described, may have, at least essentially, occurred, after the ice-border had already receded from the great moraines and may thus be called finiglacial.

As to the latest subsidence, which has lasted during a great part of the postglacial epoch, it may properly be named after this epoch, though it is not possible as yet to state exactly when this subsidence commenced.

As seen below, the first indications of the finiglacial subsidence were found at Uddevalla already in 1884 by statistical analyses of the late glacial fauna at Kapellbacken, together with a discovery of a younger, late glacial clay upon the shell-beds, but, being apparently still too isolated, their publication was put off until more evidence could be gathered.

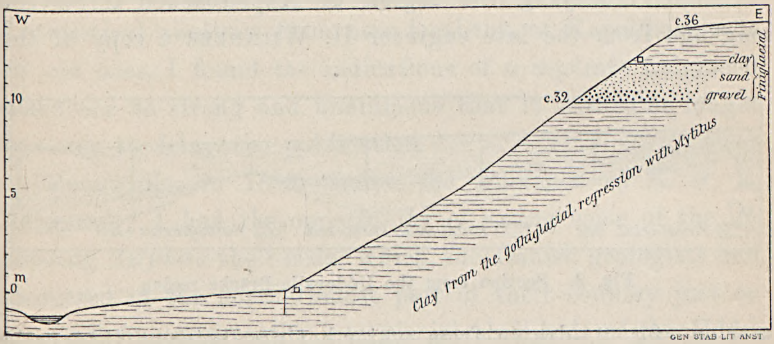

Fig. 1. Section near Munkedal.

In 1888, N. of Gullmarfjorden near Munkedal, some other considerable late glacial shell-beds were observed, also indicating a finiglacial subsidence, and the occurrence of two clay-beds, separated by gravel and sand, also pointed in the same direction. Thus, at the point where the rivers Munkedalsälfven and Örekilsälfven join, the section reproduced in fig. 1[1] was measured on the same occasion, showing the following layers: from the surface of the river to a height of 11 *m*, the upper part of a thick clay, immediately overlain by 0.6 *m* coarse gravel with pebbles as large as a fist. This deposit, no doubt indicating the emergence of the region up to the level of the breakers, was followed by 1.3 *m* pure sand of

[1] In all sections in this paper length and height are on the same scale.

mean coarseness, indicating a new transgression of the sea. That the amount of the new subsidence was considerable, is shown by the fact that sand had been covered by clay, the actual remnants of which were still 1.8 *m* thick. The surface of the clay is here 36 *m* above the sea, and with regard to the depth, necessary for a lasting deposition of such a clay-layer, it is evident that this clay must have been accumulated during a subsidence, reaching much higher than the postglacial one and being, no doubt, the same which in this paper has been called the finiglacial subsidence.

When studying the region of Kapellbacken I received long ago from the late engineer H. WILANDER a copy of the

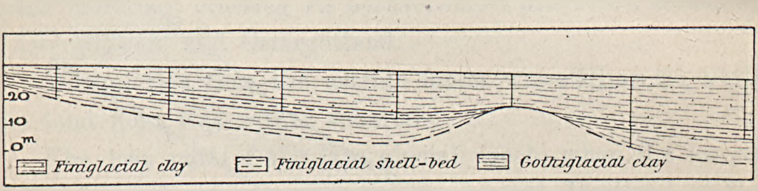

Fig. 2. Section from the Uddevalla-Bräcke region.

section, fig. 2, drawn from water-borings between Uddevalla and Bräcke, and showing at the base some 8 *m* of a somewhat reddish clay, no doubt of gothiglacial age, overlaid by 2—3 *m* of the wide-spread shell-bed with *Balanus*, *Saxicava*, and *Mytilus*. This bed was covered by over 20 *m* of a blackish clay which now, most probably, must be regarded, at least for the most part, as finiglacial.

This seems to agree well with the sequence of layers, found by me at Kapellbacken, and evidently also with the old description by A. ERDMANN of a railway cutting at Marieberg, just north of Uddevalla, where he found a blackish clay, containing arctic molluscs, resting upon a shell-bed of the same kind as those of Kapellbacken, both being no doubt finiglacial.

This sequence of layers seems thus to be quite normal in the Uddevalla region, though it has hitherto not attracted the attention which it no doubt well deserves with regard to the finiglacial subsidence.

For my own part, I have not had much opportunity to pursue the study of this question in the tract named, my later investigations in Bohuslän being mostly confined to the northernmost part of that province, and especially to the geological map-section of Strömstad, where the late glacial shell-beds are much more poorly developed and exposed than in the Uddevalla-region. Thus, the solution of the question about a separate finiglacial subsidence for a time made very little progress, until, during later years, by adding a number of statistical analyses from new localities at Kapellbacken to the old ones, I found the indications of a separate finiglacial subsidence so strong and unanimous that it seemed no longer necessary to delay the publication.

Meanwhile, in 1890, under the guidance of K. J. V. STEENSTRUP, I had the opportunity of seeing some of the interesting *Zirphæa*-shell-beds, which the Danish geologists had discovered in the northernmost part of their country just on the coast opposite to the late glacial shell-beds of the Uddevalla-region, and, evidently for good reasons, correlated with these. In 1899 A. JESSEN in his excellent geological description of Vendsyssel[1] made some very interesting remarks on the *Zirphæa*-beds. He stated that these beds are deposited directly upon the *Yoldia*-clay and that they consist of sand with gravel below and above, a sequence of layers apparently indicating a minor subsidence, subordinated to the great late glacial upheaval of land. He thinks it possible that a certain, especially conspicuous, cut terrace marks the very limit of this subsidence.

Yet, as he did not know anything about the corresponding conditions in Western Sweden, the investigation of which was as yet unpublished, he thought that this apparently iso-

[1] A. JESSEN, Danm. geol. Und. 1 Række Nr 3, 1899, p. 223.

lated phenomenon could possibly be explained by changes in the currents of the late glacial sea.

It is, certainly, no mere chance that the thickest and best developed finiglacial shell-beds of Scandinavia occur in that very region of Sweden where the plankton-bearing, salt current from the open sea past Vendsyssel reached our late glacial west coast. Thus, the Uddevalla-region can be said to mark their maximum development, while they gradually get less thick and less characteristic to the North as well as to the South.

The land-emergence which succeeded the late glacial oscillations was, as well as probably the upheaval between the gothi- and finiglacial subsidences, with respect to the whole area of upheaval, a peripheral phenomenon, being less and less accentuated toward the central parts of the region. Thus, such actual land-formations as peat-bogs and river-channels occur between the late glacial and postglacial marine layers only along the southern parts of the Swedish coasts, while, farther to the North, they are represented by deposits from more or less shallow water, accumulated during the time between the main depressions.

The fauna of the postglacial transgression is characterized by a real invasion of southern salt-water species, and not, like the late glacial fauna, adapted to the brackish water from the melting glaciers, and is found best developed in northern Bohuslän at the greatest distance from the great rivers Göta älf and Glommen. Thus, in the region around Strömstad several rich postglacial shell-beds 4—6 *m* thick are easily accessible, for example at Nötholmen and Tofterna near the town and at other places, where the thickness of these shell-beds rises even to 10 *m*, thus approaching the greatest known thickness of the finiglacial shell-beds, or some 12 *m*, which was observed at Kuröd near Uddevalla in 1898.

In illustration of the above remarks more detailed descriptions of a few characteristic localities will here be given.

Kapellbacken at Uddevalla, a finiglacial sea-bottom.

Ever since the early days ef geology, when the rising of the land in Sweden was a phenomeneon which aroused lively discussion, one of the classical arguments was the considerable accumulation of marine shells at Kapellbacken near Uddevalla, known through LINNÆUS, LYELL and many other scientists.

The Swedish zoologist SVEN LOVÉN, who had visited Spitzbergen in 1837, found that the fauna of the more highly situated shell-beds, such as that of Kapellbacken, was an arctic one, while that of the lower beds was more closely allied to the fauna still existing on our coasts.

Since that time several authors have written about the shell-beds, especially about those at Uddevalla, and the species observed have been enumerated.

This no doubt is partly due to the fact that the late glacial shell-beds which, from the beginning, attracted the greatest interest just in this region, are by far the thickest and best developed in the whole of Scandinavia; partly to the fact that some of these beds were very easily accessible just in the neighbourhood of Uddevalla, the most renowned and interesting of these localities, or that of Kapellbacken, being situated at only a ten minutes' walk south of the town and just along the highway from Göteborg.

However, many of the visits, even to Kapellbacken, may have been rather short, and the ultimate reason why the published lists of fossils from this locality nevertheless were rather long was, according to the authors' own statements, to be found in the little museum of Uddevalla, where, by the interest of consul R. THORBURN, a great number of shells were brought together. Thus, among earlier authors, I may here only quote J. GWYN-JEFFREYS and C. J. A. THUDÉN, and among later ones W. C. BRÖGGER, who in his turn principally follows

THUDÉN and is followed by A. LINDSTRÖM in the description of the geological map section »Uddevalla».

Yet, all the lists of fossils from Kapellbacken have been seriously affected by a partly erroneous labelling in the above named museum, where a number of shells have received the label Kapellbacken, though, undoubtedly, they must have another origin; either the different collectors have used the name of the renowned locality in a sense somewhat too comprehensive, or the labels have quite simply been mixed up. Nor is any distinction made between species collected from the many different layers, which, during very different parts of the late glacial and postglacial times, were deposited at Kapellbacken. Under such conditions no really exact and reliable knowledge of the faunas of Kapellbacken could be had when the most important fact, or the immigration-epoch of the different southern species, had to be made out only by conjecture.

During my own first visit to Kapellbacken in 1881 I did not find a single specimen of the true southern species in the main shell-bed, but found on its cultivated surface *Cardium edule* and *Nassa reticulata* which, however, might have been brought there with fertilizers, but possibly could also have been derived from some younger layer. In 1883 I commenced a systematic investigation of the different layers at Kapellbacken in order to determine the real composition of the fauna and its successive evolution during the time required for the deposition of the shell-beds at this place, sometimes no less than 4—5 *m* thick. In this investigation the chief purpose was to determine which species had really lived together at different times and levels.

It was therefore necessary to avoid the pell-mell collecting-method, mixing specimens from different parts of a large locality or from *talus*-material, derived, perhaps, from very different layers.

When collecting samples of the shell-deposit for examination, I have therefore always carefully cut away every trace of down-slidden shells, cut out a cube of the material, and taken off from its sides all shells which had been cut across, the material in the sample thus being just as it was *in situ.* In this way different series of samples were collected from different points and at each point from different levels of the old sea-bottom.

But in such a broken landscape as that of the west coast of Sweden, with its innumerable steep rock-ledges, it is evident that shells from animals which lived at different depths could in many places become mixed by the sliding down of specimens living on higher situated rock-slopes.

Furthermore, in such a topography it could be exspected that, during the emergence of the land, material from uplifted parts of the shell-beds might be cut through by stream-action and by redeposition be mixed up with younger shell-deposits in process of formation.

To obtain an idea of these different kinds of natural falsification of the fossil faunas and the influence it may have had at different localities it seemed necessary to work out detailed hypsometrical maps of the topography around the shell-beds to be studied.

Finally, it is a fact that many shell-beds, though they may contain almost quite the same species, have a very different character with regard to the dominating forms, which really indicate their mode of formation. Thus, in many cases the ordinary lists of fossils, being only naked enumerations of the species, would have shown no appreciable difference, and this seemed to make it necessary to elaborate actual statistical analyses showing the frequensy of the forms of which the fauna was composed

A short description of the method used in these statistical analyses is given at the end of this paper.

In this way I first examined five samples from the great shell-bed at the brook-section of Kapellbacken at the point marked with E 26 on the accompanying map. The samples represented the different layers of the shell-bed from the bottom to the top with interstices of 1 *m* and were statistically analysed already during the following winter.

The somewhat unexpected results then obtained making it desirable to get further evidence from some place in the neighbourhood, I secured, through the kind assistance of A. LINDSTRÖM, two samples of the shell-material from the opposite side of the small brook-valley at the point D 28 of the map. The agreement between the analyses of these samples and of the previous ones made it desirable to extend the investigation, and, during repeated visits, the collection of samples from new sections was gradually enlarged, until it embraced the whole drainage-area of the small valley-depression in which the shell-beds and the accompanying other marine sediments were deposited.

Of the 24 statistical analyses here published 14 were made by myself, while for 5 of them, in the separation of the shell-material belonging to the different species, I received a valuable help through the following students of Stockholms Högskola: G. AMINOFF, E. LARSÉN, E. LINDEGREN, N. ODHNER and Y. SCHWARTZ. In the remaining 5 analyses the same part of the work has been done by my wife, E. HULT DE GEER, who has also performed the weighings pertaining as well to the last named 10 analyses as to 7 of my own and assisted in my revision of the whole material.

The main work for the map, as well as the levellings, was done by myself in 1894 and completed in 1904, partly with the help of my son STEN DE GEER. The map was measured in the scale of 1:2000 and is here reproduced in 1:5000.

Morphology of the old sea-bottom at Kapellbacken.

The part of the late glacial sea-bottom which is represented on the accompanying map 1 has in our days the following appearance. The northern border of the map is situated 0.6 *km* S. of the small river Bäfveån, which forms the harbour of Uddevalla, passing right through the town. The southern limit of the mapped area lies not quite 0.9 *km* farther to the south and the breadth of the area is not quite 0.4 *km* in West and East.[1]

The map embraces a depression in a mountain-slope, northward facing the enclosed Uddevalla-depression and on all other sides immediately surrounded by naked mountain-ledges, rising to the North some 50 *m* above the sea, at the middle part of the eastern side some 70 *m*, and at least at one point farther southward to 110 *m* above the sea level.

The bottom of the depression between the rocks is covered by marine sediments, and, as seen by the 5 *m* isohypses, lying at the northwestern corner of the map less than five metres above the sea and in the higher southern parts, as at the water-shed of the high road, rising to about 65 *m*, in the small valley east of this point to more than 75 *m*, and at the water-shed of the road crossing the eastern limit of the map to about 69 *m*.

The sediment-covered depression is divided into two subordinate depressions, running south—north and separated by a lower rock-ledge, the summits of which seldom rise more than some 10 *m* above the surroundings, while the sediment-covered passes are some 5 *m* lower.

This bipartition seems, with regard to the whole situation, to have been very effective, with regard to down-washing as well as to re-deposition, both of which processes must have gone on practically without any interference in both of the twin depressions.

With regard to the rôle that down-sliding may have played at Kapellbacken, it is possible and probable that many shells of Balanids and other animals, once living no doubt in

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[1] To facilitate the orientation the maps accompanying this paper are divided in 0.1 *km* squares with the o r i g o in the SW corner.

great number on most of the steep rock-walls facing the west, have fallen down after the death of the animals and become mixed with shells from lower levels. Still, the situation being rather enclosed and wave-action thus reduced to a minimum, the downslidden shells have, in most cases, probably been accumulated chiefly in the immediate neighbourhood of the rock-walls, though it may be possible that the action of deep-reaching storm-waves to some extent have been able to transport shells down-hill when the slope was sufficient.

On the other hand, it is evident that here, as may be the rule for the shell-beds in Western Sweden, the situation was much too enclosed to admit any real shore-action. Thus, the opinion, sometimes expressed in the literature, that our shell-beds have been thrown up by the waves from lower levels are only explainable by lack of study on the spot.

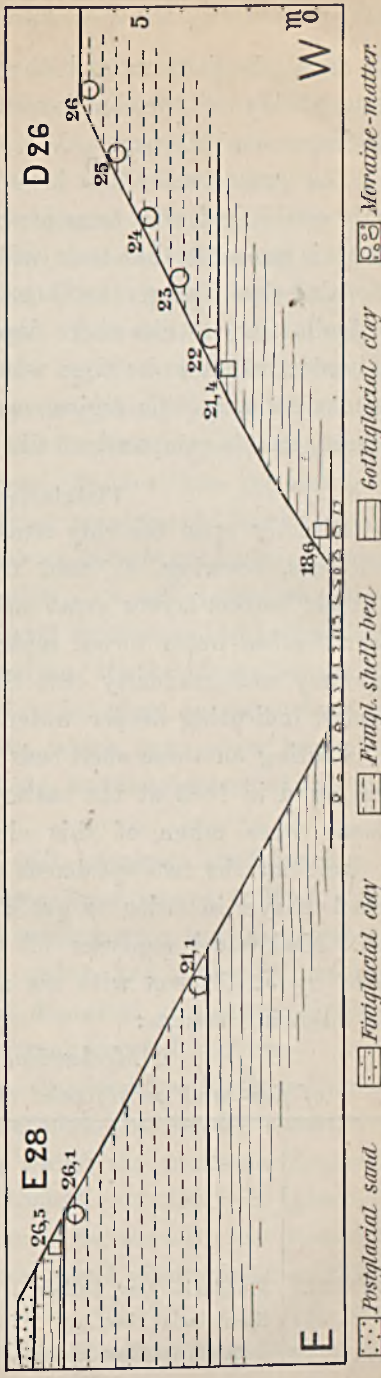
Concerning the stream-action at Kapellbacken, two small brooks have been at work, the greater in the eastern and the smaller in the western depression, but they both seem, as far as is known, not to have cut through any shell-beds proper in their upper courses. Thus it can at most be expected that they may have cut out a smaller number of shells from the clay- and sand-layers in the higher parts of the region which first emerged and then redeposited such shells at lower levels, while the formation of shell-beds was still going on there. Still it seems probable that in the case of Kapellbacken even this circumstance would scarcely have had any greater influence on the original composition of the faunas in the brook-sections here examined, though very likely the great quantities of shell-material cut through and carried away by the brooks from just these sections may, at still lower levels, have become mechanically mixed up with younger, postglacial deposits, thus giving rise to a more seriously falsified but at this place hitherto very little explored fauna.

The succession of sediments in the depression at Kapellbacken.

Gothiglacial layers.

About 100 *m* south of the point where the greater, eastern brook is crossed by the highway, the little brook-valley has been cut down to the moraine, some boulders of which were seen at the valley-bottom. Above the moraine follows a glacimarine clay with *Yoldia* (*Portlandia*) *arctica*, *Arca glacialis*, *Tellina* (*Macoma*) *calcaria* of a large size and some other arctic species but without any southern forms This clay was already observed by LINNÆUS and after him by several visitors, but its fauna has not, as far as is known, been thoroughly examined. The thickness of the clay is here about 3 *m*, and its mechanical composition has been determined by J. JÖNSSON on two samples (190) and (22), which I had carefully taken

Fig. 3. Brook-section at Kapellbacken between E 28 and D 26.



out from the bottom and the top of the clay-layer at the western side of the brook-section D 26; the results are given below, on this page.

The extension of this lower, glaci-marine clay is not directly established, no borings having been made at Kapellbacken, but it is probable that it is widely distributed, though often concealed by younger sediments. The glaci-marine clay is, no doubt, here as elsewhere deposited at and off the receding ice border, about at he time when the land-subsidence reached its maximum, in this region somewhat more than 141 *m* above the sea, and is composed of silt from the subglacial rivers.

Finiglacial layers.

Directly upon the clay named follow the thick finiglacial shell-beds, showing, as seen from the accompanying tables, in their bottom-layers great masses of *Mytilus edulis* L. and other shallow-water forms, which, as we ascend upwards, very regularly and gradually cede their dominant position to other species, indicating deeper water.

Resting on these shell-beds a clay-layer, about 1 *m* thick, was found in 1883 at the eastern side of the brook, and specimens were taken of this clay just above its substratum as well as the two specimens of the gothiglacial clay, mentioned above, in order to get a comparison of their composition. Mechanical analyses of these 3 samples were kindly made by J. Jönsson with the apparatus of Schöne and gave the following results:

Mechanical analyses
of fini- and gothiglacial clays from Kapellbacken.

			Sand.	Loam.	Clay.
			> 0.05 *mm*	—	0.01 *mm* >
E 28	27.1	Finiglacial clay, bottom	12.5 %	9.1 %	78,4 %
D 26	21.4	Gothiglacial clay, top	4.3	15.0	80.7
» »	18.0	Gothiglacial clay, bottom	4.4	10.7	84.9

From this analysis it is seen that the gothiglacial clay is very fine and uniform and contains but very little sand, while the upper or finiglacial clay contains about thrice as much, being still tolerably fine. This latter clay no doubt marks the maximum of the finiglacial subsidence.

In 1898 I found on a small, isolated rock-shelf an interesting little shell-bed at X 0.32, Y 0.42, lying, according to the spiritlevel, 46 *m* above the sea. This shell-bed, L 46, was underlaid by a clay, probably the upper or finiglacial one, and contained mainly the ordinary finiglacial species, which must have lived on the spot, as the dominating situation forbids downwashing from older layers. Besides these remaining species, characterizing the finiglacial transgression, there also occur some southern immigrants, such as *Anomia ephippium*, *Litorina litorea*, *Cardium edule*, *Hydrobia ulvæ* and *Aporrhais pes pelecani*, showing that the finiglacial subsidence had been followed by upheaval, that the shore-line at the deposition of this shell-bed had already receded to its close neighbourhood, and that certain southern colonists, which have never been found in the transgressional shell-beds, had immigrated at this stage of the sea-regression.

As further on stated, still younger shell-bearing deposits occur at a somewhat lower level, where, at M 34, a postglacial sand-layer was found resting upon the finiglacial clay, just at the side of the brook-valley, and probably pertaining to a series of small deltas, deposited at successively lower and lower levels, where the brook entered the sea.

Thus, almost the whole finiglacial subsidence is represented at one and the same place by layers, showing the transgression with deepening water, the maximum depression with the clay-deposit and though not the late glacial, at least the postglacial regression of the sea with the littoral and delta-deposits, indicating a continued amelioration of the climate.

At Fredriksborg in 1888 the accompanying section, fig. 4

was measured, showing below the finiglacial transgressional shell-bed a sand-layer, towards the bottom clayey, which evidently pertained to the upheaval between the gothiglacial and the finiglacial subsidences, while the shell-bed is covered by the finiglacial clay, marking the maximum of this younger subsidence.

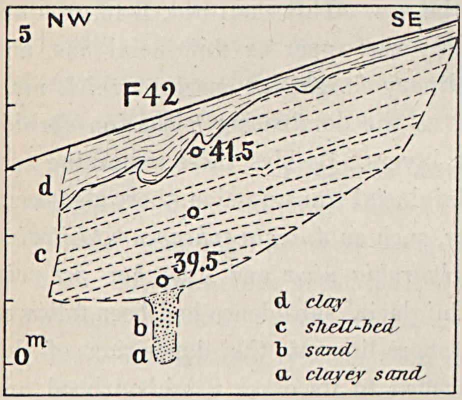


Fig. 4. Section at Fredriksborg F 42.

The surface of the shell-bed just below the clay showed some curious grooves, which might be explained by stranding ice-bergs, the same being also true of the surface of the finiglacial shell-bed W of Kristineberg at the section C 16 at X, Y, of the map Pl. 43 and figs. 5-6 though at this place no finiglacial clay was left, the situation there being more open and exposed to denudation by storm-waves. The grooved surface of the regularly stratified and uncommonly well preserved finiglacial shell-material was here discordantly covered by evidently rearranged shell-material, interbedded with small sand-lenses in a rude stratification, following the sharply marked, grooved surface of the finiglacial sea-bottom. While, in the subjacent, finiglacial layers the shells pertaining to the same individual of *Saxicava*, *Mytilus* and the *Balanidæ* among others were very often found together *in situ*, this was never the case in the upper layer, where these shells evidently occurred only as mechanically redeposited material. Still, a few southern forms were found, as *Cardium echinatum*, *Ostrea edulis*, *Cyprina islandica*, sometimes with both shells together, *Hydrobia ulvæ*, *Bittium reticulatum?* and *Aporrhais* *pes pelecani* which, no doubt, had lived on the spot when this layer was forming. Whether, except *Hydrobia* and *Bittium*, also other small, southern forms thrived on this kind of bottom, in spite of the accumulation of coarse shell-gravel

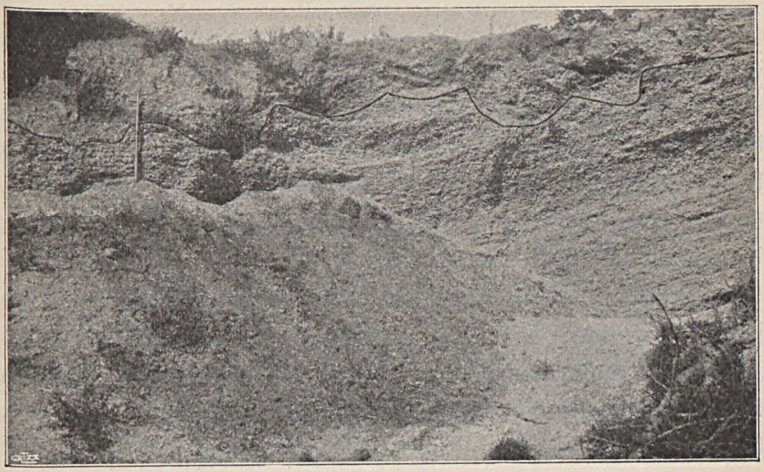


Fig. 5. See below.

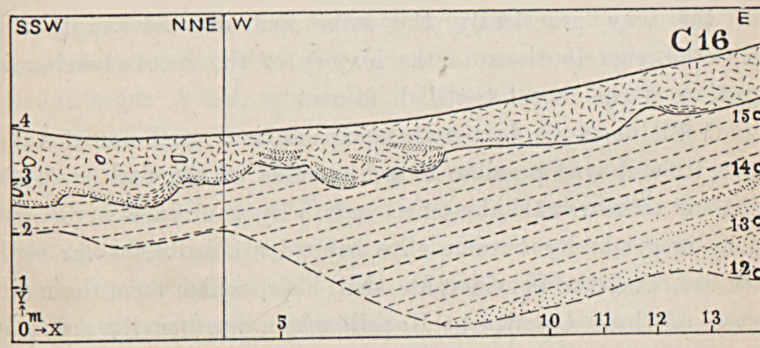


Fig. 6. Section at Kristineberg, Kapellbacken C 16. Postglacial layers, discordant upon finiglacial beds.

from older beds, is not yet known, as no detailed analysis of this shell-bed has been made. It seems probable that in this superficial layer the scanty fauna, hitherto known, which so sharply differs from that in the finiglacial beds, pertains to the true postglacial time.

Statistical analyses of the fauna in the different layers at Kapellbacken and some supplementary localities.

At the end of this paper are added some tables, containing the main results of the statistical analyses of shell-deposits hitherto made at eight different points of the old sea-bottom at Kapellbacken, one point at Kuröd, 2 *km* ENE of Uddevalla, and one point at Evenås on the island Skaftölandet close by the sound Strömmarna, 28 *km* WSW of Uddevalla.

It must be admitted that the results of the first analyses, performed in 1884, were quite unexpected and at the same time somewhat disappointing, the evolution of the fauna from the bottom-layers upward pointing to a deepening of the water instead of the expected late glacial land-emergence. At the same time, as the species liking deeper water increased in number in the said direction, the fauna was still all the way practically the same and did not supply the expected contributions to the history of the successive immigration of the recent Swedish fauna.

Still, facts are better than expectations, and now for the first time it was possible to get an idea of the real composition of these remarkable shell-beds. By continued investigations it gradually became sure beyond all doubt, as far as I can see, that the considerable shell-beds, which form the main mass of these deposits at Kapellbacken, were really accumulated during a land-submergence causing a successive transgression of the sea, and the very uniformity of the fauna has proved to be of special interest, since it has turned out that these thick deposits must have been accumulated during a relatively very short time.

A closer study of the table of analyses from Kapellbacken shows at one point, C 16, a small number of species which do not occur in the shell-beds at the other points but are common in the gothiglacial clay. Rolled lumps of this clay being found in the generally clean and sandy shell-material of this locality, it seems highly probable that the said shells have been washed out from parts of the gothiglacial clay which may have rested on the little rock-ledge immediately east of the locality. The shell-beds show a very regular dip of 18°—10° just from that side, and it is easy to understand how shells, washed out from the above named clay could easily enough slide down and become re-deposited among the true finiglacial shells.

Such secondary, gothiglacial species have thus been set apart in the table as not belonging to the finiglacial fauna of this locality.

The dominating, finiglacial forms belong to the *Cirripedia*, the *Gastropoda* and the *Pelecypoda* together with one *Echinus*, which are also the only groups treated in these analyses.

Besides the above named groups there are observed a single small pincer-fragment of a *Decapod*, probably a *Pagurus*, a few specimens of a *Serpula*, a few *Bryozoa*, numerous spiculæ of the sponge-genus *Tetca*, especially in the middle layers at point F 42 where they form a conspicuous, thin layer in the shell-beds. Furthermore there occurred at several points, a number of *Ostracoda* and *Foraminifera* of which dr A. Goës in 1884 had the kindness to determine *Nonionina depressula*.

It seems indubitable that of these different groups the first three, which play the main rôle in these statistical analyses, also in most other cases are best fitted for calculations of this kind and at the same time with respect to their conditions of life are by far the best known and thus most reliable of all the marine fossils ordinarily available.

Of course it is always desirable to state which of the more common, smaller and less well-known forms, as *Foraminifera*, *Ostracoda* and *Diatoms*, occur together with the different faunas of the leading groups, but for the purpose of this paper it seems unnecessary to encumber the investigation with these forms which are in several respects of less importance.

As to the general character of different faunas, it seems proper to give them, as the botanists do with respect to the floras of different localities, a designation after their most dominant genus or species. Yet, instead of changing into latin adjectives the names of species next in number to the leading forms, it may be as well only to add their names to the leading designation. When necessary, the name of the leading species may be added before its name of genus.

Thus, at Kapellbacken every shell-bed belonging to the finiglacial transgression must be designated as a *balanium* and, with only single exceptions, as a *Hameri-balanium*. The bottom-layers as well at the lower as at the higher parts of the investigated area are characterized by a very great number, often some 400 *pro li* or more, of *Verruca Stroemia* and generally at the same time by quite as great a number of *Balanus crenatus*. *Balanus Hameri* on the contrary is much less common in the bottom-layers than in the upper ones. In the same way *Mytilus edulis* is most common and best preserved in the bottom-layers, and decreases upwards, where generally mere fragments are found, while the opposite is true of *Crenella lævigata*. Likewise the pins of *Echinus* (*Strongylocentrotus*) are considerably more numerous in the bottom-layers than higher up. As to the *Gastropoda*, several of these seem to be more common in the upper layers of the different localities, with the exception of those at higher levels.

Among the *Gastropoda* several species have been met with which never or seldom are found in the actual seas around Scandinavia. To these belong *Cingula castanea*, which occurs at all horizons of the older layer, belonging to the finiglacial transgression, and I have also found it in corresponding layers of other localities. It is a true arctic species, of which only 2 isolated specimens have been found in Scandinavia at Vadős by G. O. SARS.[1] About the same is true of *Moelleria costulata*, which in Scandinavia has been found, by the same author,[2] living only in single specimens at three places in Northern Norway, but is also reported from a few shell-beds. Somewhat rarer, but still observed at four different horizons of the said older layers, was a little *Gastropod*, which as to its exterior reminded of a small *Limnæa*, but which I could not refer to any known genus or species. Mr N. ODHNER, to whom it was shown, has kindly told me that it was really a new form, with which he succeeded to identify some single specimens from Bellsund and Hornsund at Spitzbergen, found among the collections of the Riksmuseum. He has described the shell and the animal of this new species, in his manuscript giving it the name of *Ptisanula limnoides* n. gen. et n. sp. Among some undetermined youngs of *Gastropoda*, ODHNER recognized 1 specimen of *Jeffreysia opalina*, which is marked in the table. But another, very small form, of which I had found two specimens, may also be a new one, though the material is too incomplete to allow a reliable description.

Concerning the interesting form, which was mentioned from Kapellbacken already by HISINGER under the name of *Capulus hungaricus* and which has afterwards been referred to a subgenus *Pilidium* (*Piliscus*) and to the species *P. radiatum* M. SARS, of which this author had found a few living specimens at one locality in northernmost Norway, I have come to the opinion that the subfossil form, of which I have got 12 specimens from Kapellbacken and, at my visit in Canada in 1891, by the kindness of Mr FERRIER in Montreal, 6 specimens from the late glacial locality of Mile End close by, show quite the same characters as the subfossil specimens

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[1] Bidrag till kundskaben om Norges arktiske fauna. I. Mollusca regionis arcticæ Norvegiæ. Univ. Program Christiania 1878 p. 174.

[2] Loc. cit. p. 127.

at Kapellbacken. From Canada J. W. DAWSON[1] mentions only two specimens, one from Montreal (probably: Mile End) and another from Point Levi near Quebec. He uses in the text the name *Capulus Ungaricus* LIN. (commodus? Midd.) and gives a recognizable figure, designated *Capulus commodus.*

This subfossil form seems to connect *Capulus* and *Pilidium* in such a way that it seems better to join the different forms under the original name of *Capulus.* Still, as far as I have seen, the late glacial form is different enough from the recent *Capulus radiatus* M. SARS to deserve a new name, for which I propose that of *Capulus glacialis* n. sp. If it should turn out that there are really transitions, the fossil form must in every case deserve the designation *C. radiatus* var. *glacialis.*

Descriptions of the named forms of *Ptisanula* and *Capulus* will be published in the journal of Geologiska Föreningen in Stockholm.

Among other *Gastropoda* I have also seen several specimens of *Scalaria borealis* BECK, which was already in 1835 mentioned and figured from Kapellbacken by LYELL,[2] though it was not until 1839 described by BECK in LYELL's paper on the late glacial shell-deposits at Beauport in Canada.[3] As this species did not occur in any of the statistically examined specimens, it could not be entered in the table. The same is true of *Sipho latericeus* MÖLL., of which 2 single specimens were found on the talus of the locality C 16, and also of some other species, belonging to the same group of the *Gastropoda,* but observed only in specimens too young, or too badly preserved to allow of a reliable determination. Together with *Buccinum groenlandicum* I found, already at my first visit at Kapellbacken, also more heavy forms, seemingly allied to

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[1] The Canadian Ice Age, Montreal 1893 pp 247 and 208: pl. 1, fig. 14.

[2] On the proofs of a gradual rising of the land in certain parts of Sweden. Phil. trans., Part I, London 1835, p. 37, Pl. 2. fig. 11 & 12.

[3] Geol. Trans. London 1839.

Buccinum undatum but such varieties are not in the tables separated from the main form.

Though from the good agreement of the statistical analyses of Kapellbacken the main features of the fauna and of its evolution seem already sufficiently established, it is likely enough that of the rarer forms new interesting finds may still be expected in these layers, representing a sea with conditions at the same time so favourable for animal life and so unlike those of our present sea.

In the bottom-layers, immediately above the fine gothiglacial clay, the shell-beds contain sand and gravel with stones some 10—15 *mm* large, this as well as the fauna indicating very shallow water. The gradual change of the fauna upwards, where several of the low water species such as *Mytilus* occur almost only as small fragments, probably washed down from higher levels to which the *Mytilus*-belt at that time had risen, seems difficult to explain in any other way than by a rising of the sea-level, in this case produced by a subsidence of the land.

In full accordance with this result of the biological analyses is the fact that the coarse sediment of the lower shell-layers higher up is replaced by a layer of clay, containing not very much more sand than does the subjacent, fine gothiglacial clay, as seen from the analyses p. 1184. This clay, which here reaches a thickness of about 1 *m*, is observed resting upon the finiglacial shell-beds at the localites X 0.44; Y 0.65 : 24 D 28, E 42, and G 50 *m* above the sea, though at the point last named the section is now destroyed. No very energetic search for fossils in this clay has yet been made, but the heights to which it rises show conclusively that this layer cannot have been deposited during the postglacial land-subsidence which here cannot have reached much more than some 36 *m*, the great invasion of southern forms, which characterize the true postglacial layers, never being found at higher levels in this region.

Still, at a height of 68 *m* above the sea-level, the fauna changes in the ordinary way from the bottom-layers upwards, showing that the finiglacial transgression of the sea reached a still higher level. Yet there are some indications that this level may not have been situated very much higher. Thus, *Mytilus* becomes at 65—70 *m* more and more numerous in all layers, while *Crenella*, even in the uppermost beds, which were deposited in less shallow water than the lower ones, is here universally uncommon. The same is the case with most of the *Gastropoda*, which evidently required deeper water. As the highest point where finiglacial shells were found is situated at nearly 75 *m*, this level marks a minimum of the finiglacial transgression which may yet have risen even somewhat, though probably not very much, higher, as the fauna on the higher parts of the finiglacinal sea-bottom here described seems to show that the water in which that fauna lived never became very deep.

Comparison with the finiglacial beds at Kuröd.

Of the uncommonly thick shell-beds NE and ENE of Uddevalla that of Kuröd was visited in 1888, showing on that occasion a section through the finiglacial shell-bed to a depth of about 7 *m*. In 1898 this point was revisited, and the section was then 12 *m* deep. The shell-beds here, just as at several points of Kapellbacken, show a dip reaching some 20 and even 27 degrees away from the rock walls along the side of which the animal life evidently had the best opportunities. Some interesting variations of the dip at certain levels may be due to changes in the water-action, produced by corresponding changes in the height and form of the shore-line. The top of the shell-bed was unconformably covered by a littoral bed, about 1 *m* thick and consisting of shells, gravel, and pebbles, approaching 0.5 *dm* in size. According to well agreeing barometric measurements made at the two visits, the surface of the shell-bed lay, at the NW side of the section, nearly 58 *m* above sea-level and at the highest point about 60 *m*. From this follows that the littoral covering represents the finiglacial recession of the sea. At both the visits specimens of the shell-material were secured for analysis, but a preliminary inspection having shown that the fauna was much poorer and more monotonous than that of Kapellbacken, only one specimen from a depth of nearly 11 *m*, or about 46 *m* above sea level, has hitherto been analysed with the result recorded in the first column of the table.

This analysis, as well as the inspection of the other specimens, shows that this heavy shell-bed is a very pronounced *saxicavium*, while the other species are reduced in number and few. The relation between *Mytilus* and *Crenella* as well as that of the *Balanidæ* and *Echinus* seems to be most analogous with the middle part of the beds at Kapellbacken pertaining to the same transgression. This layer may thus have been deposited in water of moderate depth, while the specimens from somewhat higher levels seem to indicate a deepening of the water, as was the case at Kapellbacken. Still, the great abundance of *Saxicava*, the shells of which are at this locality less thick and rugged, being more straight and regular than at Kapellbacken, seems to indicate that this place was more favourable for this than for other species perhaps just because of the uncommonly rapid accumulation of its shells, witnessed by the extraordinary thickness of the transgressional shell-layers at this place. In this connection it is worthy of remark that of the ordinarily less hardy *Gastropoda* the omnipresent *Trophon clathratus* is the only one here represented.

The very striking difference in the composition of the no doubt contemporary faunas at Kapellbacken and Kuröd affords an example of what is to be seen everywhere along our present coasts, namely that the composition of the recent fauna differs considerably at different localities, according to bottom, depth, salinity, currents, and vegetation. The predominance of certain species thus being often a product more of local conditions than of a certain epoch, it seems better, when possible, at least for the present, to use other designations for the sub-divisions of our Quaternary deposits than the names of different fossils, though, of course, this somewhat rougher method of correlation must be used when no other is available, as especially for many deposits from earlier epochs. When, however it has become established by other means that certain species correspond to a distinct epoch, there is of course no objection to be made to the use of its name to designate the epoch in question.

As to the less dominating species of the late glacial transgression the following words may be added. It may at present be permitted only to refer to the table, with the remark that even of the groups analysed some rare and thus less characteristic species have been found which did not occur in the specimens analysed.

The finiglacial regression at Kapellbacken.

As already mentioned, it is not yet known to what level the finiglacial transgression rose in this region, but some 10 *km* farther to NW, near Stale, there occurs at a height of about 102 *m* above the sea a clayey shell-bed with the common finiglacial species, including *Mytilus edulis* in great numbers, and single specimens of *Litorina litorea* and *Tellina baltica.* If these latter have immigrated into the land as late as during the finiglacial subsidence, it is necessary to assume that this transgression has reached the height named and possibly also extended just to some marked beaches in the neighbourhood at the height of 110 *m.*

The maximum of the transgression being reached, the finiglacial regression followed sooner or later, though, as is often the case with deposits formed during an upheaval of land, the beds from this epoch were, in most cases, soon after their deposition destroyed by the wave-action along the receding shore-line. Still, at several places they might be preserved, as is the case with the littoral covering of Kuröd 58 *m* above the sea, and in the middle of the mapped area of Kapellbacken on the east side of the brook, where I found in 1898 at the height of 46 *m*, a little isolated shell-bed at the very foot of a steep rock-ledge, rising some 20 *m* above the place. This shell-bed was only 0,6 *m* thick and rested upon a clay of uncertain, but most probably finiglacial age. The situation was so sheltered, that it seems not possible that shells from any older bed could have been washed down to this place. Two specimens were analysed, one 0,1 and one 0,4 *m* above the bottom. The fauna is evidently a littoral one, though it is possible and probable that several forms may have lived on the steep rock-side, somewhat above the level where they became deposited. Yet, very likely, the surface of the sea may have stood some 50 *m* above the actual sea-level, when this bed was formed.

As was already the case with the youngest beds from the finiglacial transgression, this shell-accumulation is a *crenatus-balanium* with many of the species of the last named localities still inhabiting the region with the addition of a few newly arrived, southern colonists. Thus, *Tellina baltica*, *Litorina litorea*, and *Anomia ephippium* had already arrived, when the transgression had extended to 70 *m* above the sea but at this stage of the recession *Litorina litorea*, *Lacuna divaricata*, and *Anomia* had become much more numerous, while *Cardium edule*, *Hydrobia ulvæ*, *Tectura virginea*, and single specimens of *Aporrhais pes pelecani* had made their entrance on the scene.

It may be mentioned that the threshold of the older, finiglacial sound, by which this region during the earlier part of the time in question stood in connection with the brackish water of the great Vener-basin, had been closed when the shore-line had receded past the level of 56 *m*. It seems that the southern marine colonists commenced their immigration very soon after the water of this region had become less brackish and better adapted to new-comers from the open sea.

The colonists, however, are few and of the same species which have been found in several of the younger, finiglacial shell-beds in other parts of Bohuslän, while the numerous southern species which characterize the great invasion of the postglacial subsidence are here still totally missing.

This was also what could be expected in view of the well defined and very regular height of the upper limit of the postglacial subsidence in the adjoining parts of southern Sweden and Denmark. Judging from those heights it is very improbable indeed that the thus well defined postglacial sea-shore in this region should have reached as high as 50 or even 40 *m*.

At Berg in Dragsmark, about 26 *km* WSW of Uddevalla, and therefore in a region somewhat less upheaved than the foregoing, two finiglacial shell-beds are found, the higher 52 and the lower 41 *m* above the sea. In both occur, together with the main mass of earlier finiglacial inhabitants: *Tellina baltica*, *Litorina litorea*, *Anomia ephippium*, and *Mytilus modiolus*, but only in the lower one *Cardium edule*, *Hydrobia ulvæ*, and *Litorina obtusata*, which thus seem to have arrived at this region at about the same stage of the land-emergence as they appeared at Uddevalla.

About 2 *km* SW of Berg another interesting shell-bed was found and investigated in 1904 on the eastern shore of the island Skaftölandet, due E of Klubben at Fiskebäckskil and belonging to Evenås.

This is the only place in Sweden where a true postglacial shell-bed is found resting immediately upon a shell-bed of finiglacial age.

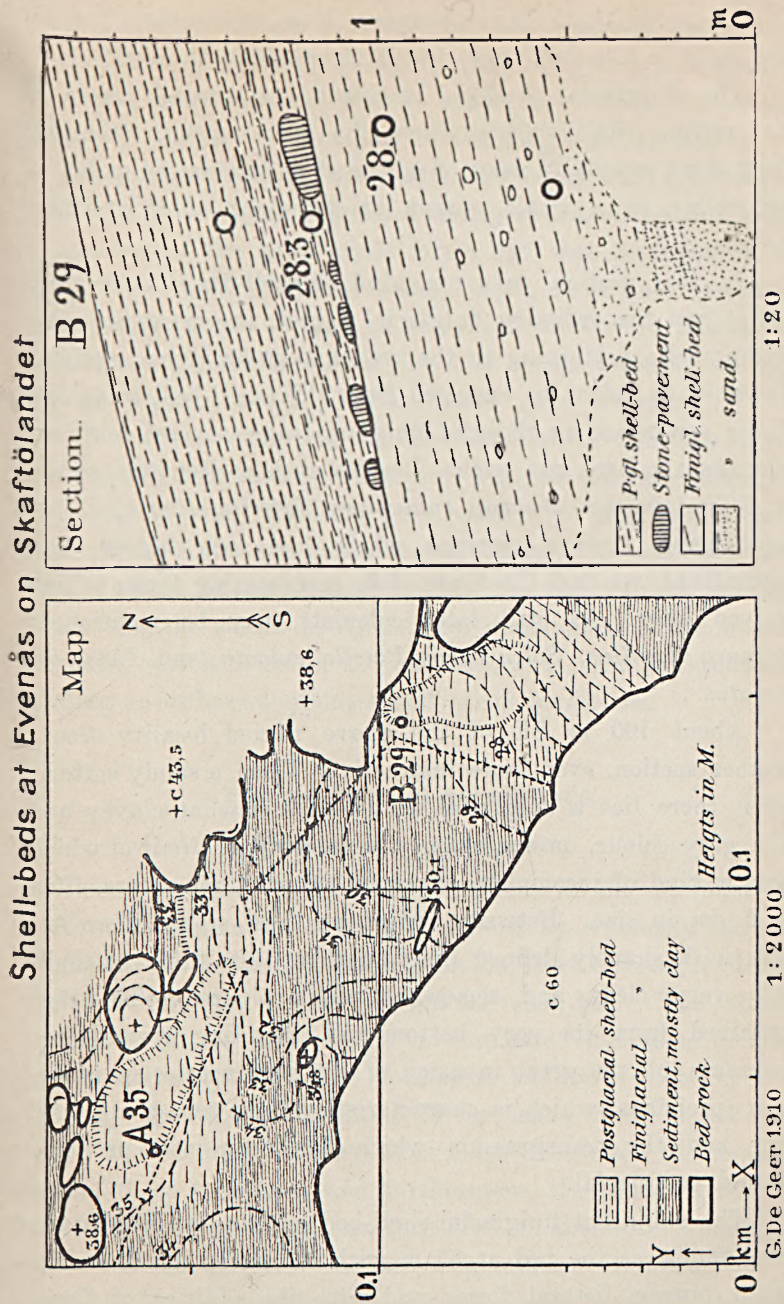
Shell-beds at Evenås on Skaftölandet
Map.
N
S
+c 43,5
+38,6
+38,6
A 35
B 29
30,1
c 60
Postglacial shell-bed
Finiglacial "
Sediment, mostly clay
Bed-rock
Heigts in M.
0.1
0 km → X
Y
G. De Geer 1910
1 : 2000
Section.
B 29
28.3
28.0
P.gl. shell-bed
Stone-pavement
Finigl. shell-bed
" sand.
1 : 20
1
m 0

Fig. 7.

As seen by the accompanying map and section, Fig. 7, this point is situated very nearly 29 *m* above the sea.

The finiglacial shell-bed is observed at several places in the narrow little valley where the beds were investigated. They were especially easy of access at a dominating point of the valley in a small section at a height of 35 *m* above the sea.

In this section only one kind of shell-deposit occurred, and it had the ordinary finiglacial aspect, the great majority of the shells pertaining to the well known finiglacial natives. However, as might be expected from this shell-bed, being one of the lower among those of finiglacial age, several southern colonists are here met with. Besides such earlier immigrants as *Tellina baltica*, *Anomia ephippium*, *Litorina litorea*, *L. obtusata*, and *Tectura virginea* which had long before been naturalized, we find *Cardium edule* representing forms which arrived later. As still later colonists may be mentioned: *Purpura lapillus*, *Solen ensis*, *Patella vulgata*, and *Tapes decussatus.*

About 100 *m* SE of the above named locality occurs another section, even more instructive. Upon a sandy bottom-layer there lies a finiglacial shell-bed, somewhat clayey and of a grey colour, on the sharply defined upper limit of which rests a kind of incomplete pavement of scattered stones, often 1—2 *dm* in size. Between and above these stones there follows with sharply defined limit another, quite different shell-bed, very clean and somewhat violet-coloured. This bed contained from its very bottom and extending upwards the remnants of the great invasion of southern species in numerous specimens, which is characteristic of the true postglacial time and the transgression which has been most properly termed postglacial.

The subjacent finiglacial shell-bed contains essentially the same fauna as the bed at 35 *m* with the exception of half a dozen purely littoral forms and with the addition of *Tapes* *pullastra*, *Scrobicularia piperata*. *Trochus tumidus*, *Onoba striata*, *Rissoa membranacea*, *Mytilus modiolus*, and pins of *Amphidetus*, to mention only some southern colonists which immigrated during the last part of the finiglacial recession.

A comparison of these, with the fauna at Kapellbacken from the time of the finiglacial transgression, shows that quite a number of the more arctic forms had then disappeared, at least from more shallow water, while it is quite probable that many forms, which at an earlier time were littoral or sublittoral, gradually moved down to deeper water as the conditions changed and the surface-water grew warmer.

When the evolution of the fauna in its different stages has proved more closely connected with the successive changes of level, it will, probably, be possible to decipher several such changes in the habitudes of different species. At present it seems advisable not to draw too far reaching conclusions from the actual bathymetrical distribution of the marine animals, which, besides, as well known, is very different according to different climates and other conditions.

The postglacial subsidence.

Postglacial beds at Evenås.

The postglacial subsidence, which, in the peripherical parts of Scandinavia, is so well defined by a sharply marked shore-line at the limit of transgression, is at Evenås, no doubt registered by the upper postglacial shell-bed. The stone-pavement at its base seems to indicate that some erosion has occurred between the formation of the two beds; and the very essential modification of the fauna of the upper bed shows that some time may have elapsed between the deposition of these two beds, and furthermore, the relatively great number of newcome, southern forms, which abound in the upper bed. seems to indicate that the accumulation of this one must have taken a not inconsiderable time. How far the finiglacial sea receded, before the post-glacial transgression commenced is not known, but that the postglacial beds even in this region were deposited during a distinct subsidence seems indicated by the facts at hand. As this is the highest point in the neighbourhood to which it has been possible to trace the true postglacial fauna, it seems reasonable to assume that the postglacial subsidence in this region has not extended more than to about 30 *m* above the sea. It is very probable that the subsidence, having attained its highest limit became stationary for a time before the commencement of the last emergence of the land during the postglacial regression, which, judging from the very great contemporary changes in the fauna, has probably been much slower than the preceding earth-movements. During this time by far the greater part of the comparatively rich, actual marine fauna immigrated to our west coast, though many forms did not come, till the land-emersion was already ended.

Even such a small specimen as that analysed, making scarcely a handful of the postglacial shell-material at Evenås, indicates clearly enough that very different conditions had now set in.

From this time the fauna is characterized not only by single southern colonists, but by a true inundation of southern forms, such as *Bittium reticulatum* and the much less numerous *B. adversum*, a very great number of *Rissoidæ* of many different genera and species, *Nassa reticulata*, several species of *Venus* and *Tapes*, of which latter genus only single specimens were found among the colonists of the immediately preceding time. The same is true of *Aporrhais* and *Ostrea* which now become very common, the latter often dominating in true *Ostrea*-beds together with *Lucina borealis* and some other forms, thriving in this company, just as *Trophon* in the finiglacial *saxicavia* and *balania*. Among other characteristic postglacial forms may be added *Corbula gibba*, *Pecten varius*, *Mactra elliptica*, *Emarginula reticulata*, and *Dentalium* *entale.* Especially such small forms as *Bittium*, *Corbula* and several of the *Rissoidæ* are excellent leading fossils, widespread as they are and often exhibiting a great number of individuals, represented at most postglacial localities.

Yet, the number of species which immigrated during this time is so great that it is not possible here to give even a general synopsis of it as in the case of the finiglacial beds, the more important forms of which are already seen from the analysis of the Kapellbacken fauna.

Concerning the postglacial deposits, therefore, only a short description may be added in view of the somewhat poor representation of this fauna, found at Kapellbacken as compared with the well-developed and rich, postglacial shell-beds in the neighbourhood of Strömstad in northern Bohuslän. As regards the postglacial beds at Kapellbacken, deposited in a narrow bay into which the river Bäfveån had its outlet, they do not show the ordinary rich evolution of the contemporary marine fauna from more open localities.

Postglacial beds at Kapellbacken.

During a visit to Kapellbacken this spring I found that the southern forms observed in 1881 on the surface of the ground just E of the central brook had not been carried there by man, nor, at least not all of them, transported by the brook from the younger finiglacial beds, which occur about a hundred meters farther to the south, but where at least four of the forms of the lower locality are missing. The deposit at this locality consists of sand, forming a kind of low wall along the eastern side of the small brook-valley from a level of some 36 *m* down to probably at least some 30 *m*. This sand seems scarcely to reach half a meter in thickness and was probably deposited by the brook during the annual flood-time, the postglacial subsidence being at or very near its maximum. Thus, some of the species of that time became imbedded in the sand and preserved until our days. At lower levels the sand rests on finiglacial clay, while, farther to the south, its substratum is the upper part of the great, finiglacial shell-bed. Hence the sand at M 34 contains, together with the contemporary forms, many shells the redeposition of which from this subjacent bed is indicated as well by the appearance of these heavy shells as by the statistical comparison with the composition of the fauna in the substratum. Of the postglacial forms *Bittium reticulatum*, *Nassa reticulata*, and *Rissoa membranacea* are the most important, though even *Ostrea edulis* is not at Kapellbacken found at higher levels. The most numerous of the probably contemporary forms are *Litorina litorea*, *Hydrobia ulvæ*, and *Cardium edule*, which are so common that they can scarcely have been transported to their position by the brook, while this is more likely to have been the case with the other species occurring immediately below in the substratum.

The other point, already mentioned, where postglacial beds have been found, is at C 16, where the surface-layer of redeposited finiglacial shells intercalated with small sand-layers, was during this time unconformably accumulated upon the above described, problably ice-grooved, surface of the finiglacial shell-bed. The postglacial forms here found are *Cardium echinatum*, *Lucina borealis*, *Ostrea edulis*, *Aporrhais pes pelecani*, *Cyprina islandica*, *Hydrobia ulvæ*, and fragments of a small *Montacuta* and apparently also of *Bittium reticulatum*. This locality lies 16 *m* above the sea. About the fauna at lower levels I have nothing to add to some notes made in 1881 about shells, observed in a postglacial clay, dredged up with clay from the Uddevalla harbour in the mouth of the Bäfveån from a depth of some 3 *m*. The species found here are enumerated in the table. The occurrence of *Mya arenaria*, which has never been found in any uplifted sea-deposits in Scandinavia, may indicate that at least a part of these shells have been deposited after the emergence of the land had practically ceased.

Postglacial beds in the region of Strömstad: at Nötholmen and Tofterna.

In the western part of the region contained within the geological map-section Strömstad, there probably occur the thickest postglacial shell-deposits in Scandinavia. Thus, as shown in fig. 8, at Lunnevik some 12 *km* N of Strömstad a shell-bed of this age is met with about 8 *m* in thickness and resting upon 1 *m* of probably finiglacial sand with the upper surface grooved as by ice-pressure and resting upon 2 *m* of gothiglacial clay with a purely arctic fauna.

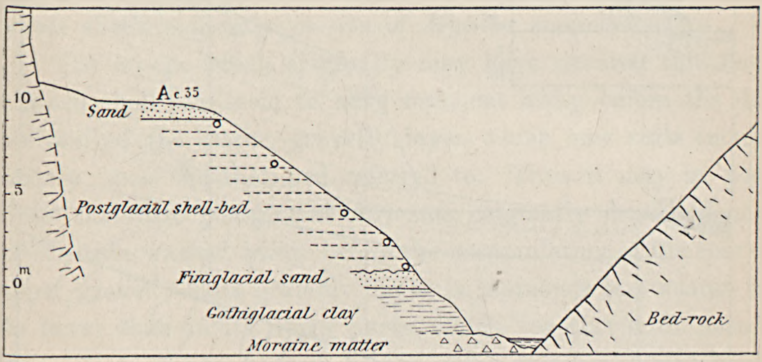

Fig. 8. Section at Lunnevik.

More easy of access is a postglacial shell-bed on the eastern shore of Nötholmen close by the harbour of Strömstad. The situation is most easily seen on the map, Pl. 44 and fig. 8.

The shell-beds are here found along the eastern base of a steep granite wall, rising abruptly some 20 *m* to the plateau of granite which occupies the greater part of the island. The Quaternary deposits occurring between this rock-ledge and the sea occupy a narrow strip of land, at the middle some 30—40 *m* broad but northward less, and southward somewhat more. On the latter side the strip is divided into two by a lower rock-ledge. The surface of the ground slopes rather regularly from the foot of the rock-wall down to the shore of the sea, sometimes as much as 30°, or just as much as the slope of equilibrium of an ordinary talus.

Shell-material having been taken away for various purposes, good sections were exposed in 1890, when the main part of the investigation was carried out. By diggings and borings it was then established that, on the subjacent bed-

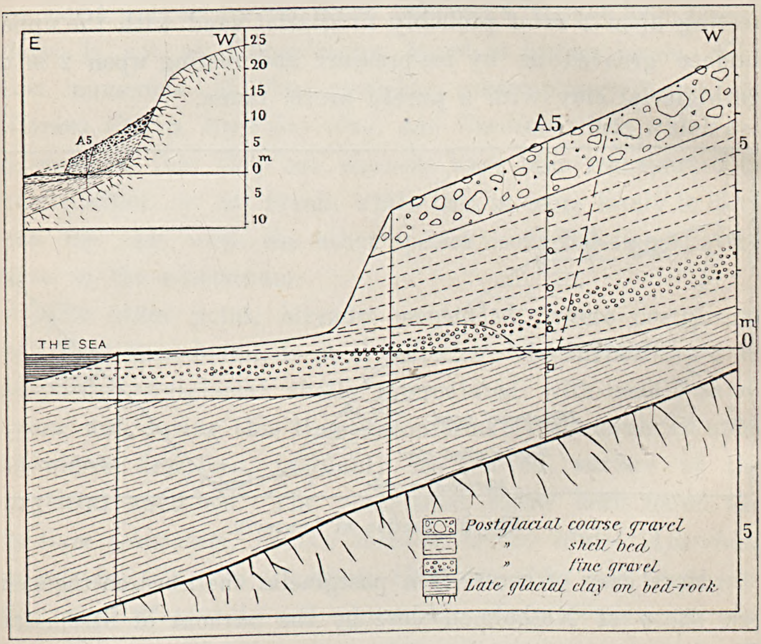

Fig. 9. Section at Nötholmen.

rock rest layers of clay, still somewhat over 5 *m* thick at the actual shore, but already half-way towards the steep rock-side less than 3 *m*. Still higher only the bottom-layers of the clay may be left, the thinning out in this direction being probably due to denudation. Thus, in the superjacent shell-beds thick, glacial shells like *Saxicava rugosa*, *Tellina calcaria* and others often occur, showing by their appearance that they must have been washed out from older layers and as even *Yoldia arctica* was found among such redeposited shells it is probable that even the lower parts of the gothiglacial clay have contributed to this secondary addition to the real, postglacial fauna, and that also an eventual finiglacial clay-covering must have been partly cut away.

On the surface of the remaining clay-layers lies the postglacial shell-bed, about 4 *m* thick, having, in its lower part, layers rich in small pebbles, often a few *cm*, but sometimes up to 5—6 *cm* in size. In its higher parts the shell-bed present a much finer material and contains innumerable masses of small species, such as *Rissoidæ*, *Bittium*, and others, small, undoubtedly redeposited fragments of *Mytilus edulis* and whole shells evidently *in situ* of *Mytilus modiolus.*

The layers which originally may have covered this fine-grained shell-bed seem to have been cut away before the deposition of the coarse, gravelly layer which now rests immediately upon the shell-bed referred to. Thus it may be possible that also postglacial clay was originally deposited and afterwards washed away before the accumulation of the coarse upper gravel. This gravelly layer is moreover less coarse in its lower than in its upper parts, which, together with masses of smaller stones, contain also a great number of real boulders up to more than 1 *m* in size. This uppermost part of the section represents the postglacial regression of the sea, evidently, inaugurated at the beginning of the uplift through the action of storm-waves on the bottom, facilitated by the great slope at this place. At a later stage of the uplift the waves were enabled to carry out small pebbles to this point, and finally, when the adjacent granite-hills emerged above the sea-level, the breakers rolled down the boulders and the coarse material of the surface-bed, thus building up a kind of submarine talus. This process, of course, only going on during storms, a great number of shells could thrive at this place well sheltered against every direct attack of the breakers. Thus, oysters, *balanæ*, and other marine shells are often found, sitting on the stones in this layer, which is sometimes developed as a real oyster-bed.

At this locality only one statistical analysis has been hitherto carried out and this on a specimen of 0.2 *li*, taken out 0.5 *m* above the subjacent elay. As the main interest of such analyses is to elucidate the faunistical and bathymetrical evolution on one and the same spot, where other local conditions were continually the same or changed only gradually, it seems unnecessary here to reproduce the whole analysis; therefore only the figures *pro li* for the most dominating forms may be quoted. The analysed bottom-layer represents a *verrucium* containing 1449 specimens of *Verruca Stroemia* in 1 *li*, while *Bittium reticulatum* is the next in order with 1391, followed by 840 *Rissoidæ*, 422 *Anomia ephippium*, 179 *Tectura virginea*, 112 *Alvania punctura*, 93 *Anomia aculeata*, 77 *Saxicava rugosa* v. *arctica*, 64 *Trochus cinerarius*, and so on.

In the upper parts of the shell-bed *Verruca* seems to be much less common, and the scarcity or absence of more pronounced littoral forms seems to indicate that this postglacial bed, as well as the thick, finiglacial beds in the more southern parts of the province, has been built up during a subsidence which caused the postglacial sea to rise somewhat also in this part of the country.

Another large, postglacial shell-bed is to be found in a small valley at Tofterna on the north side of the island Öddön, about 3 *km* SW of Strömstad and is reproduced on the map, Pl. 45. At this locality also the shell-bearing layers occupy a small strip of regularly sloping land between the sea-level and the steep mountain-sides. This strip of land had no doubt, when deposited in the sea, a fairly regular slope towards NNE, but is now partly cut through by a brook, running in the same direction. Where this brook enters the map, the ground that formed the old sea-bottom lies about 14 *m* above the present sea-level, but according as the land emerged above the sea, the brook-valley was extended and superposed upon the latest formed sea-deposits. The depth of this little cut valley is now about 5 *m*, and all the material, including innumerable shells which, gradually, become redeposited by the brook, has been, perhaps several times, mixed up with the living fauna, a process which is still going on at the present mouth of the brook.

In its southern and middle parts the brook-valley has been cut down through the postglacial shell-bed, and some meters down into the subjacent clay-layers, so that shells washed out from these have also taken part in the cycles of redeposition, probably several times repeated.

This locality in that way affords a concentrated exhibition of the different agencies which are at work in the commingling and falsification of the faunistical record in certain of the shell-beds.

Thus, in examining the shell-beds here at Tofterna it is always necessary, when considering the different ways in which different faunas have become mixed, to bear in mind, as well the repeated redeposition by running water, as the marine redeposition by wave-action, and even the probably not uncommon sliding down of low-water forms, living on the steep rock-sides, and their commingling with species living in deeper water. It is easily understood how important it must be to make a detailed examination of the conditions in every locality where it is intended to study the real evolution of a local fauna.

Even at Tofterna I have found in the postglacial shell-bed, several clay-forms, and among these also *Yoldia arctica* sometimes with both shells together, such forms still being, no doubt, washed out by the brook from the lower clay-beds. But which may be the youngest epoch, represented by the uppermost part of the clay-beds, is perhaps as yet not quite settled, the fauna, having lived on clay-bottom in deeper water at the end of the finiglacial time being not yet sufficiently known. The total thickness of the clay-beds at the point where the brook has in former times made a swing towards the NW and where the specimens for analysis were taken is 6.3 *m* and the thickness of the superjacent shell-bed was about 5 *m*. Even this locality affords a good opportunity for collecting postglacial species.

At a somewhat greater distance from Strömstad, or about 8 *km* SSE of the town, just at the southern border of the map-section Strömstad,[1] there occurs on the island Rössö—Långö at a height of 9 *m* above the sea a section, showing from the top the following layers: a stony, littoral shell-bed up to 1 *m* thick, rich in *Litorina litorea* and *obtusata*, *Tapes decussatus*, *Patella vulgata*, and other postglacial low-water shells. This bed rested upon a clay-layer, of which only 2 *dm* were left at this place, though at the side of the section the clay apparently was much thicker. Below this clay followed a lower, postglacial shell-bed, more than 2.8 *m* thick, with such forms as *Corbula gibba*, *Emarginula fissura*, *Tapes pullastra*, *Mytilus modiolus*, and some other species, not observed in the upper layer. Common to both the horizons were several other postglacial species, as *Bittium reticulatum*, *Nassa reticulata*, *Lucina borealis*, *Pecten varius*, *Tapes aureus*, *Timoclea ovata*, and others. Here it is clear that the postglacial clay, no doubt representing the maximum subsidence of that time, was preceded and followed by shell-beds, evidently deposited in lower water, thus indicating that the postglacial transgression, though probably with diminished amplitude, can be traced at least as far as to this region of the land.

Conclusions.

The facts put forth in this paper, seem to show that the gothiglacial subsidence, which had reached its maximum be-

[1] Geol. kartbladet Strömstad; Sveriges Geol. Undersökn., Ser. Ac, N:o 1 Stockholm 1902, p. 58.

fore the recession of the land-ice, was followed by a wave of land-emergence, commencing in the peripheral parts of the glaciated area and following after the receding ice-border. By this emergence the glacial sea-bottom, which universally was covered with fine clay, was along all the rising coasts greatly denuded by the wave-action. Thus, during this rapid upheaval of land a very considerable redeposition of clay must have been going on.

The result of this denudation and redeposition was that the rock-ledges and hills in the coast-region to a very great extent were swept quite clear of their loose clay-covering, this being concentrated in the deep, steep-sided rock-valleys, where it was heaped up to a considerable thickness, reaching some 50, or even 100 *m.*

It is evident that the water, especially in the coast-belt, was during this time generally much commingled with suspended clay-particles and that the fauna must as a rule have been confined to species adapted to muddy water and a clay-bottom.

The remarkable contrast between this rather scanty fauna and the extraordinary prolificness of the finiglacial fauna to which the masses of individuals of the superjacent shell-beds bear testimory, seems to become quite intelligible if viewed in the light of the explanation here proposed, namely, that this fauna immigrated during a new submergence of the land. It seems evident enough that the change from the former successive emergence of clayey shores to a submergence of the already thoroughly clean-washed shore-levels, must have had a very essential influence upon the amount of shore denudation and at the same time upon the conditions of the sea-water, which must have become very much clearer, and thus suitable for a richer organic life. The astonishing number of individuals, however, answering well to the subarctic conditions, does not in any way correspond to the relatively restricted number of species. Very characteristic in deed is the remarkably insignificant immigration of new species during the deposition of these most heavy shell-beds. The cause of this evidently not having been unfavourable conditions of life, it seems to prove that the deposition of these beds must have been very rapid, which is just what might be expected from the recent investigations concerning the late Quaternary chronology and the shortness of that part of the finiglacial time during which it seems probable that the climatical conditions were favourable for accumulations of this kind.

The coast-regions of Western Sweden seem to afford an uncommonly good opportunity, as well for the study of these interesting and surprisingly rapid changes of level, as for the equally shifting evolution of the marine fauna. This region represents the connection between the more distal parts of the late glacial sea-bottom off Fennoscandia in Denmark where the land-ice first gave place to the approaching glacial sea and its fauna, and, on the other side, the more proximal inner parts of the finiglacial sea in Vestergötland, Dalsland, Vermland, and the Christiania-region, which much later became free from the land-ice and accessible to the sea and its fauna. Furthermore, there are along the Swedish west coast, and, apparently here only, good opportunities for the study of the whole postglacial subsidence with its rich immigration of new species and the connection between its different *facies*, to the South, in Skåne and Halland, with a marked transgression above land-formations, such as peat-bogs and river-valleys, and, to the North, in Bohuslän to a more proximal *facies* with a less marked transgression and a less easily discernible limit which here can still be connected with the leading southern *facies* and on the other hand probably also by and by with the even more proximal development of the postglacial fauna in the more enclosed and locally differentiated region of the Christiania-fiord.

As the recession of the land-ice in Eastern Sweden, along the area of the late glacial inland sea, was in such a marvellous way mechanically registered in the annual layers of the seasonal clay of that epoch; in the same way in Western Sweden, where the late glacial sea was of normal saltness, the remarkable changes of level which followed after and were probably partly caused by the recession of the heavy land-ice, were no doubt also carefully registered by all the modifications exhibited in the marine fauna which was step by step compelled closely to adapt itself to the changing conditions. By sufficiently detailed methods of observation, such as levellings and mappings of leading localities of the old sea-bottom, together with systematic and thorough statistical analyses of the fauna in successive stages of its evolution — it will, no doubt, here be possible in a near future to decipher in a very satisfactory way perhaps what is the best existing record of the late Quaternary evolution of a still existing fauna.

Method of statistical analysis.

The purpose of the statistical analyses being to fix the proportion between the different species, the quantity to be analysed must depend upon its content of shells. Thus, in an ordinary shell-bearing sand or clay it may be necessary to wash out some 5—10 dm^3 before a sufficient quantity of shells is reached. In the case of post-glacial shell-beds with an overwhelming number of small shells, occurring together with larger forms, the best way seems to be to wash the material over a sieve with holes 5 *mm* and, if necessary, also over another with holes 2 *mm* in diameter or square. Thus, one or several dm^3 are washed until the number of the larger forms is sufficient, while of the finer material only a smaller fraction is analysed, after which the results of the different portions are reduced to the same quantity as, for instance, to 1 dm^3.

Concerning the late glacial beds of shell-sand, which generally are poor in species but extremely rich in individuals, especially of larger size, I commenced by analysing samples of 1 dm^3, but soon found that 0.5 dm^3 were often sufficient, thus at the same time making it possible to perform a greater number of analyses.

Before the washing and sieving is commenced, the well dried sample is weighed and its approximate volume recorded. After sieving, the portions of different coarseness are weighed and analysed separately. The analysis is performed by means of fine pincers, so that the shells and shell-fragments belonging to different species are put into different boxes, the larger shells being taken first. Some experience is, of course, necessary before it will be possible also to recognize even fragmentary shells, but especially with respect to late glacial shell-beds with their restricted number of species, it will be possible rather soon to reduce the remaining undeterminable fragments to an inconsiderable minimum, which is weighed as well as the quantities of lime represented by shells, belonging to the different species, and of rocky material, divided into stones larger than 10 *mm*, gravel 10—2 *mm* and sand between 2—0.05 *mm*. Sometimes it may even be useful to distinguish sand of mean grain between 1—0.5 *mm* from coarse and fine sand.

In determining the number of individuals it is in the case of *Gastropoda* usually best to use the summit, but sometimes the columella or the mouth may be better preserved and thus preferable. For *Pelecypoda* I began by always distinguishing the right shell from the left and counted the most numerous but finished by taking the mean as more reliable. Thus it is necessary only to count all the whole shells and the fragments with *umbo* and to note half the number. Still, in the case of very unsymmetrical forms, or of forms with one shell fixed, it seems better sometimes to count only one of the shells belonging together. The same applies to the

Brachiopoda. As to the *Balanidæ*, at first I counted all the different parts and thereby found that the *opercula* are generally preserved in a much smaller number than the *parietes*. Thus, it would be better to count the *parietes* and to divide the result with 6. But this implies nevertheless the necessity of separating a very great number of compartments, belonging to different species, and it has proved quite sufficient to count only one of the two unique shells of the six compartment pieces belonging to one individual. In the choice between *carina* and *rostrum*, *carina* seems to be preferable, being by its protruding *alæ* more easily as well recognized, as also picked out from the other compartments, though the specific characters of *rostrum* are somewhat more conspicuous.

In consideration of the dominating rôle which the *Balanidæ* often play in the finiglacial shell-beds, it was indispensable to find out characters by which isolated parts of the shells, belonging to different species, could be distinguished from one another. This latter was not always found possible only with help of the few characters, described in the literature although these are, no doubt, quite sufficient for application on living or tolerably complete specimens.

Among the new characters here used in the separation of *Balanus crenatus* and *B. porcatus* may be mentioned the often well defined lines of accretion on the inside of the upper part of the compartments of *B. crenatus*, while the corresponding part of *B. porcatus* is smooth, the latter having at the same time, a shell which is often more dense and dark. *Balanus Hameri*, not having the walls perforated, is more easily recognized. Of *Verruca Stroemia carina* and *rostrum*, being rather similar and better preserved than the other parts of the shell, have been counted and the result divided by 2.

In this way, figures have been obtained, indicating the number of individuals of the groups named.

Of the other groups only the *Echinoidea* have been mentioned in the tables, though their number of individuals could not be determined. Still, it has proved possible to form an idea of their relative importance at different levels by counting the basal parts of their pins. This is quite feasible, at least in late-glacial beds, where there is no danger of confounding different species of this group.

The picking out of the parts to be counted must, of course, be continued until no more such parts can be found within the respective sizes of grain, intended for analysis.

When the material is to be weighed as well as counted, it is necessary to pick out not only all the individually preserved parts of every species, but also as much as possible of its other fragments.

For some purposes, such as the discrimination between transgressional and regressional beds, the counting method may be sufficient when the shells are not too broken. For other purposes, for example for making out the importance of different species as constituent parts of the rock, the weighing method is necessarily perferable.

Also when the smaller forms, as *Ostracoda*, *Foraminifera*, and *Diatoms*, are not at once analysed, it is advisable to preserve even the finer grain-sizes for future examination and for the determination of the percentage of lime, which, as concerns the coarsest material, can be made mechanically.

As to the chemical composition of two of the dominating species at Kapellbacken, Dr H. SANTESSON has kindly made the determinations here given:

Chemical analyses of shells from Kapellbacken.

	Org. matter	Undis-solved	Iron dixo. & al. diox.	Carb. lime	Carb. magn.	Phos-phor acid	Total
Balanus Hameri	0.24	0.42	0.06	97.89	1.00	0.054	99.66 %
Saxicava rugosa	0.05	0.36	0.26	98.30	0.36	0.025	99.36 %

By such determinations of the chemical composition of the shells of more important species it will be easy to calculate the main composition of the biogene matter of statistically analysed shell-beds.

The method of the statistical analysis and some of the results obtained were, in 1892, laid before the Association of Scandinavian Naturalists — Skand. Naturforskaremötet i Kjöbenhavn forhandl. 1892, p. 447 — and were also communicated to my pupils at Stockholms Högskola. Among these, P. A. Öyen has used the method in several places in Norway, though hitherto not as a means for detailed investigations into the sequence of layers at single, leading localities, whereby the real faunistical and bathymetrical evolution is, no doubt, much better elucidated, but for comparisons between different localities where local influences may often counterbalance the general changes. It is, thus, unfortunately not yet possible to tell to what degree the finiglacial shell-beds in Norway represent the transgressional or the regressional stage of this epoch.

Plan for a two days' excursion in the region of Uddevalla and Strömstad.

Start from Stockholm by night train to Herrljunga (on the Stockholm—Göteborg railway). Early in the morning by the Herrljunga—Uddevalla train. Between Salstad and Rånnum stations: during about half an hour passage along and between the mountains Hunneberg and Halleberg, circumeroded remnants of the Cambro-Silurian beds, once covering the pre-Cambrian base-level plain of Sweden. At this place the post-Silurian erosion has cut away the Silurian beds proper down to a great intrusive sheet of diabase, which thus nowadays forms a protecting covering of these mountains, the lower parts of which consist of Cambrian sandstone, some 30 *m*, resting upon the base-levelled Archæan plain and covered by Cambrian alum shale of about the same thickness. This contains nodules of limestone which are burnt by means of the bituminous alum-shale, which thereby gets a reddish colour. Thus from the Salstad side M:t Hunneberg shows where the level of the alumshale occurs by a series of red spots at the lime-kilns.

A beautiful jointed structure, produced by the cooling of the diabase-bed, is well seen from the train when passing the narrow fissure-valley at Lilleskog station, especially at its northern side, which is upheaved by a fault 30 *m* above the southern side. This fault, the throw of which has been exactly determined by levellings of the Cambrian layers, is of a special importance by proving the fault-nature of a series of parallel, marked low ridges or steps, crossing the surrounding base-levelled Archæen plain and being of quite the same nature as the step-like ridge, which in both directions forms the continuation of the fault directly indicated by the break and throw of the Cambrian layers. The same fault-line passes, no doubt, Trollhättan, where the high western shore corresponds to the uplifted southern rim of Halleberg.

At Kuröd, some 3 *km* E of Uddevalla, the train is left for a short visit to the thickest shell-deposit in Scandinavia. By train or walk to Uddevalla.

From Uddevalla directly by steamer through narrow and picturesque sounds some 32 *km* toward WSW to Evenås at the east side of the island Skaftölandet: postglacial shell-bed, resting upon a bed of finiglacial age.

Back to Uddevalla by steamer.

At the limit between the parishes of Bokenäs and Högås a mountain top, moraine- and forest-covered down to 141 *m* above the sea-level, this figure marking the highest level, reached by the gothiglacial sea, by which the bed-rock was laid bare up to the small moraine island, being a conspicuous witness to the denudation.

Not quite 6 *km* W of Uddevalla the navigation is somewhat obstructed by a terminal moraine, trending about at right angles to the fjord and marking a short stationary stage in the recession of the ice-edge.

From Uddevalla some 10 minutes walk southward from the town to Kapellbacken, where the different parts and layers of this classical locality are studied and collections made.

Night in Uddevalla.

By train from Uddevalla to Strömstad.

This railway passes a region, uncommonly difficult to the railway engineer. The once widespread gothiglacial clay-layers having been, during the gothiglacial land emergence, to a great extent swept down from the bare rock-ledges and concentrated in the deep fissure valleys, these re-deposited, very thick clay-beds lying in often very insufficiently drained depressions, have retained an uncommonly great quantity of water at some depth not seldom amounting to more than 50 %. Higher up in the railway-cuttings the amount of water generally was found to be 20—30 %.

This loose mixture of clay and water, which sometimes might rather be called clayey water than clay, is generally covered by a thin crust of dry clay, which often is a very unreliable substratum for a heavy railway embankment. Especially where the line crosses deep valleys, great difficulties have arisen by the breaking in of the clay-crust with the superposed embankment. Sometimes, enormous masses of earth were filled out, before the bottom was reached or sufficient stability attained. By the sinking in of the embankment the subjacent clay-beds were forced to the sides and pushed up in great faults, forming striking models of the Jura mountains, in several cases to a distance of some 100 *m* on each side of the railway.

Sometimes it was possible to prevent such displacements of the clay by a well ajusted loading of its crust with thinner embankments on both sides of the railway proper.

On the other hand, the loose consistence of the clay in the railway cuttings has often given rise to considerable landslides, in several respects reminding of glaciers. Predisposing for such landslides is often also the position of the clay, without any substratum of moraine-matter, directly upon the steep and smooth rock-slopes.

Another difficulty was the lack of gravel and sand in this region, generally making it necessary to build the embankments of clay, which especially was unfavourable when the material sunk down into the loose, watery clay, where it was only too apt to assume the same consistence.

At Strömstad a visit is made to some subglacial giants' kettles 1.5 *km* NE of the town, the largest of which was in 1889 partly emptied by the author down to a depth of some 3 *m*, showing: down to 1.5 *m* ordinary beach-gravel with some boulders, resting upon 0.2—0.5 *m* hard, clayey moraine matter. Below the moraine-bed followed coarse gravel with hundreds of well rounded pebbles, large as an egg or a fist, together with single larger boulders. In 1904 the giant kettle was completely emptied by care of Consul J. H. Sylvander and its measurement was then performed by Prof. A. Hamberg,[1] the whole depth being 6.3 *m*, while at the opening the greatest diameter was about 3 *m* and the smallest one a few *dm* less. The threshold between this giant kettle and a smaller one in the adjacent niche lies 21.8 *m* above the sea-level.

Everywhere to be observed: Norwegian and Skagerack boulders, drifted from more western parts of the submarine ice-borders, but missing in the moraines regionis.

By rowing-boat to the postglacial shell-bed at the east side of Nötholmen. Collections. Back to Strömstad.

By steamer to Tofterna on the north-eastern shore of the

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[1] A. Hamberg, Uppmätning af en stor jättegryta vid Strömstad. Geol. Fören. Förh., Bd 28 1906, p. 194.

island Öddö. Collections at the postglacial shell-bed. Close by is to be seen the remarkable dike of rhomb-porphyry, which runs parallel to the border of Fennoscandia and the Swedish coast for some 70 *km.*

By steamer northward. Landings, eventually, at the eastern side of Långö-rännan: »Monkyrkan» and other great shore kettles.

Some 12 *km* to the north, SE of Kattholmen and S of Lunnevik probably the thickest known postglacial shell-bed in Scandinavia. Connection between topography and banking of granite.

Farther by steamer through the narrow passage of Svinesund to Fredrikshald and by train to Dal's Ed. The railway follows at several places the southern of the great Fennoscandian terminal moraines, especially at the valleys represented by glacifluvial transverse oses, deposited along the same ice-border. Thus, after the passage east of Fredrikshald of the deeply eroded marine sediments in Tistedalen a transverse ose, damming up Lake Femsjön, is passed and, later on, from the region of Aspedammen station and somewhat past the Swedish frontier at the bridge over Lake Norra Kornsjön the railway is often constructed along the very side of the terminal moraine, which has also been used as a natural embankment for the highway in this elsewhere rather dissected region. Around Mon station extensive, naked rock-ledges with numerous peat-bogs, both elongated in the strike-direction of the gneiss.

Arrival at Ed station, see Guide of Dal's Ed: map, Pl. 17.

A. Statistical analyses of shell-deposits from the finiglacial transgression.

Locality: Height in *m* above the sea	Kuröd.		Kapellbacken.									
	A 58.		A 10.		C 16.							
Samples: » » » » » »	c. 46.		9.5.		12.		13.		14.		15.	
Samples: » » » » » base	x.		x.		0.		1.		2.		3.	
Volume analyzed,[1] in dm^3.	0.5.		0.5.		0.5.		0.5		0.5		0.5.	
	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.
Redeposited.												
Leda pernula MÜLL.	.	.	.	.	2	+	2	+	2	+	2	0.1
Yoldia arctica GRAY	.	.	.	.	2	+	2	+	2	0.1	2	+
» *lenticula* FABR.	.	.	.	.	2	+	2	+	2	+	10	+
Arca glacialis GRAY	.	.	.	.	.	.	.	.	2	0.2	.	.
Thracia papyracea POLI	.	.	.	.	.	.	2	+	.	.	.	.
Axinus flexuosus MONT.	.	.	.	.	.	.	2	+	.	.	.	.
Pelecypoda: total	—	—	—	—	**6**	+	**10**	+	**8**	**0.3**	**14**	**0.1**
Transgressional inhabitants (incl. gothiglacial relics)												
Pecten islandicus MÜLL.	—	—	1	6.1	—	—	2	0.5	—	—	—	—
Mytilus edulis LIN.	3	6.5	10	18.0	6	10.2	18	50.4	12	11.9	2	2.4
Crenella lævigata GRAY v. *striata*	36	3.1	48	0.9	—	—	6	0.6	2	+	4	0.2
Astarte borealis CHEMN.	3	0.5	—	—	—	—	—	—	—	—	—	—
» *compressa* MONT.	—	—	—	—	8	+	2	1.1	—	—	2	+
» *elliptica* BROWN.	—	—	—	—	—	—	—	—	—	—	—	—
Tellina calcaria CHEMN.	—	—	—	—	14	6.8	2	2.3	2	+	—	—
Mya truncata LIN.	—	—	—	—	2	+	—	—	—	—	2	0.1
Saxicava rugosa LIN.	366	387.9	240	42.6	70	21.4	214	58.5	262	30.0	90	13.9
Zirphæa crispata LIN.	—	—	—	—	4	+	2	+	—	—	—	—
Pelecypoda: total	**408**	**398.0**	**299**	**67.6**	**104**	**38.4**	**246**	**113.4**	**278**	**41.9**	**100**	**16.6**
Lepeta cæca MÜLL.	—	—	—	—	10	0.1	—	—	2	+	2	+
Puncturella noachina LIN.	—	—	44	0.2	—	—	—	—	2	+	8	0.1
Mölleria costulata MÖLL.	—	–	16	0.1	—	—	—	—	2	+	—	—
Margarita groenlandica CHEMN.	—	—	—	—	—	—	—	—	2	+	—	—
» *helicina* FABR.	—	—	14	0.1	—	—	4	+	—	—	8	+
Capulus glacialis n. sp.	—	—	10	0.1	—	—	—	—	—	—	—	—
Velutina lævigata PENN.	—	—	2	+	—	—	—	—	4	0.2	—	—
Litorina palliata SAY	—	—	—	—	—	—	—	—	—	—	—	—
Lacuna divaricata FABR.	—	—	—	—	2	+	2	+	—	—	—	—
Ptisanula limnoides ODHNER n. sp.	—	—	—	—	—	—	—	—	—	—	—	—
Jeffreysia opalina JEFF.	—	—	—	—	—	—	—	—	—	—	—	—
Cingula castanea MÖLL.	—	—	12	+	2	+	—	—	—	—	2	+
Trophon clathratus LIN.	3	1.2	8	0.3	6	1.0	6	3.5	2	+	8	0.3
Buccinum groenlandicum CHEMN.	—	—	—	—	—	—	10	12.2	12	6.8	6	2.5
Neptunea despecta LIN.	—	—	—	—	—	—	2	20.5	—	—	—	—
Natica affinis GMEL.	—	—	4	+	4	+	8	6.6	2	0.1	—	—
» *groenlandica* BECK.	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda: total	**3**	**1.2**	**110**	**0.8**	**24**	**1.1**	**32**	**42.8**	**28**	**7.1**	**34**	**2.9**
Balanus Hameri ASC.	48	121.2	76	78.2	42	89.2	16	116.2	24	147.8	160	42.3
» *crenatus* BRUG.	174	30.0	90	4.0	564	38.6	424	82.1	758	171.2	364	82.0
» *porcatus* DA COSTA	15	4.7	4	0.2	32	4.6	4	8.6	16	5.0	4	3.1
Verruca Stroemia MÜLL.	21	1.1	—	—	1,960	59.7	402	10.8	244	8.8	116	3.2
Balanidæ: total	**258**	**157.0**	**170**	**82.4**	**2,598**	**192.1**	**846**	**217.7**	**1,042**	**332.8**	**644**	**130.6**
Echinus droebakensis MÜLL. (pin-bases)	9	+	4	+	416	3.7	70	0.7	98	0.9	136	0.6
Colonists												
Anomia ephippium LIN.	.	.	.	.	.	.	.	.	.	.	.	.
Tellina baltica LIN.	.	.	.	.	.	.	.	.	.	.	.	.
Litorina litorea LIN.	.	.	.	.	.	.	.	.	.	.	.	.

Locality: Height in *m* above the sea	Kapellbacken.													
	D 26.										E 28.			
Samples: » » » » » »	22.		23.		24.		25.		26.		21.1.		26.1.	
Samples: » » » » » base	0.		1.		2.		3.		4.		0.		5.	
Volume analyzed,[1] in dm^3.	1.0		0.5.		1.0		0.5.		1.0.		0.25.		0.25.	
	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.
Redeposited.														
Leda pernula MÜLL.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Yoldia arctica GRAY	.	.	.	.	.	.	.	.	.	.	.	.	.	.
» *lenticula* FABR.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arca glacialis GRAY	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thracia papyracea POLI	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axinus flexuosus MONT.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pelecypoda: total	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Transgressional inhabitants (incl. gothiglacial relics)														
Pecten islandicus MÜLL.	+	+	—	—	1	0.5	—	—	—	—	4	18.6	—	—
Mytilus edulis LIN.	9	16.6	4	8.7	+	0.7	+	1.6	1	0.2	4	9.9	+	0.3
Crenella lævigata GRAY v. *striata*	6	0.2	20	1.4	37	1.4	77	2.9	73	2.8	4	0.3	78	4.7
Astarte borealis CHEMN.	—	—	—	—	1	1.7	—	—	—	—	—	—	—	—
» *compressa* MONT.	1	+	—	—	—	—	—	—	—	—	8	+	—	—
» *elliptica* BROWN.	—	—	—	—	—	—	2	+	2	0.1	—	—	—	—
Tellina calcaria CHEMN.	1	1.1	1	0.2	—	—	—	—	1	0.9	4	+	—	—
Mya truncata LIN.	1	+	—	—	—	—	—	—	1	2.5	+	+	—	—
Saxicava rugosa LIN.	180	64.9	79	36.1	101	50.9	107	65.7	135	45.4	122	79.8	148	115.5
Zirphæa crispata LIN.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pelecypoda: total	**198**	**82.8**	**104**	**46.4**	**140**	**55.2**	**186**	**70.2**	**213**	**51.9**	**146**	**108.6**	**226**	**120.5**
Lepeta cæca MÜLL.	—	—	—	—	—	—	—	—	1	+	12	0.3	4	+
Puncturella noachina LIN.	2	+	2	+	6	0.1	12	0.1	11	0.2	—	—	4	0.2
Mölleria costulata MÖLL.	2	+	—	—	9	+	10	0.1	13	0.1	—	—	—	—
Margarita groenlandica CHEMN.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
» *helicina* FABR.	—	—	6	+	20	0.1	8	+	6	+	—	—	—	—
Capulus glacialis n. sp.	—	—	—	—	—	—	2	+	3	+	—	—	—	—
Velutina lævigata PENN.	1	+	—	—	1	0.5	1	+	1	+	—	—	—	—
Litorina palliata SAY	1	+	—	—	—	—	—	—	—	—	—	—	—	—
Lacuna divaricata FABR.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptisanula limnoides ODHNER n. sp.	1	+	—	—	3	+	3	+	1	+	—	—	—	—
Jeffreysia opalina JEFF.	—	—	—	—	—	—	—	—	—	—	1	+	—	—
Cingula castanea MÖLL.	1	+	18	+	22	+	8	+	12	+	6	+	16	+
Trophon clathratus LIN.	8	0.6	6	0.3	7	1.2	12	1.2	30	2.1	+	+	+	+
Buccinum groenlandicum CHEMN.	—	—	—	—	2	1.2	2	0.1	5	0.5	+	+	—	—
Neptunea despecta LIN.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natica affinis GMEL.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
» *groenlandica* BECK.	—	—	—	—	1	+	—	—	—	—	—	—	—	—
Gastropoda: total	**16**	**0.6**	**32**	**0.3**	**71**	**3.1**	**58**	**1.5**	**83**	**2.9**	**19**	**0.3**	**24**	**0.2**
Balanus Hameri ASC.	52	48.6	160	247.8	194	287.1	198	273.6	218	182.1	16	55.8	224	401.4
» *crenatus* BRUG.	451	33.9	224	22.6	95	10.6	56	5.9	75	9.9	264	32.8	68	14.1
» *porcatus* DA COSTA	54	4.2	22	4.3	31	4.6	58	8.0	43	6.4	52	22.1	60	5.1
Verruca Stroemia MÜLL.	384	10.4	75	1.5	15	0.4	7	0.1	4	0.1	422	11.1	8	0.1
Balanidæ: total	**941**	**97.1**	**481**	**276.2**	**335**	**302.7**	**319**	**287.6**	**340**	**198.5**	**754**	**121.8**	**360**	**60.7**
Echinus droebakensis MÜLL. (pin-bases)	71	+	40	+	14	+	6	+	15	+	192	1.5	8	+
Colonists														
Anomia ephippium LIN.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tellina baltica LIN.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Litorina litorea LIN.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Locality: Height in *m* above the sea	Kapellbacken.											
	F 42.				H 68.						K 70.	
Samples: » » » » » »	39.5.		41.5.		65.5.		66.5.		67.5.		69.6.	
Samples: » » » » » base	0.		2.		x.		x + 1.		x + 2.		0.	
Volume analyzed,[1] in dm^3.	0.5		0.5.		0.5.		0.5.		0.5.		0.33.	
	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.
Redeposited.												
Leda pernula MÜLL.	.	.	.	.	.	.	.	.	.	.	.	.
Yoldia arctica GRAY	.	.	.	.	.	.	.	.	.	.	.	.
» *lenticula* FABR.	.	.	.	.	.	.	.	.	.	.	.	.
Arca glacialis GRAY	.	.	.	.	.	.	.	.	.	.	.	.
Thracia papyracea POLI	.	.	.	.	.	.	.	.	.	.	.	.
Axinus flexuosus MONT.	.	.	.	.	.	.	.	.	.	.	.	.
Pelecypoda: total	—	—	—	—	—	—	—	—	—	—	—	—
Transgressional inhabitants (incl. gothiglacial relics)												
Pecten islandicus MÜLL.	2	7.9	—	—	2	9.3	2	33.4	—	—	(+)	—
Mytilus edulis LIN.	+	1.3	22	23.0	46	126.3	10	30.9	4	18.6	126	210.5
Crenella lævigata GRAY v. *striata*	42	0.5	94	4.3	2	0.2	6	1.2	2	0.1	—	—
Astarte borealis CHEMN.	+	0.6	—	—	+	+	2	+	4	18.0	(+)	—
» *compressa* MONT.	—	—	—	—	2	+	4	16.7	2	0.6	(+)	—
» *elliptica* BROWN.	6	+	—	—	—	—	—	—	4	3.8	(+)	—
Tellina calcaria CHEMN.	—	—	—	—	4	5.4	—	—	2	2.5	6	0.4
Mya truncata LIN.	2	0.5	2	+	4	0.9	4	57.9	8	91.6	(+)	—
Saxicava rugosa LIN.	106	29.0	294	143.6	152	449.6	14	26.5	52	243.4	108	40.1
Zirphæa crispata LIN.	2	+	—	—	2	1.2	—	—	—	—	(+)	.
Pelecypoda: total	**160**	**39.8**	**412**	**170.9**	**214**	**592.9**	**42**	**165.6**	**78**	**378.6**	**240**	**251.0**
Lepeta cæca MÜLL.	—	—	—	—	—	—	—	—	—	—	(+)	—
Puncturella noachina LIN.	16	0.1	14	0.1	—	—	—	—	4	+	(+)	—
Mölleria costulata MÖLL.	—	—	6	+	—	—	—	—	—	—	—	—
Margarita groenlandica CHEMN.	—	—	2	+	—	—	—	—	—	—	—	—
» *helicina* FABR.	—	—	4	+	—	—	2	+	—	—	—	—
Capulus glacialis n. sp.	4	+	—	—	—	—	—	—	—	—	—	—
Velutina lævigata PENN.	—	—	2	+	—	—	—	—	—	—	—	—
Litorina palliata SAY	—	—	—	—	2	0.1	—	—	—	—	—	—
Lacuna divaricata FABR.	—	—	—	—	—	—	—	—	—	—	—	—
Ptisanula limnoides ODHNER n. sp.	—	—	—	—	—	—	—	—	—	—	—	—
Jeffreysia opalina JEFF.	—	—	—	—	—	—	—	—	—	—	—	—
Cingula castanea MÖLL.	2	+	6	+	—	—	—	—	—	—	—	—
Trophon clathratus LIN.	4	0.4	6	+	8	0.7	4	2.1	4	3.8	+	+
Buccinum groenlandicum CHEMN.	+	1.2	(+)	—	+	0.7	6	3.9	—	—	—	—
Neptunea despecta LIN.	—	—	—	—	—	—	—	—	—	—	—	—
Natica affinis GMEL.	—	—	—	—	—	—	2	+	—	—	—	—
» *groenlandica* BECK.	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda: total	**26**	**1.7**	**40**	**0.1**	**10**	**1.5**	**14**	**6.0**	**8**	**3.8**	+	+
Balanus Hameri ASC.	154	247.1	86	306.1	2	40.0	44	261.0	24	230.5	69	186.1
» *crenatus* BRUG.	188	10.0	54	8.2	644	105.4	48	8.9	6	2.0	1,392	146.5
» *porcatus* DA COSTA	50	4.3	14	5.3	26	43.6	20	51.9	8	14.6	51	11.2
Verruca Stroemia MÜLL.	6	+	2	+	50	1.5	22	1.2	16	1.2	24	1.6
Balanidæ: total	**398**	**261.4**	**156**	**319.6**	**722**	**190.5**	**134**	**323.0**	**54**	**248.3**	**1,536**	**345.4**
Echinus droebakensis MÜLL. (pin-bases)	2	0.1	8	+	430	5.5	144	4.5	18	0.1	36	0.2
Colonists												
Anomia ephippium LIN.	.	.	.	.	.	.	.	.	.	.	6	0.1
Tellina baltica LIN.	.	.	.	.	.	.	.	.	.	.	6	0.8
Litorina litorea LIN.	.	.	.	.	.	.	.	.	.	.	(+)	—

[1] All the analyses in this paper are reduced to the same volume, or 1 dm^3.

100170

B. Statistical analyses of shell-deposits from the finiglacial regression.

		Kapellbacken.				Evenås.	
	Locality: Height in *m* above the sea.	L 46.				B 29.	
	Samples: Height in *m* above the sea.	45.7.		46.0.		28.	
	Samples: » » » » » base.	0.1.		0.4.		0.7.	
	Volume analyzed,[1] in *dm*³.	0.2.		0.2.		0.5.	
		Ind.	Gr.	Ind.	Gr	Ind	Gr.
Redeposited.	*Leda pernula* Müll.	10	0.1	5	0.1	—	—
	Nucula sp.	—	—	5	0.1	—	—
	Axinus flexuosus Mont.	10	0.2	5	0.1	—	—
	Pelecypoda: total	**20**	**0.3**	**15**	**0.3**	—	—
Transgressional relics.	*Pecten islandicus* Müll.	10	+	5	0.2	6	1.1
	Mytilus edulis Lin.	125	81.5	90	44.2	174	33.4
	Crenella lævigata Gray *striata*	5	0.7	—	—	—	—
	Astarte compressa Mont.	—	—	—	—	6	1.4
	» *elliptica* Brown	—	—	10	3.2	4	3.4
	Tellina calcaria Chemn.	35	12.5	40	9.3	10	2.6
	Mya truncata Lin.	5	0.2	—	—	2	12.7
	Saxicava rugosa Lin.	430	52.6	515	63.8	54	44.3
	Pelecypoda: total	**610**	**147.5**	**660**	**120.7**	**256**	**98.9**
	Chiton marmoreus Fabr.	—	—	—	—	4	+
	Lepeta coeca Müll.	10	0.1	10	0.1	2	+
	Puncturella noachina Lin.	—	—	5	0.1	4	+
	Litorina rudis Maton	—	—	—	—	6	0.1
	Trophon clathratus Lin.	25	8.7	10	2.1	—	—
	Buccinum groenlandicum Chemn.	5	0.3	10	1.9	—	—
	Natica affinis Gmel.	10	0.5	15	1.5	—	—
	Gastropoda: total	**50**	**9.6**	**50**	**5.7**	**16**	**0.1**
	Balanus Hameri Asc.	45	59.0	15	37.3	—	—
	» *crenatus* Brug.	1,085	208.6	1,575	189.5	446	31.7
	» *porcatus* da Costa	30	25.3	10	23.7	42	27.7
	Verruca Stroemia Müll.	35	0.2	45	0.7	76	2.9
	Balanidæ: total	**1,195**	**293.1**	**1,645**	**251.2**	**584**	**62.3**
	Echinus droebakensis Müll.	200	1.0	10	0.1	202	1.8
Regressional colonists.	*Anomia ephippium* Lin.	100	5.0	15	1.2	8	0.1
	Mytilus modiolus Lin.	—	—	(+)	—	2	0.8
	Cardium edule Lin.	20	20.1	55	29.3	—	—
	Tapes pallustra Mont.	—	—	—	—	2	0.2
	Scrobicularia piperata Bell.	—	—	—	—	4	0.2
	Tellina baltica Lin.	15	1.2	10	1.5	—	—
	Pelecypoda: total	**135**	**26.3**	**80**	**32.0**	**16**	**1.3**
	Chiton ruber Lowe	—	—	—	—	2	+
	Trochus tumidus Mont.	—	—	—	—	8	0.4
	Tectura virginea Müll.	5	0.9	—	—	18	0.2
	Litorina litorea Lin.	150	12.4	80	11.5	—	—
	» *obtusata* Lin.	—	—	—	—	6	0.1
	Lacuna divaricata Fabr.	5	0.1	—	—	18	+
	Hydrobia ulvæ Penn.	150	0.4	55	0.1	2	+
	Onoba striata Mont.	—	—	—	—	2	+
	Rissoa membranacea Ad.	—	—	—	—	2	+
	Aporrhais pes pelecani Lin.	—	—	+	+	—	—
	Purpura lapillus Lin.	—	—	—	—	2	+
	Gastropoda: total	**310**	**13.8**	**135**	**11.6**	**50**	**0.7**
	Amphidetus sp.	—	—	—	—	4	+
	Fusus sp.	5	0.4	—	—	—	—

[1] All the analyses are reduced to 1 *dm*³.
[2] The determination of the species thus marked has been kindly made or controlled by N. Odhner.

C. Statistical analyses of shell-deposits from the postglacial regression.

	Locality: Height in *m* above the sea.	Evenås.		Kapellbacken.				Uddevalla hamn.	
		B 29.		M 34.		C 16.			
	Samples: » » » » » »	28.3.		34.		16.		—3.	
	Samples: » » » » » base.	0.		0.2.		4.		?	
	Volyme analyzed.[1] in *dm*³.	0.5.		0.5.		—		—	
		Ind.	Gr.	Ind.	Gr.	Ind.	Gr.	Ind.	Gr.
Finiglacial transgressional relics.	*Pecten islandicus* Müll.	+	+	—	—	—	—	—	—
	Mytilus edulis Lin.	124	44.5	18	10.4	—	—	(+)	—
	Crenella lævigatus Gray *striata*	—	—	6	+	—	—	—	—
	Astarte compressa Mont.	2	+	—	—	—	—	—	—
	» *elliptica* Brown.	2	1.3	2	+	—	—	—	—
	Tellina calcaria Chemn.	4	2.1	—	—	—	—	—	—
	Mya truncata Lin.	2	6.6	—	—	—	—	—	—
	Saxicava rugosa Lin.	44	31.2	96	45.1	—	—	—	—
	Pelecypoda: total	**178**	**85.7**	**122**	**55.5**	—	—	—	—
	Chiton marmoreus Fabr.[2]	6	0.2	—	—	—	—	—	—
	Puncturella noachina Lin.	6	+	2	+	—	—	—	—
	Litorina rudis Maton	72	5.0	—	—	—	—	—	—
	Buccinum groenlandicum Chemn.	—	—	+	+	—	—	—	—
	Gastropoda: total	**84**	**5.2**	2	+	—	—	—	—
	Balanus Hameri Asc.	—	—	92	125.1	—	—	—	—
	» *crenatus* Brug.	1,776	166.4	214	8.1	—	—	—	—
	» *porcatus* da Costa	26	46.8	2	+	—	—	—	—
	Verruca Stroemia Müll.	12	+	10	0.3	—	—	—	—
	Balanidæ: total	**1,814**	**213.2**	**318**	**233.5**	—	—	—	—
	Echinus droebakensis Müll.	6	+	20	0.1	—	—	—	—
Finiglacial regressional colonists.	*Anomia ephippium* Lin.	2	+	—	—	—	—	(+)	—
	Ostrea edulis Lin.	14	58.0	4	+	(+)	—	(+)	—
	Cardium edule Lin.	58	7.2	24	5.6	—	—	(+)	—
	» *echinatum* Lin.	—	—	—	—	(+)	—	(+)	—
	Cyprina islandica Lin.	—	—	—	—	(+)	—	(+)	—
	Tellina baltica Lin.	—	—	2	+	—	—	—	—
	Pelecypoda: total	**74**	**65.2**	**30**	**5.6**	—	—	—	—
	Chiton ruber Lowe[2]	(+)	—	—	—	—	—	—	—
	Tectura virginea Müll.	12	+	—	—	—	—	—	—
	Litorina litorea Lin.	56	8.8	224	92.2	—	—	(+)	—
	» *obtusata* Lin.	18	1.9	—	—	—	—	—	—
	Lacuna divaricata Fabr.	30	0.2	—	—	—	—	—	—
	Hydrobia ulvæ Penn.	+	+	52	+	—	—	—	—
	Onoba striata Mont.	+	+	—	—	—	—	—	—
	Rissoa membranacea Ad.[2]	90	20.2	6	+	—	—	—	—
	Aporrhais pes pelecani Lin.	—	—	—	—	—	—	(+)	—
	Gastropoda: total	**206**	**31.1**	**282**	**92.2**	—	—	—	—
	Amphidetus sp.	+	+	—	—	—	—	—	—
Postglacial colonists.	*Pecten septemradiatus* Müll.	—	—	—	—	—	—	(+)	—
	Cardium exiguum Gmel.[2]	18	0.8	—	—	—	—	—	—
	Venus ovata Penn.	14	0.5	—	—	—	—	—	—
	Tapes decussatus Lin.	4	6.7	—	—	—	—	—	—
	Lucina borealis Lin.	—	—	—	—	(+)	—	—	—
	Montacuta Maltzani Verkr.[2]	(+)	—	—	—	—	—	—	—
	Mactra elliptica Brown.	6	+	—	—	—	—	—	—
	Mya arenaria Lin.	—	—	—	—	—	—	(+)	—
	Pelecypoda: total	**42**	**8.0**	—	—	—	—	—	—
	Rissoa interrupta Ad.[2]	(+)	—	—	—	—	—	—	—
	» *inconspicua* Ald.[2]	(+)	—	—	—	—	—	—	—
	Aclis supranitida Wood.[2]	(+)	—	—	—	—	—	—	—
	Bittium reticulatum da Costa	360	1.8	10	+	(+)	—	—	—
	Nassa reticulata Lin.	30	2.5	6	0.2	—	—	(+)	—
	Gastropoda: total	**390**	**4.3**	**16**	**0.2**	—	—	—	—

100170

Studies in the Late-Quaternary history of Southern Sweden.

By

HENR. MUNTHE.

(With Pls. 46—49).

As an introduction to *the guide for the Quaternary Congress-excursion in some areas of Southern Sweden*, I have found it appropriate to give *a general view also of the late-Quaternary history of Southern Sweden as a whole.* This, again, makes it necessary first of all to glance at *the late-Quaternary development of Northern Europe* (Fenno-Scandia and adjacent countries) during the same time.

Besides, this paper contains an account on *the Pile-dwelling at Alvastra* (by O. FRÖDIN and L. von POST).

1. A view of the Late-Quaternary development of Northern Europe.

For this purpose I have compiled two sketch-maps, Pl. 46 A and B, which are intended to illustrate some of the more important geological phenomena in question, viz.

1) *The more important pauses in the recession of the ice-border of the latest glaciation as yet known* (Pl. 46 A);

2) *The amount of the maximum depression of land when the ice-border retreated* (Pl. 46 A);

3) *The probable maximum upheaval of land within the southern peripheric regions of the depression area* (Pl. 46 B);

4) *The maximum transgression of the Ancylus Lake* (Pl. 46 B); and

5) *The amount of the upheaval of land after the maximum subsidence during the Litorina epoch* (Pl. 46 B).[1]

The more important pauses in the retreat of the ice-border.

The lines indicating pauses (and partly also oscillations) of the ice-border during the melting away of the latest ice-sheet are, as seen on the map, Pl. 46 A, rather incomplete as regards great parts of Fenno-Scandia.

As to the course of these lines within *Denmark* I have followed chiefly the general survey recently given by Ussing (1910, fig. 11)[2] and, besides, I have added a few other lines. For *Germany* I have, following Keilhack's map of 1909, drawn a few lines among which the more continuous one probably represents the extreme line of the latest glaciation, since it is in a direct connection with those lines in Denmark and Russia which may presumably be regarded as corresponding to the line in question.[3] As to this line in *Russia*, just mentioned, as well as the lines in *Finland*, I have followed the scheme of Ramsay (1909 etc).

For *Kola* as well as for the northern and north-western parts of *Norway* Tanner's lines (1907) are used.

Within *S. Norway* the lines are marked out on the map according to papers by Vogt (1891) and W. C. Brögger (1900—1901).

As regards *S. Sweden* G. De Geer, in 1896 and previously, has published maps on smaller scales including, *inter alia*, the

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[1] By the *Baltic* I mean the waters filling the whole depression from the Danish islands and Schleswig to the innermost part of the Bothnian Gulf, the subparts being *Östersjön* (The East Sea), *Finska viken* (The Finnish Gulf), *Bottenhafvet* (the Bothnian Sea), and *Bottenviken* (the Bothnian Gulf).

[2] See the Bibliography at the end of this paper.

[3] According to Keilhack, however, the southernmost line in Germany (see the map) also belongs to this glaciation.

terminal moraines then known, and recently (1910) a summary of the results as yet obtained by Swedish geologists has been published by Sveriges Geologiska Undersökning (S. G. U.). This map, on the scale of 1 : 500 000, also shows glacial striæ and oses (cfr. G. De Geer 1909; Swed. åsar, singul. ås), and, besides, it illustrates the extent of late-glacial land according to G. De Geer's conception which, as to some of the Baltic districts of S. Sweden, is differing from that of mine (see further on). The terminal lines on my maps 46 A und 47 (se below) are compiled chiefly from this last-mentioned map and, besides, I have tried to construct the interjacent portions as well as some other lines from the geological map-sheets and from the topographic maps.

The drawing of the lines within the Skagerak and Baltic, etc. (see my map, A) are to be regarded only as hypothetical but may illustrate their probable courses there.

The lines in question are developed mostly as *terminal moraines*, but also, as, for instance, sometimes in Southern Finland, the northern part of S. Sweden, and S. Norway, as *glacio-fluvial deposits*, in the first place *marginal oses*, *marginal plateaus* (terraces)[1] and *terminal* (*outwash*) *plains*.

Besides, more or less important *oscillations of the ice-border* have taken place in connection with the formation of some of the terminal lines of different districts of the glaciated area.

As is evident from the terminal lines and the position of the ice-shed (see the map, Pl. 46 A), the ice-border retreated more rapidly within the southern, south-eastern, and eastern areas than in the western ones. This may have been probably

[1] As to the nomenclature of these deposits I think the name of *plateaus* preferable to that of terraces urged by De Geer, since this last name is used for several other deposits and, therefore, is not so fixed as the other one Moreover, the deposits in question are now-a-days in most places really isolated plateaus.

depending in the first place upon the more continental climate within the former, lower lying regions than that of the western, more humid mountainous districts. Probably also the fact, that within its former regions the ice-border at times to a great extent emerged from wide waters, into which several large and relatively warm rivers opened, caused the more rapid retreat there. A strikingly slow retreat took place inside the Skagerak, as proved by the terminal lines converging from S. Sweden towards the Kristiania fjord (cfr. MUNTHE 1901).

As to the central parts of Fenno-Scandia the lines are too little known to allow a general view of the different positions of the retreating ice-border. Of special interest is the fact that in Norrland (Northern Sweden), at least during a later stage of the glaciation, the ice-shed was situated E. of the water-shed (see the map, Pl. 46 A); hence, in consequence, the ice pressed upwards towards the high land to the W., damming up large systems of ice-lakes (see A. G. HÖGBOM and A. GAVELIN 1910, as well as previous papers cited there). Similar ice-lakes as well as wide-extended late-glacial lakes and rivers of a more normal drainage have existed also within other areas, as in Denmark, N. Germany, Russia, and S. Sweden. In this connection I need only recall the well known system of great river-valleys (»Urstromtäler») of N. Germany, described by KEILHACK and others. As regards S. Sweden the ablation phenomena in question will be treated at some length farther on in this paper.

The amount of the maximum depression of land when the ice-border retreated (Pl. 46 A).

When the land-ice melted away, Fenno-Scandia and parts of some adjacent countries were, probably through the weight of the ice, depressed to a greater amount than to-day (relatively to the sea-level which, practically spoken, may be considered as *constant* during the whole of the late-Quaternary epoch). As regards Sweden, this fact was stated long ago by S. Lovén and based upon finds of arctic marine molluscs, mammals, etc. in deposits now considerably elevated above sea-level as well as of the glacio-marine relict fauna (*Cottus quadricornis*, *Gammaracanthus loricatus*, etc.) yet living in many lakes (Wettern etc.) which now-a-days are situated within districts that formerly were below the surface of the late-glacial sea or of the Baltic ice-lake (see farther on).

By studying more in detail the gravelly beaches, erosion terraces, clean-washed rocks and blocks, etc. which mark the very uppermost limit then reached by the sea in different parts of Fenno-Scandia, G. De Geer (1888 and 1890) first pointed out, that within this relatively large area, the amount of the depression of land in late-glacial times increased fairly regularly towards the central parts of Fenno-Scandia. The amount of this depression was illustrated by *isobases*. In the same way *isocatabases* indicate the amount of land-subsidence during later times.

As suggested to by some geologists (G. De Geer and others) there seems to be a close correspondence between the character of the rock-ground and the area of deformation, this latter being chiefly limited to the pre-Cambrian region of Northern Europe (Fenno-Scandia, cfr. the map).

As may be seen from the following account this isobase system of Fenno-Scandia etc., shown on Pl. 46, A., is of a much more heterogenous and complex nature than was thought before. Neverthless it may be published here in order also to give an idea of the historical evolution of the questions under consideration.

Most data are obtained from G. De Geer's map of 1896, and, besides, I have used those of A. G. Högbom 1904 (for the districts round the Bothnian Gulf and Sea), of W. Ramsay 1896 etc. and of V. Hackman 1898 (for Finland and NW.

Russia), of V. Tanner 1907 (for Finmarken etc.), of A. Gavelin 1910 (containing a summary of the researches of the isobases of NW. Norway and adjacent districts of Sweden), and of W. C. Brögger, Kolderup, Rekstad, Öyen, a. o. (for WSW. and S. Norway).

As to the interior regions of Northern and Central Sweden etc. the true significance of the isobases is still very doubtful, and, in consequence, they may be excluded here [cfr. the papers by A. G. Högbom (1904) and A. Gavelin (1910)].

It was long the common opinion that also in the Baltic district the uppermost marks of the waves' action just mentioned were formed by the *sea*, as was really the case with those of Western Sweden etc., i. e. regions which were in an open situation towards the sea (Ocean). However, I have emphazised (1902 and later), that in several Baltic districts these marks are to be referred *not only to the sea, but partly, and more commonly, also to the Baltic ice-lake*, the Baltic having only during some different and relatively short late-glacial stages been in connection with the Ocean. Hence the formation and position of these lake marks have nothing directly to do with the contemporaneous marine marks of Western Sweden etc., which is, consequently, also the case with the two isobase systems in question.

Practically, however, these isobases within the southern and central parts of the Baltic (see the map, Pl. 46 A) may be considered as »marine» and as equivalent to those of W. Sweden etc. In order not to make the map too indistinct, the isobase system which is to be referred to the Baltic ice-lake stages, will be omitted here.

That the southern parts of the Baltic had really in late-glacial times the character of an ice-dammed lake (or lakes) is evident from the fact that an early and intensive upheaval of land took place within this as well as within other peripheric districts of the once glaciated area. This upheaval is proved by the existence of supramarine deposits with arctic plants (*Salix polaris* etc.) and animals within present shore districts, as, for instance, NW. Skåne, which shortly before was covered by the sea to a depth of about 45 metres (Gunnar Andersson in 1893). In the meantime the ice-border continued its recession and the Baltic ice-lake had its outlet within the Öresund district and (or) the Great Belt.

Later on, when the ice-border reached about the isle of Gotland see the map, Pl. 46, A) this lake probably discharged into the Ocean — into the White Sea — through the strait then existing, probably for a short time, within the southern Onega district (W. Ramsay 1900). Then an upheaval of land here again changed the Baltic into an ice-dammed lake which for a time had its outlet through the late marine district of Onega; this ice-lake persisted until the ice-border had retreated to the northernmost part of Mt. Billingen (W. of Lake Wettern). Then the Baltic again came into connection with the Ocean.

The isobases of these marine epochs, as regards also the Baltic districts W. of Onega and N. of a line from Bråviken to the North of Karlsborg etc., therefore refer to *the true marine ones.* (See the NE. part of the map, Pl. 47.)

The elevation of land just mentioned probably had the character of waves proceding in a centripetal direction from the peripheric regions (round Fenno-Scandia) of the glaciated areas, where, therefore, the 0-isobase is to be found on the map, Pl. 46, A. About the same character (of waves) had, later on, the reverse process of land-subsidence.

From the above remarks may be concluded that the uppermost limits of the late-glacial waters were by no means developed at the same time, the peripheric regions which first had been free from ice having been elevated much earlier than the more central ones. Only the districts lying on the same isobase were possibly depressed about to the same amount at the same time. Not knowing exactly the rapidity of the rise of land, we cannot map all the different stages of the shrinking water-areas in question. Hence it is evident that the late-glacial waters, figured on older and more recent maps, did by no means exist to their full extent at one and the same time. I have, therefore, only tried to illustrate the probable extent of late-glacial land within the Baltic coasts of Sweden when the Baltic was first connected with the North Sea across the northern part of S. Sweden (cfr. the map, Pl. 47). As appears from Pl. 46, A., the marine 0-isobase etc. had, so to say, travelled as far towards the North as up to the southern part of the isle of Öland, or, more possibly, still further N.; in other words, the Baltic shore-line of then was in the district mentioned probably at approximately the same level as to-day. Southwards the land had a wider extent than to-day and, therefore, the isobases are replaced by *isocatabases*.

As is also seen from the map, the »marine» late-glacial isobase system has about the same extent and shape as the ice-sheet, which speaks in favour of the extent and amount of land-depression being closely related to the extent and thickness of the land-ice.

The irregularities of the isobase systems seem to bear a relation to the general geology and orography of the area, concave parts of the lines commonly coinciding with larger depressions in more or less eroded sedimentary rock-complexes, as, for instance, the depression of Lake Wenern; partly they were also depending on the varying manner in which the ice-border retreated. Thus belts of larger oscillations of the ice-border sometimes show a convexity of the lines, which may have been a result from the fact that the upheaval of land continued during the oscillation; hence the uppermost marks of the sea (lake) are met with at higher levels outside than inside (or, at least, within) the oscillation belt. This is the case, for instance, at Ed in Dalsland (see G. De Geer 1909), W. of Mts. Billingen—Falbygden in Västergötland, etc. This fact, then, does not necessarily prove an irregularity (a relative pause in the of upheaval land, as is thought by some geologists (cfr. TANNER 1907, p. 95).

In addition to the shore-marks and shore-deposits (gravel and coarse-grained sand) of the late-glacial waters, *fine sand-* and *clay* or *marl* strata were formed at a lesser or greater depth. The clay is commonly laminated, each »lamina» representing the deposition of one year (»seasonal clay» in English). Based upon that fact G. DE GEER has tried to give an absolute chronology of the late-glacial period, the results of which are still unpublished and cannot, therefore, be discussed; but he is of opinion, that the recession of the ice-border from NE. Skåne to Norrland required a time of about five thousand years. At the terminal lines of »Central Sweden» a stop of about two hundred years is estimated. The first figure, however, seems to be too small, since later on there are found evidences of *several more stops and oscillations of the ice-border* than those just mentioned. (See farther on.)

The probable maximum upheaval of land within the southern peripheric regions of the depression area.

To what extent the upheaval really continued within the peripheric regions before the postglacial land-subsidence commenced, we cannot yet determine, the marks being now below the sea-level. But probably the southern and south-western Baltic districts were uplifted up to about 125 metres higher than to-day, this amount of upheaval being less and less in a centripetal direction. On the map Pl. 46, B, I have tried to give an idea of these features.

This relatively high site of the Baltic peripheric regions is proved by the finds of submerged lacustrine layers (peat-bogs etc.) on the sea-floor of the S. Baltic, Kattegat, North Sea, and some other peripherical districts, as well as by the presence of marked submerged river-channel-shaped depressions there, the bottom of which are in N. Öresund about 50, in the Great Belt about 67, and S. of the Little Belt about 80 metres below the present sea-level. Besides, the bottom of the old erosion bed of the River Trave, near Lübeck in North Germany (Lü. on the map). is stated to be at least 55 metres below the present sea-level (FRIEDRICH and HEIDEN 1905). The figures cited might indicate only *a minimum of elevation* of the south-western Baltic district. Their highest elevation probably was reached after the Baltic had been isolated for the last time, i. e. through the emergence of the old sounds of Närke (see farther on). Probably the 0-isobase of then in W. Sweden may be places between Göteborg and Strömstad (see map B), and in E. Sweden S. of Norrköping (N. on the map).

As can be seen from this map as compared with HINTZE's maps of 1908, our opinions differ considerably as to the amount of the elevation of land (see also MUNTHE 1909 b), since HINTZE's hypothesis requires, for instance, an elevation of about 225 to 250 *m* in the northern part of the Kattegat, i. e. about where my isocatabase of 50 *m* runs. My figure is chosen since portions of peat, evidently occurring in situ, have been found here on several occasions during fishing operations (with trawls) at depths varying between 35 und 47 *m* (E. ERDMANN 1908).

Otherwise, within more northern districts, the rising of land is proved to have decreased gradually during the times corresponding to HINTZE's »fastlandstid» (the continental time). So, for instance, the Kristiania district during that time and, moreover, during the whole late-Quaternary time seems to have been more depressed than now-a-days, which, *inter alia* proves the inaccuracy of HINTZE's hypothesis.

From what has been said above it is evident, that, for instance, the isocatabase of 125 is placed somewhat arbitrarily. I hold it, however, to be not unlikely, that the elevation was still greater and that the so-called »Storeggen» or »Haveggen», the marked pebbly beaches at the outermost parts of the continental plateau W. of Norway (see the map, Pl. 46, B), may be looked upon as having been formed during the time in question rather than during the last interglacial period, as W. C. Brögger thinks (1900—1901). These beaches as well as dead shells of shallow-water and shore molluscs are found down to a depth of about 200 *m* there, which figure, therefore, may fairly well indicate about the maximum elevation of that time. If the phenomena in question had been interglacial in age they had probably been covered by glacial deposits on a very much larger scale than appears really to be the case.

The maximum transgression of the Ancylus Lake.

During the land elevation mentioned above, the Baltic was isolated from the Ocean and gradually transformed into a *fresh-water lake, the Ancylus Lake* (Munthe 1887 and 1910 a), the most characteristic inhabitants of which were *Ancylus fluviatilis* Linné and several other true fresh-water organisms as well as some marine relicts. This lake at first had its outlet within Närke (where the latest connection existed between the late-glacial Baltic and the Ocean). Later on the outlet was transferred to the Karlsborg district (W. of Lake Wettern) and still later to the Öresund district. This maximum transgression of the Ancylus Lake towards the South, which is illustrated by the red isobases on the map, Pl. 46 B, was probably caused by the gradually more important upheaval within the central parts of Fenno-Scandia, later on combined with a commencing gradual subsidence in the southern and eastern peripheric districts.

As far as is hitherto known, it is probable that the ice-sheet had still a fairly wide extension in Norrland during the early time of the existence of the Ancylus Lake, and that the upheaval of land had not yet commenced at that time within these more central districts of depression. In consequence, the isobases of these districts should not be reckoned to those of the late-glacial Sea, as has hitherto been done, but most probably, as I have recently pointed out (G. F. F.

1909, p. 194), to those of the Ancylus Lake. The system of Ancylus isobases shown on the map may, therefore, be considered to continue in the »late-glacial» isobases of the Bothnian districts etc.

The amount of the upheaval of land after the maximum subsidence during the Litorina epoch.

While an upheaval of land probably continued somewhat equably during postglacial times and does so to-day within the *central parts* of the old depression area, *the peripheric regions of the area were during the (middle? and) later part of the Ancylus epoch as well as during the first half part of the Litorina epoch subjected to a subsidence*, the amount of which gradually increased in a centrifugal direction, However, evidences of that subsidence are not known farther inwards than the vicinity of Kristiania, the uppermost limit of this (Tapes-Litorina) subsidence being to-day situated about 80 *m* above sea-level (ÖYEN 1905).[1] Possibly, therefore, the innermost boundary of the subsidence is to be found at about the same isobase (80 *m*) of that time within the Baltic district (see the map Pl. 46, B). This question has, however, not yet been studied in detail in Sweden.

A result of this subsidence of land was, *inter alia*, that the districts round the Danish islands etc. were submerged below the sea-level to such a degree that the Baltic was connected with the Kattegat. In consequence, the Baltic was gradually transformed from a fresh-water lake into a somewhat salter and warmer sea than now-a-days. It has been called *the Litorina Sea*, since two forms of *Litorina*,

[1] When ÖYEN (l. c. p. 14) says, that the uppermost Tapes niveau is now about 80 *m* above sea-level along the line Hamar (at lake Mjösen in SE. Norway) to Aamot (W. of Kristiania), I think it is not right to consider this niveau as the uppermost Tapes-Litorina level for the direction of the 80 isobase (SW. to NE.) would deviate too much from that of the system in the vicinity. — When HÄGG (in 1910) says, that the Litorina limit near Strömstad is met with at about 66 *m* above the sea, where BRÖGGER isobase of 45 *m* runs, this is another and, most probably, also wrong extreme.

which have now retired to the southernmost parts of the Baltic, then lived as far towards the North as Bottenhafvet (*L. litorea*), and in the northernmost parts of Bottenviken (*L. rudis* var. *tenebrosa*). The surface saltness from Gotland to the innermost part of the Baltic was then, on an average, double the size of to-day.

At that time also the sea round Norway and Denmark, etc. was relatively warm. So, for instance, *Ostræa edulis* then lived in the westernmost part of the Baltic and *Tapes decussatus* in the southern part of the Kattegat, these two species living to-day not farther inwards than the central part of the Kattegat and the North Sea respectively.

Since the maximum extent of the Litorina Sea is not yet known in the districts round Bottenhafvet and Bottenviken, only a few figures, indicating some maximum heights at which Litorina deposits have hitherto been found, have been inserted on the map, Pl. 46, B, whereas isobase lines must be omitted. On the other hand, the outer parts of the isobase system of that time have been worked out with a relatively great accuracy all round Fenno-Scandia (see the map just cited). These lines coincide very well with those published by V. TANNER in 1907. In contrast to the highest marks of the Baltic late-glacial seas and lakes as well as of the Ancylus Lake those of the Litorina Sea were possibly developed about contemporaneously within the whole district. That is probable from the above mentioned fact that *Litorina rudis* var. *tenebrosa*, the innermost occurrence of which to-day is at the shores of Bornholm in the S. Baltic, is found as a fossil to such a height as 50 *m* above sea-level near the northernmost part of Bottenviken.

From what has been said above it is evident, that the opinion first expressed by T. F. JAMIESON (1891) and later (1892) confirmed by myself may to a certain extent be correct, viz. that a movement of land within the central regions of the glaciated Northern Europe also caused a gradual movement in the opposite direction within the peripheric parts and vice versa. So, for instance, were the periferic districts rising when the central ones were still depressed, and, later on, when the former were sinking, the latter were evidently rising. These alternate movements of the earth's crust have, however, been more or less complex. Now-a-days the elevation of land seems to be confined to Fenno-Scandia, while the Baltic districts etc. outside of this region do not show any traces of elevation. (Cfr. SIEGER 1893).

As may be proved from the above account, these alternating movements have played a great rôle in the late-Quaternary history of Fenno-Scandia. Several very important and interesting problems bearing on this fact still remain, however, for study and solution before this history can be written more successfully, especially as regards the development of the different waters, whose old shore-lines are now partly submerged below the sea. Moreover, a closer study of the course and the amount of the displacements which the shore-lines of the late-Quaternary lakes have been subjected will also certainly bring to light important facts about the nature also of the movements of the earth's crust in wider areas, as we have every reason to infer from GAVELIN's researches (1907) within a small area near Tranås in S. Sweden.

A glance at the immigration of the Late-Quaternary floras and faunas of Fenno-Scandia.

As to this important and interesting question I have found it appropriate here to give only a few data on the flora, since I intend to deal with it also in the chapter on Southern Sweden. Following the metod used by GUNNAR ANDERSSON in 1906 and L. VON POST (in 1909) I have attempted to illustrate the question by a diagram (fig. 1) showing the main stages of the Baltic history in correlation with the migration of some of the more representative plants. Besides, an attempt is made to establish a probable chronology for S. Sweden expressed in thousands of years. On the curve illustrating the retreat of the ice-border from Skåne to Northern Sweden also the pauses and oscillations of the ice-border previously discussed and shown on the map B are indicated in

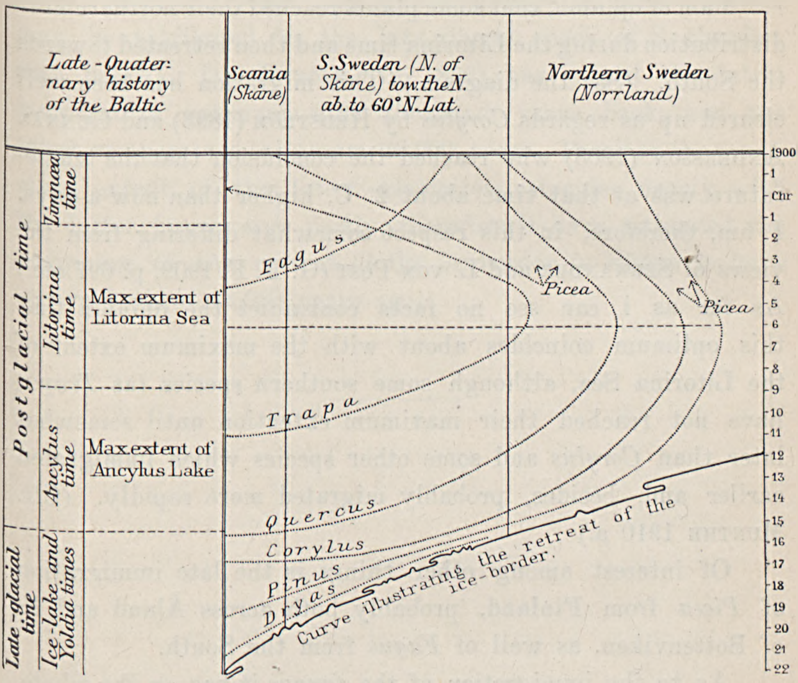

Fig. 1. *Diagram illustrating the probable migration of some plants in Sweden during late-Quaternary times.*

a schematic way. The more marked oscillation indicated on the part of the curve that represents Norrland, refers to the great oscillation described by Högbom (1893 and later), and which is proved by the occurrence of moraine resting upon thick strata of glacio-lacustrine clay and sand.

Probably such great oscillations took place also earlier, or when the ice-border was in the southern parts of the Wetter basin (see farther on) as well as when parts of the terminal lines in the northern district of S. Sweden were formed; for also here occur moraine and glacio-fluvial deposits resting upon glacio-lacustrine and glacio-marine clays etc., and a boreal marine fauna has been found in terminal moraines of S. Norway. Some Norwegian geologists are, moreover, of opinion, that the fact just named possibly indicates an interglacial epoch.

I am of opinion, that some plants reached their northernmost distribution during the Litorina time and then retreated towards the South. (See the diagram.) This migration has been well cleared up as regards *Corylus* by HEDSTRÖM (1893) and GUNNAR ANDERSSON (1903) who reached the conclusion that the temperature was at that time about 2° C. higher than now-a-days. I am, therefore, in this respect somewhat differing from the views of SERNANDER and L. VON POST (G. F. F. 1909, p. 697 etc.) As far as I can see no facts contradict the opinion that this optimum coincides about with the maximum extent of the Litorina Sea, although some southern species (as *Trapa*) have not reached their maximum extention until somewhat later than *Corylus* and some other species which immigrated earlier and, besides, probably migrated more rapidly. (Cfr. MUNTHE 1910 a.)

Of interest among other things is the late immigration of *Picea* from Finland, probably both across Åland and N. of Bottenviken, as well of *Fagus* from the South.

As to the immigration of the *faunas* it has, on the whole, been about parallel with that of the floras, arctic-alpine forms having been replaced by subarctic, these again by boreal ones, and, finally, temperate and southern species immigrated. Also several species among the land and marine animals indicate a temperature optimum within Northern Europe during post-glacial times, most probably coinciding approximately with the stage just mentioned.

As to the stages younger than the maximum extent of the Litorina Sea the chronology (in thousands of years before and after the birth of Christ = 0) is based chiefly upon the results attained by MONTELIUS (in 1906), W. C. BRÖGGER (1905), and others. Thus, I think that the whole of the Litorina and Limnæa epochs continued approximately ten to eleven thousand years. To judge, *inter alia*, from the great changes of level and the migration of plants and animals which took place during the Ancylus epoch, this epoch probably continued several thousand years, and approximately the same duration may be attributed to the late-glacial epoch of S. Sweden. (See below). Dr. EKHOLM (in 1899) has placed the latest temperature optimum nine thousand years back, and the latest temperature minimum 26,000 years. Possibly the maximum extent of the latest glaciation coincides nearly with the latter figure, and, partly, therefore, I have estimated the beginning of the retreat of the ice-border in Skåne to have occurred about 24,000 years ago.

78—100170. G. F. F. 1910.

2. The Late-Quaternary history of Southern Sweden (N. of Skåne).

In this chapter I intend to give a somewhat fuller review of the late-Quaternary history of Southern Sweden than that which can be gathered from the above survey of the development of Fenno-Scandia. For this purpose I have compiled the map, Pl. 47, which may serve to illustrate in the first place: 1) *the more marked terminal lines, indicating pauses and (or) oscillations in the general recession of the ice-border of the latest glaciation; 2) the gradually reached maximum extent* a) *of the ordinary late-glacial lakes*, b) *of the ice-dammed lakes (incl. the Baltic), and* c) *of the Yoldia Sea, as well as* 3) *the outlets of the lakes mentioned.* For *glacial striæ* and *oses* reference may be made to the map on the scale 1 : 500 000 (S. G. U. 1910) already mentioned in the introductory chapter.

I am sorry I have had no time to work out a map illustrating the maximum extent of the Ancylus Lake and the Litorina Sea within Southern Sweden.

Terminal lines.

The motion of the land-ice's was, during the latest glaciation, approximately from N. to S. within the middle parts of S. Sweden with a gradual deviation towards the SE. in the eastern and towards the SW. in the western districts. Thus, the glacial striæ and the oses proper run at about right angles to the terminal lines. At the end of the glaciation, however, the ice within the Baltic depression assumed the character of a more separate stream, which during a great oscillation epoch traversed the southern parts of Skåne from SE. to NW. and the south-western parts of the same province in a direction nearly from S. to N. Later on the recession of the ice-border commonly proceeded more regularly, only at some stages interrupted by considerable pauses and oscillations marked by belts of terminal deposits.

As appears from the map, three more continuous lines of this character traverse the southern and three the northern parts of S. Sweden (N. of Skåne). Besides, there are traces of a few interjacent lines. The relatively inconsiderable annual moraine lines, of which in places occur several tens, are as yet observed only within the northern part of the map. They have, however, not been inserted.

In the following pages I will give a short review chiefly of the six marked lines just mentioned. They are denoted A—A to F—F on the map.

A—A. This line runs from the vicinity of the town of Warberg (on the Kattegat) towards the SE. passing Falkenberg, Halmstad, and the northern part of Skåne.

B—B. This line runs parallel to the line A—A. It includes, *inter alia*, some marginal plateaus, the largest of which is met with at Bredåkra (in the province of Blekinge, cfr. G. De Geer 1909). In the vicinity of Kalmar and SW. of this town the line is represented by some marked terminal moraines and then it probably crosses, as G. De Geer first pointed out, the isle of Öland in a SE. and, later on, a S. direction. It, possibly, also continues in some marked gravelly grounds at the bottom of the Baltic, e. g. ESE. of the southernmost ends of Öland and Gotland, and E. of the last-mentioned island. Possibly, the continuation is to be found at the isle of

Ösel (Fr. Schmidt) and in Esthonia (G. De Geer). At Kalmar portions of seasonal glacial clay are found in and overlain by moraine. This fact indicates that the ice-border oscillated while retreating within this district. (See below.)

C—C. The northernmost parts of this line appear in the vicinity of Göteborg. At Fjärås etc. the line is represented by large marginal oses, and SW. of Kalmar there are, to judge from the topographic map-sheet as well as from verbal information by Dr. H. Hedström, a number of marked terminal moraines. Its further continuation possibly passed the large fields of glacio-fluvial gravel and sand SE. of Borgholm (Öland) and then a streak of marginal oses in northern Gotland (cfr. Hedström, G. F. F. 1906, p. 421); it then probably traverses Gotska Sandön etc.

The above mentioned *interjacent terminal lines* have not yet been studied so as to allow of a sure mapping. It may, however, be mentioned that several observations made within the areas at and round the southern part of Lake Wettern prove the existence of *at least one large oscillation* of the ice-border there. That is evident since a thick moraine bed has been found resting upon thick glacio-lacustrine clay- and sand-deposits, as, for instance, in the so-called »Rosenlunds bankar» E. of Jönköping (see farther on). A younger system of glacial striæ diverging from the southern areas of the marked Wetter basin also indicates this oscillation of the ice-border.

D—D. This line enters the map within its NW. part (near Krokstad). After an interruption it probably appears S. and SSE. of Wenersborg and is then represented by a marked line, which, commencing in the vicinity of Wartofta (SE. of Falköping, cfr. fig. 2), runs towards the E. and NE. to Wettern. At Kymbo and Härja it includes marginal plateaus, deposited in an ice-dammed lake (see below). The continuation of

Fig. 2. A portion of *the terminal line* D—D, near Wartofta. The highest hill is named Warkullen. To the right of it the ice-lake-plane is visible, about 230 *m* above sea-level. — (From the explanation to »Tidaholm».)

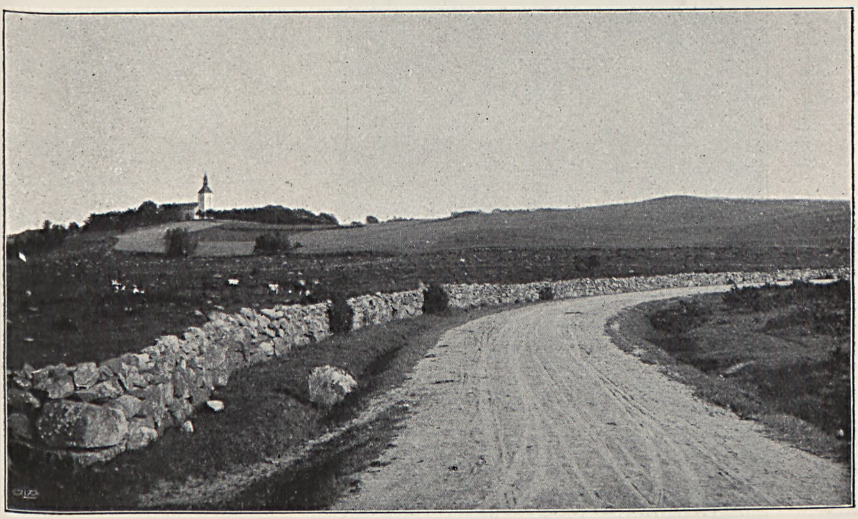

Fig. 3. A portion of *the terminal line* E—E, at Edsvära church. — (From the explanation to »Falköping».)

Fig. 4. The distal side of *the marginal plateau* at Mjölby. — Photo by the author.

this line is probably near Tranås and at Malexander (at the northern part of Lake Sommen), since marginal plateaus are developed there.

E—E. This line, which runs nearly parallel to the line D–D, is the southern one among the (two) lines which previously and somewhat improperly have been called »the terminal moraines of Central Sweden». It crosses Lake Wenern and is well developed near Edsvära (fig. 3) and then it probably passes Gudhem, Dala, etc. Then the line has not been followed in detail, but it seems likely from the distribution and height above sea-level of some ice-lake deposits that it runs towards the NE. to Hjo, and then towards the SE. to Ödeshög S. of Mt. Omberg, where it assumes a nearly E. direction. The supposed NW.-direction of the ice-border, when in the Omberg—Hjo district, seems not to be inconsistent either with the development of the glacio-fluvial deposits, or with the glacial striæ near Hästholmen, since I have (in 1903) observed a system of striæ running from N30°E. to S30°W., which is probably younger than another system running about NW. to SE. Long ago (in G. F. F. 1890) the same opinion was expressed by NATHORST.[1]

Near Ödeshög and Åsbo the line is represented by marked marginal plateaus, while terminal moraines etc. exist within the interjacent district. The further continuation towards the E. is not yet known.

F—F. This line, the northern one of the »middle Swedish terminal moraines», also crosses Lake Wenern. Then it is divided first into two, later on gradually into three, four, five, and, finally, W. of Lake Wettern, into six separate lines (a—f), which again, near Linköping, seem to be reduced to three lines. Possibly all these lines, when closer examined,

[1] Based upon observations made by G. DE GEER, AHLMANN has recently (1910) emphasized the opposite opinion.

will be found to represent more independent ones. The lines are commonly developed as terminal moraines, which are especially marked on both sides of the northern part of Mt. Billingen. Near Karlsborg there are a series of small marginal plateaus, described by H. HEDSTRÖM (1901). More important such plateaus are met with N. of Karlsborg and NNW. of Motala (cfr. G. DE GEER 1909), near Mjölby (fig. 4) and Rinna (fig. 5), E. of Lake Wettern, etc., while, elsewhere, terminal (outwash) plains are found, as at Axvall (W. of Mt. Billingen) and Malmslätt (W. of Linköping). Near Axvall other plains, connected with an imposing kame-landscape etc., will be accounted for in greater detail farther on.

In places marginal oses also form parts of the lines in question. E. and NE. of Linköping the continuation of this line is represented by series of terminal moraines, but farther towards the NE. it has not yet been studied in detail and is, therefore, somewhat uncertain. Probably, however, it may run approximately as is shown on the map.

In the following chapters some of these terminal lines will be mentioned, in the first place those indicating oscillations of the ice-border and the maximum surface of the ice-lakes.

Late-glacial lakes and rivers.

In the course of the retreat of the ice-border large quantities of water organized themselves into more or less large subglacial streams and rivers, which, before leaving the ice, built up the well-known *oses*, probably for the most part gradually within the submarginal portions of the ice-sheet. After escaping from the ice-border, these rivers gave rise to more or less extensive masses of gravel, sand, and clay, chiefly deposited in the numberless water-filled depressions, which, at

Fig. 5. *The outwash plain* near Rinna. The marked terminal moraine at its proximal end is visible in the distance. — Photo by the author.

Fig. 6, showing the horizontal surface of *the valley train* N. of Lena railway station, N. of Ulricehamn, Westergötland. Photo by the author.

that time, were, to a much larger extent than now-a-days, filled with water, partly in the form of lakes, partly as current waters of all sizes, partly also as transition forms between lakes and streams. These lakes were sometimes ice-dammed.

On the map, Pl. 47, I have tried to give a general view of the extent of these late-glacial waters, chiefly based upon the distribution of the late-glacial gravelly, sandy, and clayey deposits inserted in on the geological map-sheets of Sweden.

It was, however, not till recently that these layers, as regards a few districts, were really considered as late-glacial lake- and river-deposits, having earlier been looked upon chiefly as marine sediments. Thies view was, for instance, entertained by A. ERDMANN who in 1863 published a map of the southern and central parts of Sweden showing the distribution of the glacial clay and marl known at that time.

In 1893 G. DE GEER mentioned some deposits of S. Sweden as belonging to late-glacial lake sediments, having been relatively more uplifted within the northern or (relative to the ice-border) proximal parts of the old lake-depressions with outflow towards the South. He alluded to the existence also of marks of ice-dammed waters round the southern part of Lake Wettern.

Later on, in 1892 and 1895, N. O. HOLST holds it probable that sediments, formed in lakes dammed up by the ice-border, occurred in E. and W. Skåne, and so does J. C. MOBERG in 1895 as to SE. Skåne. (As to the bibliography see MUNTHE 1907.)

However, the first geologist who clearly proved the great rôle that ice-dammed lakes really played also in S. Sweden, was A. HOLLENDER. In two small papers (1897 and 1899) he described several marks and phenomena bearing on wide-extended ice-lakes, chiefly within the NE. parts of the topographic map-sheet of »*Ulricehamn*», and, moreover, he alluded to the existence of other ice-lakes etc., as, for instance, round the southern parts of Wettern and N. of the town of Ulricehamn. HOLLENDER'S treatise on the ice-lakes of »Ulricehamn» received an interesting illustration at the hands of AXEL LINDSTRÖM, who in 1898 published the geological map-sheet of »Ulricehamn» (based on the topographical map-sheet).

Ice-lake deposits were, finally, to a somewhat larger extent mapped out by J. P. GUSTAFSSON within the map-sheet of »Tidaholm» (1898 and 1899), by Dr. H. HEDSTRÖM within that of »Eksjö», and by Dr. A. GAVELIN within that of »Tranås». The investigations within the two last-named map-sheets have not yet been published, but I have received information about them partly from the two last-named geologists partly also during my own researches there.

During recent years (1890 onwards) I have been studying the late-glacial deposits and phenomena within several other parts of S. Sweden, and some of the results are published in the explanations to the map-sheets of »Sköfde», »Tidaholm», and »Jönköping», a few data having been given also elsewhere, as in the explanations to the map-sheets of »Gällö», »Hjo», and »Boxholm» (by A. BLOMBERG) and in MUNTHE 1907 (some districts of Southern Skåne) and 1908 (in a lecture before Geologiska Föreningen in Stockholm). As to Skåne, contributions had somewhat earlier (1906) been published by A. WESTERGÅRD (on the so-called »platå-lera») and O. BOBECK.

I intended to prepare for the Congress a more special description of the late-glacial lakes and rivers of Southern Sweden, accompanied by a map on the scale 1 : 500 000, but I had too short a time at my disposal. I was, therefore, compelled to limit my object and to give but a general view of these interesting questions and to publish a map on a smaller scale (1 : 1 000 000), this being the first attempt to illustrate the distribution of these waters in S. Sweden (N. of Skåne). The reason why Skåne is omitted, is that the late-glacial deposits and phenomena there are too confused and too little worked out at present to be set forth in detail in time for the Congress.

The considerable and numberless drainage-systems which arose in connection with the melting of the ice-sheet of S. Sweden had the character partly of *ordinary lakes*, i. e. such as had their normal courses down the ordinary slope of the land of that time, partly also of *ice-dammed lakes* (more shortly called *ice-lakes*), which — from the existence of the ice-sheet within more or less large areas of the depressions, in which the lakes elsewhere might have discharged — were compelled to rise and to take their outlets across loftier districts than the more normal and lower ones.

These ice-lakes, which had their largest extent and played their greatest rôle within the districts round the southern and central parts of Lake Wettern, will be treated farther on in this paper. At first I may deal with *the more normal lakes and rivers*, which were also common and often had a somewhat large extent, even though some of them had but a relatively short existence.

To what an extent all these different late-glacial lakes really reached in S. Sweden is evident from the map, Pl. 47, which, however, claims to give but a general view of the features in question. Besides, the rivers of that time were still more numerous than the map shows, only the most considerable ones having been taken into consideration.

Ordinary Late-glacial lakes and rivers.

Many of the late-glacial deposits in question, put into the map from the geological map-sheets, are built up chiefly as wide-spread sandy, gravelly and clayey plains, which, to a certain degree, fill the depressions whose slopes arise distinctly from the plains. They indicate, therefore, more directly the real extent of the old lakes and rivers, which, naturally postulate much larger quantities of water then than to-day.

Such plains often vary in size and shape, the more extensive ones having an area of several sq.-kilometres. They may be compared most appropriately with the so-called »outwash plains» etc. of North America.

In places where such deposits are wanting and replaced by more or less scanty occurrences of glacio-fluvial deposits (oses) the late-glacial waters might none the less be inserted, since large quantities of water, escaping from subglacial channels, must once have existed also there during late-glacial times.[1] That several marked valleys served for river-valleys is evident from the large quantities of sand and well-rounded gravelly deposits which fill them to a larger or smaller extent. Those deposits are identical with the American *valley trains* (*»dalfyllnader»* in Swedish). Sometimes it is, however, difficult or impossible to decide whether such a broad valley originally served as a bed for a river or for a narrow lake.

As mentioned above, clayey deposits sometimes occur together with sandy and gravelly ones. That is the case chiefly within the wider depressions in question. The formation of that clay might commonly be explained in such a way that those depressions for a longer or shorter time were filled with ice-dammed lakes instead of lakes with a normal outflow. Hence the masses of clayey particles, carried out in those lakes by the streams escaping from the ice, were not transported right through the lakes to such a degree as in normal lakes with a more permanent motion towards the outflow, but were in part deposited there. Such *temporary ice-dammed parts of systems of ordinary lakes* were not uncommon. They

[1] Large extended peat-bogs and *Sphagnum*-mosses within several districts also indicate the existence of wide waters in older times, but they are commonly not accepted as proofs thereof unless closely connected with the late-glacial sediment areas. Besides, those *Sphagnum*-mosses have in places grown to a much larger extent than that of the lakes because of the spread of *Sphagna* over the adjacent lowlands.

were due partly to the relatively greater depression of land towards the North at that time, partly also to the then continuing elevation of land in a centripetal direction. Moreover, it was in the first place within those districts situated inside a relatively narrow part of a valley-system with a not easily eroded threshold that the deposition of clay could take place, since the waters were there dammed up more easily than within a broader and throughout open valley.

In the following pages I will give a short description of *a couple of those drainage-systems* a great number of which cross Southern Sweden principally from the marine limit districts (or the Baltic ice-lake districts) to the true ice-lake areas of the northern part of S. Sweden, thus presenting an idea of the several geological features in question.

For this purpose the ***Ätran system*** might first be chosen as an example. That system begins NE. of the little town of Falkenberg (on the west-coast of Sweden) and runs in about a NE. direction to the vicinity of Wartofta (SE. of the town of Falköping), a distance of nearly 120 *km*.

From the marine district at Köinge, the marine limit here being about 74 *m* above sea-level, this late-glacial river- and lake-system had, in the environs of Gällared, the character of wide-spread fields of gravel and sand, whose horizontal surface is about 110 *m* above the sea. At Gunnarp the same field lies about 120 *m*, at Mårdaklef about 130 and at Frölunda about 145 *m* above the sea. From here the sand becomes predominant as far as beyond Svenljunga, and at the same time layers of *clay* are met with.

Round Örsås and Svenljunga there are extensive fields of gravel and sand, about 155 *m* above sea-level.

Farther N. the gravelly plane rises, being at Sexdrega 160 *m* and at Hillared railway station about 169 *m* above the sea. Then a narrower valley commences, which opens into the broader and regular valley that includes Lake Åsunden, with sandy and clayey deposits along the sides (see the geological map-sheet »Ulricehamn»). Round the northern part of this lake those deposits are met with at 177 to 178 *m* above the sea, i. e. 13 to 14 *m* above the surface of the present lake (163.8 *m* above the sea).

Towards the NNE. the same valley, bordered by high slopes of Archæan rocks, mostly covered by morainic matters, more regularly contains sandy, gravelley, and clayey deposits, the surface of which forms extensive planes, later on eroded to a depth of a few metres by the river Ätran. (See fig. 6, facing p. 1219, and fig. 7.)

This plane rises slowly and pretty equally towards the NNE., being at Vist church (NW. of Ulricehamn) 182, at Timmele church 185, NW. of the railway station of Lena 187, at Dalum church 195, ENE. of Blidsberg church 200, S. and WSW. of Kölaby church 211, NE. of N. Åsarp church 220, and E. of Wartofta about 230 *m* above the sea. From Gällared (110 *m*) to Wartofta (230 *m*) there is, therefore, a rise in the plane of 120 *m*. The distance between those two places being 130 *km*, the avarage gradient of the rise is 1 : 900. Whithin several parts of this distance, however, the gradient is as inconsiderable as 1 : 2 000 (between Örsås and the southern part of Lake Åsunden) and 1 : 2 300 between this last point and the northern part of the same lake. From Ulricehamn to Wartofta, on the contrary, the rise is relatively considerable, the gradient being 1 : 650. Within this last-mentioned distance the lake was probably compelled to rise comparatively much towards the North, because of the continuing elevation of the narrower outlet in the SSW. On the other hand, in districts with less rising of the plane, as S. of Lake Åsunden, the water could escape more easily. The relatively small gradient within the southern part of the Åsunden—Ulricehamn valley may be explained by an easier erosion of the threshold during an earlier stage of escaping.

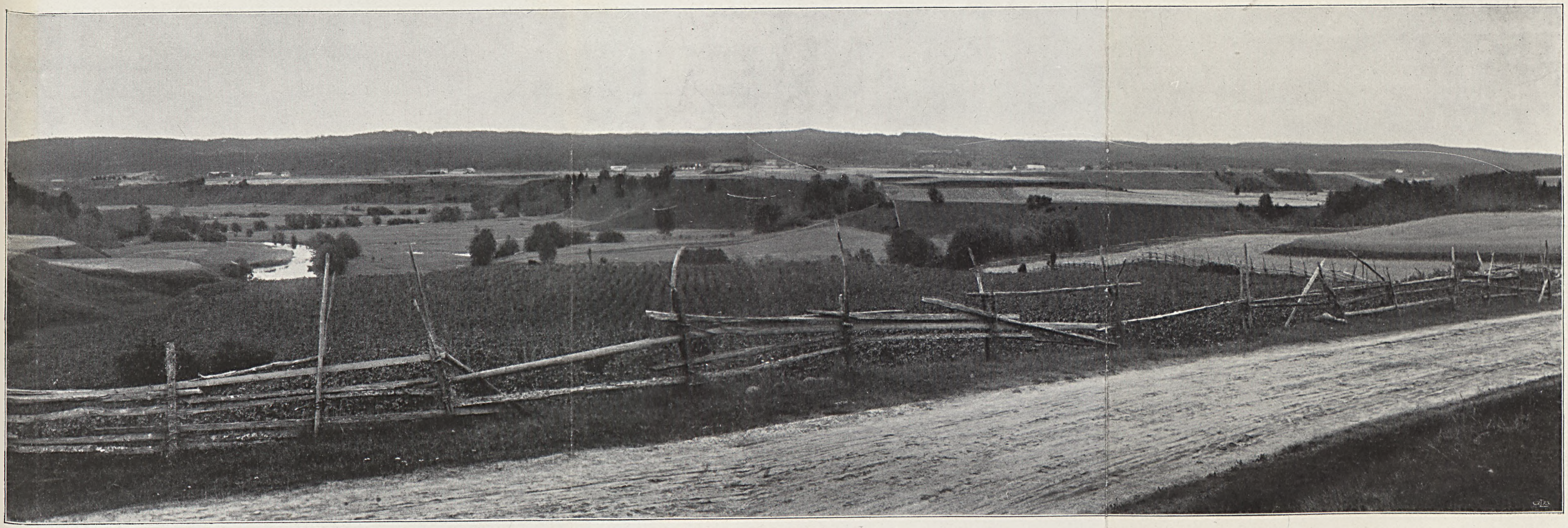

Fig. 7. A portion of *a valley train* eroded by the river Ätran. Between Dalum and Lena railway stations, N. of Ulricehamn, Westergötland. — Photo by the author.

As is evident from the map, several *branch-systems* joined the Ätran system as well as the other main-systems. Among these branch-systems there are principally two sorts, namely 1) *such as finally escaped from*, and 2) *such as were tributaries to the mainsystems.*

The former (1) were, properly speaking, at first independent, smaller systems, which, during the retreat of the ice-border, finally joined the main-system. In places such systems for a time assumed the character of outlets from the mainsystem. The other sort of branch-systems (2) commenced in a main-system and then, during a longer or shorter time, were tributaries to them. Sometimes, smaller parallel-systems finally and suddenly made their way into another one at a lower level, after a point of discharge had been opened by the retreat of the ice-border. Often the beds of such parallel-systems at first rose more suddenly than the beds of the adjacent main-system (cfr. the map's figures of the system E. of the Ätran system, N. of Ulricehamn).

In order to complete to some extent the picture of the late-glacial drainage-systems of S. Sweden, I may glance at some features of a few other districts.

The next main-system E. of that of Ätran is the ***Nissan system*** which commenced NE. of Halmstad. It had, like that of Ätran, a NE. direction and proceeded to the vicinity of Wartofta. Within this system some widely extended late-glacial lakes may be mentioned, in the first place one which may be called the *lake of Nissan* (Nissan-sjön), the sandy fields of which extend on both sides of the railway from Refteled to Gislaved and farther N. to near Nissafors.

The part of the system which HOLLENDER described as »Stråk-issjön» (the Stråken ice-lake), proceeding from the church of Bottnaryd in the S. as far as near Utvängstorp church in the N, is deserving of special notice. It will be somewhat more fully dealt with farther on and will be further explained during the excursion. The figures of the map illustrate the rise of different parts of the Nissan system.

Within the next main-system, ***the Bolmen system,*** we find, *inter alia*, the extensive lake region including the present lake Bolmen and, in connection with it, wide areas of gravel, sand, and clay. Towards the N. and NW. it was confluent with the lake Nissan and in the NE. with the next system, or ***that of Lagan.***

This system originates at Knäred, E. of the town of Laholm. A wide and marked valley was here originally filled with sandy and gravelly late-glacial deposits, which, however, have afterwards, during the elevation of land, been in part eroded. The plane of the deposits representing about the maximum surface of the late-glacial lake, is shown on fig. 8. From Markaryd the sandy and gravelly, in places also clayey, plane shows commonly a highly uniform rise towards the NNE. for a distance of about 170 *km*, viz. to the vicinity of the famous, isolated Mt. Taberg (S. of Jönköping). Hereabout the southernmost limit of the Wetter ice-lake commenced. For considerable distances the plane of that system is like a floor from which the slope of moraine resting upon Archæan rocks, generally rises more or less rapidly (see fig. 9). N. of Vernamo it is confluent with the Bolmen system. The rise of the Lagan system is also illustrated by figures on the map.

Farther to the East there were a great number of other main-systems some of which proceeded from the Baltic region. At this occasion we cannot, however, deal with them, not to make this paper too voluminous.

As regards the rise of three of these systems, viz. one proceeding N. from Karlshamn, another NNW. from Ronneby and farther on to Vexiö, and, finally, that N. from Karlskrona to Emmaboda, I may refer to the figures on the map.

Moreover an immense number of branch-systems existed, as is also seen on the map.

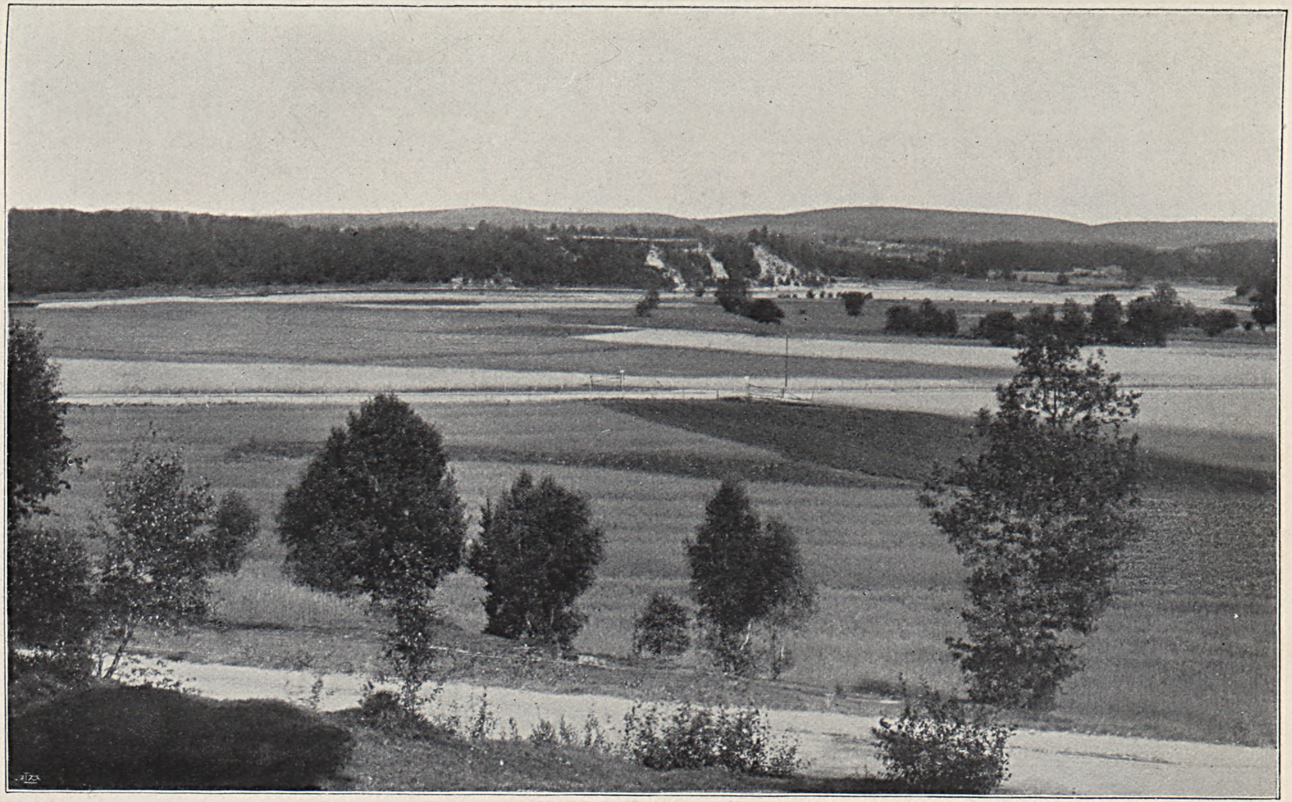

Fig. 8. *A valley train*, to a great extent eroded by the river Lagan. The plane is seen in the distance. At Knäred, E. of Laholm, Halland. — Photo by the author.

Fig. 9, showing the horizontal surface of *the valley train* below the moraine slope [to the left (E.)]. Near the railway station of Byarum, 27 kilometres S. of Jönköping, Småland. — Photo by the author.

As regards *the materials building up the late-glacial deposits mentioned*, the following remarks will suffice here.

The *gravel*, consisting of pebbles often of the size of a man's fist and very well rounded (see the pebble in the foreground, fig. 9) is commonly more or less mixed with coarse *sand*. These two sorts for the most part build up the widely extended lake- and river-deposits in question. The former are often regularly sedimented, but in places they show a cross-bedding, which, again, is more common in the river deposits. These strata are often many metres in thickness, chiefly when filling completely or in part marked and deep valleys.

The *clay* is commonly lamellated like ordinary glacial marine clay, the quantity of fine sandy particles, however, being much larger in the former, and, in consequence, the lamellæ of the fatty clay thinner.

No fossil remains at all have as yet been found in these ordinary late-glacial lake- and river-deposits.

Some features of the erosion of late-glacial deposits etc.

As the ice-border retired, the waters escaping from the ice eroded the above mentioned deposits to a greater or smaller degree according to the greater or less fall and quantities of the escaping waters, the occurrence and composition of underlying moraine or rock surface, etc. Sometimes, as in the province of Blekinge, the marked, old (in places pre-Quaternary) valleys, which were originally nearly filled with glacial and late-glacial gravel, sand, and blocks, are commonly cleared of those deposits, save more or less numerous large boulders, which now rest partly on the slopes and partly at the bottom of the deep valleys. This erosive work has presumably proceeded chiefly during late-glacial times, when the quantities of running waters were relatively abundant. Another instance of such an intensive late-glacial erosion is shown by the deep and narrow Stråken valley, which will be mentioned farther on.

While speaking of the hydrography of late-glacial time it is worth mentioning that *an inversion of the rivers* often took place, to which allusion has already been made. Since the ice-border had retreated to the northern end of a valley, the water N. of the waters-hed could run towards the North, etc.

As an instance may be mentioned the river Ätran, which now-a-days has its springs within the above mentioned branch-system on the high land E. and NE. of Ulricehamn and runs towards the N. to the vicinity of Wartofta. Here it takes a course nearly right opposite to its former one. Originally, however, the course was E. of Ulricehamn towards the South (see the map). Moreover, one can say that the ice-border has »attracted the rivers» farther and farther to the North, sometimes as far as within the true ice-lake district which would surely not have happened, if the quantities of water had not been so enormous.

More seldom the late-glacial erosion took place on the side of a pre-Quaternary valley, which had become filled to such a degree that the late-glacial stream was compelled to take another course.

The ice-lakes of Southern Sweden.

As in other countries where ice-dammed lakes have played a great rôle, as, for instance, in some of the well studied American glaciated areas, also within the northern parts of S. Sweden wide districts were, in the course of the retreat of the ice-border, covered with waters giving rise to a succession of temporary extensive ice-lakes with shifting outlets. Among those inland Swedish ice-lakes the so-called *Wetter ice-lake* assumed, during the lapse of time, the widest extent, gradually covering wide districts round the southern half part of the present Lake Wettern (see the map, Pl. 47). Moreover, the Baltic ice-lake had a much larger extent still. It will be accounted for further on in this paper.

The Wetter ice-lake. (Cfr. the map Pl. 47).

To judge from the gravelly and sandy planes round Taberg as well as E. and S. of Tenhult (SE. of Jönköping) the Wetter ice-lake may be thought to have originated within these districts, its highest marks of to-day being there about 245 *m* above sea-level. Marked erosion valleys to the South also indicate the routes of the outlets of the ice-lake there. Within the interjacent, lower districts those planes are only about 225 *m* above the sea. This indicates, in my opinion, that a lobe of the ice-border filled these lower districts right to the South of the marked Wetter basin, when the ice-lake commenced to escape at the sides just mentioned. As the ice retreated farther N. into the Wetter basin, the lake increased in size and for a time used this lowest pass. Because of the following rise of the pass, however, its surface was probably not lowered, since the highest marks more northerly reached also about 245 to 250 *m* above the sea. Towards the East the marks are found still higher, as at Barkeryd about 300 *m* (cfr. the map), probably depending on the fact that the ice-border, at its above-mentioned oscillation stage, caused the water to rise there to a relatively high level.

Later on, the outlet of the lake moved to the district WSW. of Jönköping, to the valley of Stråken. Moreover, two other passes were gradually opened here, the northernmost near Mullsjö (see further on). E. of these passes the highest marks of the lake are found to be about 250 *m* above sea-level, while the highest marks of the Stråken ice-lake near Mullsjö are at levels lower by about ten metres.

Subsequently, the Wetter ice-lake had, probably for a short time, its outlet through the valley ESE. of Härja church, and somewhat later it was confluent with the northernmost part of the Stråken ice-lake S. of Tidaholm, the highest marks being there about 250 *m* above the sea. (On the eastern slope of the marked mountain-ridge named Hökensås, the wide-spread gravelly and sandy planes deposited in an ice-lake sometimes reach a height of about 260 to even 275 *m*. Those highest deposits may be considered as formed in ponds, »nunatak lakes», locally and temporarily developed between the mountain slope and the ice-border to the E.)

About that stage the Wetter ice-lake changed its outlet towards the SW. and commenced to discharge into the Ätran system near Wartofta. During a long time, or while the ice-border was retreating from the vicinity of Wartofta towards the North to a line N. of Hjo to N. of Dala (WSW. of Hjo), a series of new and lower passes were laid bare, and over them the Wetter ice-lake discharged, until it was finally confluent with the Baltic ice-lake (see below). These stages of its history will be described more in detail in a more special part of this paper.

The Wetter ice-lake had a wide extent also E. of the present Lake Wettern. At an early stage it discharged a small part of its water into the Baltic in the vicinity of Eksjö, and later on, when the ice-border reached near Tranås, it again discharged into the Baltic, and, in consequence, its eastern shore became displaced in a westerly direction, or nearly to the water-shed between Nässjö and Grenna (see the map). Probably also a water-shed at a somewhat later time separated this drained-off district from that of the region E. of Grenna, where the highest marks of the ice-lake seem to be (according to Gavelin 1907) only about 220 *m* above sea-level near Adelöf, while those marks are found only about 205 *m* SE. of Grenna as well as N. of the Adelöf district (see the map). This level low relatively to that W. of Wettern (about 250 to 240 *m*) probably depended upon the upheaval of land having commenced earlier within the former regions.

Later on, before the ice-border reached the district S. of

Mt. Omberg, the Wetter ice-lake for a time probably discharged its water partly into the Baltic (SW. of Rinna?), partly also into the Kattegat (in the Dala district, see further on), its highest marks at that time being to the E. of Wettern probably about 160 *m*, and to the W. of the same lake about 170 *m* above sea-level (see the map).

Finally, when the ice-border reached the terminal line E—E., the highly reduced Wetter ice-lake proper really disappeared, since it was drained into the Baltic, the waves of which then for a time washed the eastern foot of Billingen.

Apart from the Wetter ice-lake and its different stages, only one somewhat greater and typical ice-lake is worth mentioning here, viz. the relatively small ***Åsle ice-lake*** within Falbygden, W. of the Wetter ice-lake.

Further information on both ice-lakes will be given in a subsequent chapter.

The Baltic ice-lake.

As alluded to before the Baltic, during the retreat of the ice-border, passed several stages, among which are also some ice-lake stages.

Apart from the oldest lake-stages of its westernmost districts, where the waters from the N. German »Urstromtäler» discharged into the Kattegat, the first great ice-lake stage commenced when the upheaval of the southern Baltic region had caused the isolation of the Baltic from the Ocean (by way of the Kattegat). This lake-stage, which was first alluded to by Nathorst (1894), seems to have continued, as already pointed out, until the ice-border melted away from the southernmost part of Lake Onega and allowed a partial drainage of the Baltic into the White Sea. Then the Baltic was changed again into an ice-lake, which had its outlet within the same Onega district. That lake-stage most probably continued during a much longer time than the preceding one, or until the ice-border had retreated to the northern district of Lake Wettern. Then the Baltic was again drained into the Ocean through the straits within the Karlsborg district.

The Baltic lakes of these times probably had a relatively wide extent within some districts of S. Sweden, as, for instance, NW. of Öland (see the map), since a marine relict Crustacean, *Limnocalanus marurus* G. O. Sars, has been found living as far inland as the present Lake Nömmen (S. of Eksjö), now 220 metres above sea-level, and, according to S. Ekman (1907), must most likely have immigrated in an active way, i. e. through the Baltic. During this stage probably an inconsiderable part of the Wetter ice-lake discharged into the Baltic near Eksjö, later on followed by the above-mentioned partial discharge at Tranås and, still later, by that S. of Mt. Omberg, when the Wetter ice-lake proper disappeared.

Then the Baltic ice-lake continued to grow larger towards the North etc. and finally reached its northernmost limit of that time, i. e. approximately along the northernmost terminal line (F_f) N. of Motala to Karlsborg to the northernmost part of Mt. Billingen. (See the map.) At this stage the Baltic probably for the last (or last but one) time during the late-glacial period came into connection with the Ocean.

The interesting question as to the complex and varying late-glacial stages of the Baltic mentioned above not having been raised until recently, there has not yet been time enough to work out many of the details bearing on it. That is, *inter alia*, the case with the exact determination of the uppermost Baltic shore-lines within different parts of S. Sweden, in the first place a distinction between the uppermost marine marks and those of the lake-stages. As the former are partly to be sought at lower levels than the latter, they probably have been destroyed or hidden during the transgressions of the younger Baltic lakes.

The rise of the Baltic to the above-mentioned Nömmen district may possibly have taken place by two separate routes (see the map), since planes of sand and gravel rise there equally inland, speaking in favour of the correctness of the hypothesis. This relatively high level of the Baltic most likely depended partly upon the general land-depression, partly also upon the upheaval of the outlet of that time (within the Onega district?), causing a comparatively great rise of the lakes' surface towards the retreating ice-border as well as over the adjacent land districts. Further to the N. and NE. the uppermost limit of the lake again declines, being to-day near Tranås about 165 metres, from Mjölby to Ödeshög about 150 metres, and near Karlsborg 153 metres above sea-level. N. of Motala the same limit is found at a somewhat higher level (162 metres above the sea), which was due to the greater depression of land there than more southerly. (Cfr. the map figures, referring to the surface of the Baltic ice-lake.)

At last, when the Baltic came into connection with the Ocean within the district of N. Billingen, *the true marine limit again commenced to form* and, because of the continued centripetal upheaval of land, the sea probably had approximately the extent shown on the map, Pl. 47. The shore of that time probably coincided with that of to-day at the northern part of Öland. As to the probable character and amount of the elevation of land of that time I may refer to the map, Pl. 46, A, showing, *inter alia*, the isobases of a somewhat older stage, continued by isocatabases further to the South. The isobases within the districts E. and W. of the northern parts of Lake Wettern are drawn according to the figures given by G. De Geer (on the map, S. G. U. 1910; 130 metres near Norrköping, 120 metres N. of Lake Roxen, etc.), and by H. Hedström and A. Gavelin (about 130 metres N. of Karlsborg). Probably, the marks of the marine limit are now NNW. of Mösseberg in Westergötland about 131 to 132, and farther N. (W. of Öglunda) about 137—140 metres above sea-level, i. e. about twenty metres lower than was previously thought.

Notes on the outlets and deposits of the lakes.

The ***outlets of the ice-lakes*** are generally, in a higher degree than those of the ordinary lakes, represented by marked erosion valleys and ravines, which will be in greater detail exemplified further on. From the situation of these valleys, at lower and lower levels, and from the elevation waves, proceeding in a centripetal direction, it is evident that each ice-lake, the extent of which is shown on the map, did not reach its maximum extent at one and the same time, their southern parts being the older which gradually disappeared when the more northern ones commenced to develope.

The ***deposits of the ice-lakes and the Sea*** are of about the same sort and character as those of the ordinary late-glacial lakes mentioned above, viz. *gravel*, *sand*, and *laminated clay*, as well as *transition forms*. Also the morphological development is, on the whole, the same, except that in the ice-lakes as well as in the sea, gravel and sand in places became heaped as *marginal plateaus*, which appears, on the contrary, not to have been the case in ordinary late-glacial lakes, probably because of their shallower waters. Several of those plateaus, known at present, are to be found on the map, the figures denoting their surface height above sea-level. As pointed out previously, these plateaus indicate approximately the level of the old waters, having been gradually deposited almost to the very surface of them. The position of these plateaus within the marine districts contradicts, as G. De Geer has shown (1909 and previously), W. C. Brögger's opinion that the land (within the Kristiania district etc.), when the ice-border retreated, had a relatively high level and afterwards sank.

Notes on the immigration of the faunas and floras in the lakes, the Baltic, and on land.

In the ice-lakes' deposits *no remains of organisms* have hitherto been found, save a leaf of *Salix polaris* within a submorainic clay in the vicinity of Jönköping (at »Rosenlunds bankar», see the geological map-sheet of »Jönköping» and the explanation to it). From our knowledge of the late-glacial lacustrine flora and fauna, found in clayey deposits of ponds etc. in other districts of S. Sweden, it is, however, evident, that arctic-alpine plants and animals were not very rare during the time in question. This may also be concluded from the rise of the temperature having been relatively considerable early enough to keep the extensive ice-sheet in ablation. Probably, therefore, the marginal portions of the ice-sheet, when in retreat within S. Sweden, had at times approximately the character of a plant-bearing belt, though not to such an extent as those of Alaska now-a-days.

The extensive waters of late-glacial times must have played a great rôle in spreading the water-plants and water-animals, in the first place some fishes (such as several species of *Salmo*, *Coregonus lavaretus*, *C. albula*, etc.).

During the Baltic ice-lake stages also the *marine relict fauna* spread widely, as is evident from the occurrences of the above-mentioned *Limnocalanus macrurus* also in the present lakes Nömmen and Mullsjön (near Hjo), etc., i. e. within districts *which were never reached by the Sea directly, but only indirectly by the rising Baltic ice-lake.* As to the marine fauna in other respects, it deserves to be mentioned that *Gadus saida* (= *G. polaris*) occurs in glacial clay at Lomma (N. of Malmö in SW. Skåne), which clay possibly is late-glacial in age. Probably also *Limnocalanus* and some other marine species (*Zanichellia polycarpa* etc.) immigrated to the Baltic of that time. More probably several other marine organisms, such as some *Diatoms* and others, found in a sandy bed between the true late-glacial clay and the Ancylus-deposits at Kalmar (N. O. Holst 1899) and at Wiborg in Finland (A. G. Nathorst 1894), immigrated during the existence of the above-mentioned strait of Onega. Later on, when the connection between the Atlantic Ocean and the Baltic took place across the northern parts of S. Sweden, most probably the before mentioned true relict fauna (*Cottus quadricornis* and *Gammaracanthus*), now living in Wettern etc., immigrated to this and other Baltic districts, while *Yoldia*, a few *Foraminifera*, *Cytheropteron montrosiense*, *Phoca groenlandica* as well as a scanty flora of *marine Diatoms*, found at Skattmansö NW. of Upsala (NATHORST 1893) in a transition layer like that at Wiborg and Kalmar, immigrated through the straits of Närke to the Mälare valley (*inter alia* at Stockholm). Moreover, the immigration of some of the organisms mentioned most likely took place during different marine stages of the late-glacial evolution of the Baltic.

The late-glacial marine faunas of Western Sweden has not yet been described in detail, but a review of its development is recently (G. F. F. 1910) given by G. DE GEER. Here it need only be mentioned that the number of species as well as the size of them, on the whole, diminish from the western districts towards the eastern ones, only one molluscan species, *Yoldia* (*Portlandia*) *arctica* (a small form) having been met with as far towards the East as at Skara, together with a few *Ostracoda* and *Foraminifera* (MUNTHE 1901). Until recently no traces of fossils having been known within the large district between Skara and the Mälare valley, it is of interest that some bones of *Gadus æglefinus* LINNÉ have recently been found in a glacial clay near the church of Bellefors, about 25 kilometres NW. of Karlsborg on the Wettern (see MUNTHE 1910 b).[1] *This poverty in fossils within the districts in question is, without doubt, in the first place caused by the immense quantities of*

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[1] This marine stage of the Baltic possibly did not last fully until the ice-border melted away from the oldest strait of the province of Närke, since a find of *Dryas* in calcareous tufa a few metres above the surface of Lake Wettern (NATHORST 1886) indicates that also here a rapid upheaval of land proceeded, shortly after the ice-border had melted away.

fresh-water discharging into the sea from the wide-extended glacial lakes, principally the ice-lakes, and then, of course, also the Baltic during a later stage.

The postglacial history of the Southern Baltic may be elucidated only by the following data.

As alluded to before, the Baltic during the older part of the postglacial epoch had the character of an inland lake, *the Ancylus Lake.* That was fully proved from the occurrences in Estland and in Gotland of gravelly and sandy beaches which are in an open situation towards the Baltic and, therefore, have been deposited at the old shores of this water, and, moreover, contain in part a true freshwater fauna with *Ancylus fluviatilis*, several species of *Pisidium*, etc. (For fuller informations see MUNTHE 1910 a.) Besides, *Limnæa ovata* forma *baltica* and other forms which live also in brackish water of to-day are common in these deposits. Later on, such deposits have been met with in Öland (by G. HOLM and myself 1888), near Upsala (cfr. J. P. GUSTAFSSON 1909), in Närke (by J. V. JONSSON, cfr. MUNTHE 1909 a), and, besides, clayey deposits, formed in the Ancylus Lake, have been described from Upland in 1893 (by myself and, more in detail, by NATHORST), from Finland [by NATHORST (1894) and others], from other districts of Sweden, as from Norsholm near Norrköping (by myself 1895) and from several other places, especially in E. Småland and Blekinge (chiefly by HOLST 1899).

Within the clayey deposits of the Ancylus Lake P. T. and A. CLEVE found a great number of *Diatoms*, some of them being characteristic of the deposits of the open Ancylus Lake, such as *Eunotia Clevei* GRUN., *Navicula patula* W. SM., etc.

In addition to the above-mentioned fossils as well as several other molluscs etc., there are found some vertebrate animals in the Ancylus deposits, viz. *Halichoerus grypus* O. FABRICIUS, *Phoca foetida* O. F. MÜLLER, *Cottus quadricornis* var. *relicta*

LILLJEB., *Coregonus lavaretus* LINNÉ, and *Lota vulgaris* JENYNS. Also some *Ostracoda*, *Cladocera*, *Cristatella mucedo*, etc. are met with. Evidently this lake played a great rôle in spreading the fresh-water animals and plants.

As pointed out previously the Ancylus Lake originated, when the latest marine strait in Närke was uplifted above sea-level. Within the southern Baltic districts and adjacent countries the land had a much wider extent then than now-a-days (see the isobases and isocatabases of that stage, Pl. 46 B), Gotland being probably a part of the Continent reaching northwards from N. Germany. (See MUNTHE 1910 a.) The lake having for a time discharged its water to the Ocean across Närke, its surface later on rose in consequence of the gradually more intensive elevation of land in the N than in the S, and, at last, another outlet arose near Karlsborg. Yet later, after a subsidence of land had possibly commenced within the peripheric regions of the old depression area, the outlet was transferred to Öresund. — During this transgression the Ancylus Lake gradually reached its uppermost limit later in the southern areas than farther to the North.

That subsidence of land finally resulted in the before mentioned connection between the Ocean and the Baltic which was changed to the relatively salt inland sea, *the Litorina Sea*. During the saltest stages the fauna and, in consequence, the surface saltness from the innermost parts of the sea to Skåne had about the same character as now-a-days between Bornholm (with about 0.8 per cent of salt) and Warnemünde (1.24 per cent of salt), since *Litorina rudis* var. *tenebrosa*, with its innermost occurrence now-a-days at Bornholm, has been found fossil about 50 metres above sea-level within the innermost part of Bottenviken, and *Scrobicularia piperata*, now not living farther in than Warnemünde, then lived in northern Gotland (with about 0.7 per cent of salt to-day). (Cfr. MUNTHE 1894.) Several other facts speak also in favour of this conclusion, as, for instance, the relation between the fossil and recent distribution of some species of *Rissoa* (*R. inconspicua*, *R. interrupta*, and *R. parva*), some higher plants (*Zostera*), *Diatoms*, etc. Moreover, the size of *Mytilus edulis* etc. shows the same, fossil specimens of about the size, which the species now reaches at Rügen, having been found as far towards the North as Skellefteå (65° N. lat.). (See also MUNTHE 1910 a.)

Besides the species mentioned above the comparatively scanty Litorina fauna of the Baltic shores of Southern Sweden contains some other molluscs, viz. *Tellina baltica*, *Cardium edule*, *Hydrobia ulva*, *Litorina litorea*, and *Neritina fluviatilis* forma *litoralis* [at first probably a freshwater form, now living as far towards true marine districts as the middle part of the Öresund (with a per cent of salt of about 1.5)]. Several vertebrate animals (as *Halichoerus*, *Phoca groenlandica*, etc., *Bothus maximus*, *Gadus callarias* and *G. æglefinus*, etc.), some *Ostracoda* and *Foraminifera* as well as *Spirorbis spirorbis*, a great number of *Diatoms*, etc. also then lived in the Baltic. (See MUNTHE 1910 a).

On the contrary, the postglacial marine fauna of Western Sweden was much richer in species than that of the Baltic Litorina Sea and includs such southern species as *Tapes decussatus* etc.. As to the isobases of the Litorina and Tapes Seas cfr. the map, Pl. 46 B.

When the transgressions of the Ancylus Lake and the Litorina Sea reached their maximum, marked beaches of gravel and (or) sand were heaped and erosion terraces formed within many parts of Southern Sweden, chiefly in the isles of Gotland (see MUNTHE 1910 a) and Öland. Beneath these beaches fossiliferous layers of supramarine lacustrine deposits [peat, gyttja (mud), lake-marl, etc.] have been found, the fossil plant and animal remains of which indicate the sequence of immigration of the supramarine flora and fauna in correlation to the different stages of the Baltic and the Seas of Western Sweden. Those deposits have a much wider distribution and have, therefore, been studied more in detail within districts not reached by the waters in question, as is, of course, the case also with similar deposits younger than the Litorina and Ancylus limits.

In the following pages I shall give a somewhat fuller view of *the evolution of the late-Quaternary land flora and fauna of Southern Sweden* than that shown from the diagram, page 1211. For still fuller information as to the flora in the first place references may be made to papers by A. G. NATHORST, GUNNAR ANDERSSON, R. SERNANDER, T. HALLE, L. VON POST, MUNTHE, and others.

During the late-glacial time an arctic-alpine flora (with *Salix polaris*, *Dryas octopetala*, some water plants, etc.) and fauna (*Ursus* cfr. *maritimus*, *Rangifer*, *Alca impennis*, *Apus glacialis*, *Pisidum Lovéni*, etc.) immigrated. The mean July-temperature probably changed from about 6 to 9° C.

At the begin of the Ancylus time such forms as *Populus tremula* and *Betula* »*alba*» occurred together with many water plants etc., and, a little later, *Pinus silvestris* immigrated. The number of fresh-water molluscs increased largely and also some land-forms appeared, such as *Pupa muscorum*. Among the vertebrate animals probably *Castor fiber*, *Cervus alces*, etc. were common. July-temperature about 10 to 13° C.

Soon enough *Corylus avellana*, *Alnus glutinosa*, etc. immigrated, and, a little later, *Tilia europæa*, *Quercus pedunculata*, etc. clothed the more fertile places. The July-temperature in the meantime rose from about 14 to about 17° C. At a somewhat later stage, *inter alia*, probably also *Trapa natans* immigrated to Skåne and gradually farther to the North. A great number of land-molluscs etc. and several mammals appeared, such as *Bos primigenius*, *Bos bison*, *Sus scrofa ferus antiquus*, *Cervus elaphus*. Among other animals *Emys lutaria* migrated as far towards the North as Norsholm (near Norrköping). Probably even *the Palæolithic man* then appeared also in Southern Sweden, since a finely wrought bone-implement has been found in Ancylus clay at Norsholm (MUNTHE 1895). Later on, HOLST (1909) dated to the Ancylus time some Palæolithic implements found in Skåne. From a somewhat later time we know culture layers (partly found beneath the present sea-level) in Skåne, which are to be dated to the latest stage of the Palæolithic age of North Europe. (KJELLMARK 1903).

During the »transgression» of the Tapes-Litorina Sea the amelioration of the temperature proceeded, allowing such southern forms as *Trapa natans*, *Hedera helix*, etc. and, among the land-molluscs, such as *Pupa moulinsiana*, *Clausilia plicata*, etc. to spread into Southern Sweden. The temperature optimum of the postglacial time probably coincided approximately with the maximum extent of the Tapes-Litorina Sea, being then about 18 to 18.5° Celcius as to the month of July, towards 16° C. to-day. *Quercus pedunculata*, *Tilia*, *Fraxinus*, *Acer*, *Ulmus*, as well as several of the previously immigrated species, as *Corylus*, *Pinus* now dominated. Among the mammals *Cervus elaphus* etc. probably had a much wider extent then than to-day.

During the regression of the Tapes-Litorina Sea, *inter alia*, *Picea excelsa* and *Fagus silvatica* immigrated, the former (from Finland) to the northern part of Southern Sweden and to Norrland, the latter from the South (Denmark). During this post-Litorina time the mean temperature probably was decreasing gradually, or without more important interruptions, to the present time, the mean July-temperature of Southern Sweden being about 16° C. I cannot agree with SERNANDER and others, who are of opinion that the temperature optimum was reached as late as during the Bronze age of Southern Sweden, an opinion for which no conclusive evidence has as yet been furnished.

3. The Late-glacial development of Falbygden in Westergötland and adjacent districts.

The late-Quaternary development of Southern Sweden having been reviewed above, I will give a somewhat more special account on some districts which are to be visited during the excursion, viz., in the first place, that of *Falbygden*. For this purpose it may be appropriate first to give a review of the rock-ground there and its relation to the leading topographical features.

a) Westergötland.

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The topographic map-sheet of »Skara». Scale 1 : 100 000. Price 0.50 kr.

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2—4. Munthe, Henr.: The geological map-sheets of »Sköfde» (2), »Tidaholm» (3), and »Falköping» (4) with explanations. S. G. U., Ser. Aa, N:is 121, 120, and 125. Stockholm 1905 and 1906. Scale 1 : 50 000. — Price 2 kr. each.

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A view of the relation between the rock-ground and the topography.

Within the districts of Westergötland which will be visited during the excursion the rock-ground is built up partly of *Archæan* and partly of *Cambrian-Silurian rocks*. (Cfr. the map in MUNTHE 1, cited above.) The Archæan rocks consisting for the most part of *gneiss* and to a less extent of *granite* etc. form a low and wide denudation plain being the basement for the once wide-extended Cambrian-Silurian strata of which only a scanty part remains now-a-days. Farthest SE. on the map cited, granite is the dominant rock, rising to a broad mountain ridge, named Hökensås.

The *Cambrian-Silurian complex* is, from older to younger strata, built up chiefly by *sandstone*, *alum shales*, *Orthoceras limestones*, *Chasmops limestone*, and a series of *Trinucleus* and *Rastrites shales.* Above this last mentioned strata rests a covering of *diabase*, probably intrusive and late Silurian in age. (Cfr. MUNTHE 1, fig. 2, p. 11, etc.)

As is shown from the map cited (as well as from its figures and curves for every 30 *m*) the lower part of the Cambrian-Silurian series ascends more or less rapidly from the Archæan lowland to the Orthoceras limestones, which form wide plains, upon which a number of isolated mountains, representing the upper parts of the complex, arise, viz. (from the North to the South) Mts. *Billingen* with *Brunnhemsberget*, *Hvarfsberget*, *Gerumsberget*, and *Mösseberg* being the most important, whilst *Borgundaberget*, *Plantaberget*, and *Ålleberg* belong to the smaller ones. [1]

Of a special interest is that the whole Cambrian-Silurian series is cross-cut within the area now obtained by the Åsle-valley just mentioned.

[1] The Cambrian-Silurian district S. of Billingen—Brunnhemsberget is commonly named *Falbygden*, which is (by the marked and deep *Åsle valley*) divided into »*East-Falbygden*» and »*West-Falbygden*».

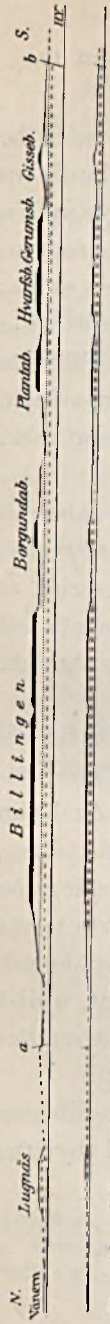

Fig. 10. *Schematic sections illustrating the orography of the rock-ground from Lake Wenern towards the South across Mts. Billingen and Falbygden.* The streaked line = the surface of Archæan rocks; the dotted line = the boundary between the Cambrian and Ordovician series. Black (at the top of Billingen etc.) = diabase. At *a* and *b* fault-lines. Scale of length and height is 1 : 400 000, apart from the height of the upper section which is three times as much as that of the lower one. (From MUNTHE 1.)

As appears from the map cited as well as from fig. 10 the surface of the Archæan rock-ground rises slowly towards the South and the same do the Cambrian-Silurian strata with their covering of diabase.

To the West of Billingen—Falbygden runs a *line of dislocation* (see MUNTHE 1, the map and fig. 8, p. 382), which is more prominent northwards, indicating a sinking of the earth's crust E. of the line in question. Other dislocation lines, but of smaller size, run along and also across the district.

That sinking of the earth's crust together with the occurrence of the hard diabase bed have been the most important causes why the Cambrian-Silurian strata are still preserved here. Their extent now-a-days is, however, due partly to the work of erosion during post-Silurian (pre-Quaternary) times, many features of the sculpture of the mountains being caused by glacial and late-glacial erosion, as will be evident from the following account.

Quaternary phenomena and deposits.

Within the district now shortly glanced at *the land-ice motion* has gone chiefly from NNE. to SSW., local orographic features having caused the deviations observed.

The ordinary *bottom moraine*, laid down chiefly during the latest stages of advance of the land-ice, is of no special scientific interest. In the Silurian districts and SSW. of them it has the character of a boulder-marl (»moränmärgel» in Swedish), within the Archæan ones in E. and W., however, that of a gravelly till (»morängrus» in Sw.).

By far the largest interest from the present standpoint offer the deposits accumulated at or a little outside the margin of the receding land-ice during its last great ablation epoch, owing to the fact that the recession of the ice-border was a) *interrupted by stages of pauses* or even of *readvances* accompanied by halts and b) *commonly took place not on land but*, within the lower parts W. of Falbygden - Billingen, *into the Yoldia Sea*, *and*, E. of the district in question, *into ice-dammed lakes*, in places also *in ordinary late-glacial lakes.* For this reason deposits of assorted and rounded gravel and sand are the most notable and characteristic accumulations here within the old terminal belts of the ice, whilst, at a distance, fine sand and laminated clay were deposited into the waters mentioned.

The glacial deposits in question belong chiefly to the following classes, which, however, are not distinctly separated

1. Subglacial deposits (stratified): *oses proper.*
2. Marginal (or in part terminal) deposits (stratified): *kames*, *marginal oses*, *marginal plateaus*, *pitted plains* (kittelfält in Swed.) p. p.
3. Terminal deposits proper:
   a) *Chiefly unstratified: terminal moraines.*
   b) *Stratified* (in part extra-terminal): *valley trains* (dalfyllnader), *outwash plains*, *pitted plains* p. p., etc.

Moreover, extra-terminal glacio-marine and glacio-lacustrine deposits (chiefly laminated clay and sand) play a pretty great rôle within some of the districts in question.

It may be remarked that many of the above enumerated deposits often show a great complexity both as to the form, position, and stratification, and that transition and mixed forms are common.

As to the *postglacial deposits* to be seen in Westergötland, a relatively complete series of *calcareous tufa with mould-lamellæ*, rich in plants and shells of land-molluscs, will be visited at Skultorp.

I. »Valle härad» to Hornborga, SE. of Hornborgasjön. (Cfr. the geological map-sheet of »Sköfde» with explanation. See especially the topographic map, on the scale of 1 : 50 000, at the end of this explanation.)

By »Valle härad» (Valle hundred) is meant the belt of land, about three kilometres in breath, which extends NNE. of Hornborgasjön (the lake of Hornborga) between Mt. Billingen in the East and the dislocation line in West. Towards N. it reaches about as far as the N. end of Billingen. The belt includes, more particularly, an interesting and typical wide *kame-landscape*, crossed by *chiefly one os* running about NNE. to SSW. Moreover, some *pitted plains* and *outwash plains* as well as *terminal moraines* and *marginal oses* are met with. All these quantities of glacial and late-glacial deposits are heaped in a trough-shaped depression probably with Cambrian sandstone as a basement. Most of these Quaternary deposits form a hilly, in part mammillated, landscape, including numerous (one says 365) lakelets of varying size, shape and depth (cfr. fig. 24, p. 91 in the explanation), and the hills being clothed by a leaf-wood flora the landscape often offers pretty views; in places Mt. Billingen is seen rising in the distance with its dark, perpendicular diabase steeps.

The materials of these glacial deposits mostly consist of Cambrian sandstone and alum shales as also of Archæan rock-fragments, etc., the alum shale causing, when weathered, the impure character of the deposits.

While the direction of the os, as is said before, is from NNE. to SSW., the numerous kame ridges run in all directions. Sometimes, however, a direction from NE. to SW., or even E. to W., is predominant. In places isolated knobs of gravel rise lofty above the ordinary landscape.

The great number of depressions here are filled partly with water, partly with peat resting upon lake-marl etc.

The route of the excursion is intended to run as follows. From *Axvall* towards NE., passing the church of *Skärf*, to N. of *Eggby* church; then towards E. to *Öglunda*, SSW. to *Ulunda*, and W. passing *Lundby* church.

At *Axvall* a wide terminal (outwash) plain extends, forming the drill-ground of Axevalla (Axevallahed), the surface of which gently rises towards the North, from about 127 to 134 metres above sea-level. Here in the North *inter alia* a marked hollow, certainly after a melted ice-block. Besides, some shallow depressions running about N. to S. cross parts of the plain. They are, most likely, erosion phenomena from the time when the plain was uplifted to and above sea-level. Probably the marine limit nearly coincides with this higher part of the plain (about 134 metres above sea-level). Near the church of Skärf there is a small kame-landscape, and farther N. the »feeding esker» belonging to the Axevalla plain is to be found. At *Sjötuna* as well as S. and N. of it a steep of Archæan hills marks approximately the fault-line mentioned above.

N. of Lake Skärflången another wide gravelly and sandy plain extends, at Tokatorp limited by a marked terminal moraine ridge running WSW. to ENE. and passing N. of Lake Emten etc. SSW. of this lake the surface of the terminal plain is about 137 metres above the sea.

Further to the E. the northern part of this plain is dissolved in a number of marked gravelly marginal ridges with interjacent depressions. An os is seen crossing Lake Emten. Also funnel- and kettle-shaped depressions are to be found here. (Cfr. fig. 11.)

Near *Öglunda church* as well as S. of it sandy and gravelly plains are 150 *m* and more above the sea. They have, probably, been formed within more local lakes between the ice-sheet and the rocky slope to the W. W. of the road also drumlins are to be seen.

At *Snickaregården* a part of the more typical kame-landscape will be visited (see fig. 12).

E. of the way to Warnhem we pass a number of marked gravelly ridges belonging partly to the kame-landscape, partly also to the os. NW. of Skarke a lofty knob of gravel will be visited.

S. of Warnhem a considerable, more irregular hill forms the southern limit of the kame-landscape. To the North of this hill a little »feeding esker» is developed. It is likely that the masses of gravel etc. building up this hill are deposited not into the sea, but a little inside the margin of the land-ice and, therefore, have got its knobby shape in stead of that of a marginal plateau or an outwash plain. Or, otherwise, it is a true terminal deposit partly corresponding with the *marginal oses* farther to the W. One of these oses, that W. of N. Lundby church, rests upon layers of glacial clay (see fig. 18, p. 76 in the explanation to the map-sheet of »Sköfde»), which indicates a re-advance of the ice-border from an originally more northern line. As AHLMANN has recently (1910) established a number of at least fifty layers are deposited here, each one probably representing the deposition of one year. From this it is evident that a pretty considerable oscillation of the ice-border had taken place here. Also 12 kilom. farther to the N. a similar section is described by AHLMANN. Whether these phenomena are to be referred to more than one oscillation we cannot yet say.

S. of this terminal line extends a wide plain of moraine(?), in places (see fig. 27, p. 96 in the explanation to »Sköfde») with funnel-shaped depressions (»Sölle» in German), and then follows

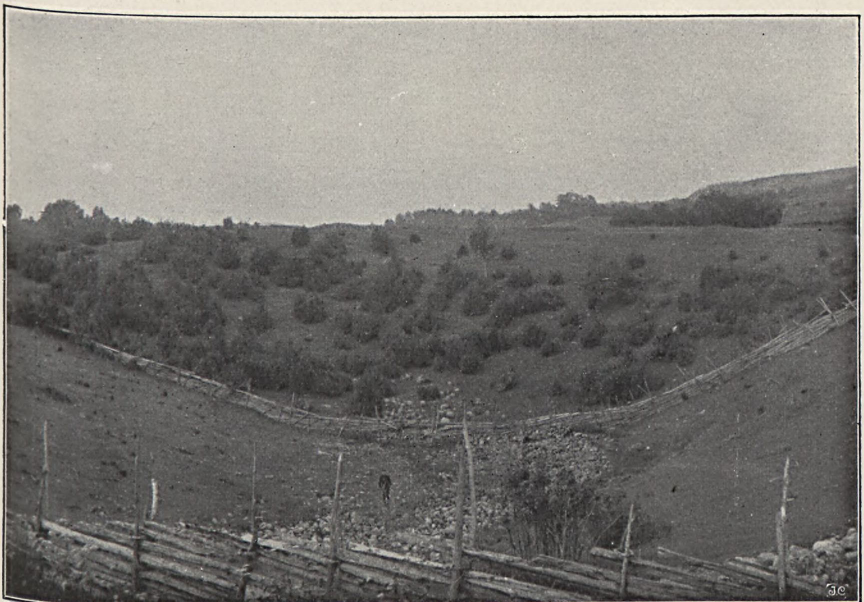

Fig. 11. *A kettle-shaped depression* near Öglunda church. — (From the explanation to »Sköfde».)

Fig. 12. A typical *kame-landscape*. At Snickaregården, S. of Öglunda church. (From the explanation to »Sköfde».)

Fig. 13. *A drumlin.* W. of Mt. Billingen. — (From the explanation to »Sköfde».)

Fig. 14. Section illustrating *the material in a drumlin.* W. of Mt. Billingen. (From the explanation to »Sköfde».)

the wide and shallow Hornborgasjön, a lake typical of our Cambrian-Silurian districts.

Axvall to Hornborga village. W. of that lake during the journey to Broddetorp we observe a belt of mostly marked ridges. They are built up chiefly by the same (but unstratified) material as the kame ridges but may be looked upon as *drumlins*, since all ridges run N. to S. and many of them have the characteristic shape of a whale-back (see fig. 13 and 14).

As regards the continuation of the excursion from Hornborga to Valtorp and Sköfde see farther on after the account of the Falbygden district.

Falbygden.

As stated above the Wetter ice-lake, in the course of the retreat of the ice-border within the district East of Falbygden and Billingen, gradually replaced the ice there. In the meantime, from having its outlet towards the South, within the district previously occupied by the Stråken ice-lake (see the map, Pl. 48, where this outlet is denoted as N:o I), the Wetter ice-lake moved its outlets to the West, across East-Falbygden, a series of new passes of discharge being there gradually laid bare, in part at lower and lower levels. However, they have not yet been mapped in detail, safe the most important which may, therefore, be mentioned here.

II. The oldest of these outlets, ***the Kymbo outlet***, denoted as n:o II on the map, arose when the ice-border nearly reached the line of the *Vättak marginal plateau* (NE. of Kymbo; see the map). This outlet passed Kymbo and Yllestad, where it got a SW. direction. The pass having before, within the Stråken district, been about 240 to 250 metres above sea-level, was then lowered from about 240 to 235 metres.

This outlet existed until the ice-border reached S. of Hångsdala.

III. At that time a new treshold, that of the ***Näs outlet,*** became free, allowing the water to escape here at Näs and to join, farther to the SW., the south-western part of the outlet valley II.

The pass of the Näs outlet is, N. of Näs church, about 230 metres above sea-level.

In the meantime, as well as afterwards, streams escaping from the ice in retreat eroded within the district SW., W. and NW. of Kelfvene (see the map) giving rise to some valleys, which later on, when the ice-border reached the northern part of Gisseberget, served for outlet-valleys for the next stage, or

IV, the Gerum outlet, which passed Skörstorp and W. of Kelfvene etc. In consequence of the rising of land in a south-northerly direction the surface of the ice-lake then was again at about 240 metres above the sea in the vicinity of the church of Ö. Gerum etc., where the pass seems to have been situated for a long time.

Probably, the continuation of this outlet a little later changed its place to the valley NW. of Orreholmen, here about 220 meters above sea, and then to another valley, viz. that NW. of Skörstorp, being about 225 metres above sea-level.

These latter valleys, probably in the first place the southern one, were for a long time the site of the outlet of the Wetter ice-lake, or until the ice-border had retreated to

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[1] When speaking of a pass etc. having been, for instance, 240 metres above sea-level, I mean that those phenomena are *now-a-days* found at the levels in question. What level above the sea those places really had when in course of formation might, at a rough estimate, be inferred from a comparison between the marine isobases of late-glacial time and the different places in question, the latter being in late-glacial time, on the whole, gradually at lower levels towards the North. (See the map, Pl. 48.)

Fig. 15. The NE. part of *the Tiarp valley*, between Hvarfsberget (to the left) and Plantaberget (to the right). Looking from Brissmestorp towards the SW. — Photo by the author.

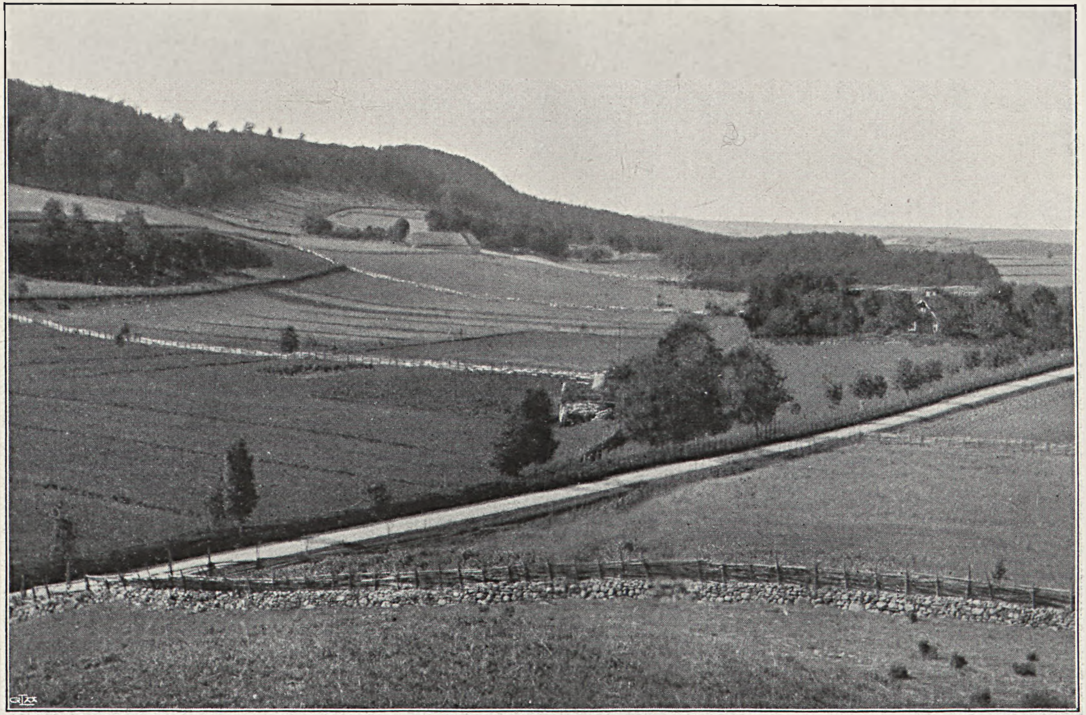

Fig. 16. *The Planta outlet.* To the left the northern slope of Plantaberget. At × an erosion terrace about 215 *m* above the sea. Looking W. from near Vådeg.
Photo by Sven Hammar. Skara.

the northernmost part of Hvarfsberget. This is also proved by the marked and deep valleys, eroded into alum shales and sandstone, which are met with NW. of the mouths of these two outlets, but on a lower level.

V. The lake at this stage discharged its waters through the important pre-existing ***valley of Tiarp,*** between Hvarfsberget and Plantaberget (see fig. 15), SW. of which, near Nya Åsle etc., deep and marked erosion valleys into alum shales and, to a less extent, into sandstone, indicate that also there great quantities of water escaped from the Wetter ice-lake during this stage. The pass of the outlet is about 225 metres above sea-level, while the uppermost marks of the ice-lake are met with at about 238 metres. A lowering of the lake's surface of about 13 metres, therefore, took place during the existence of this outlet, i. e. until the ice-border reached the northern part of Plantaberget (see the map).

VI. As regards this outlet, denoted as ***the Planta-outlet,*** and the following sub-stages, until ***the northern Dala-outlet, VII,*** was reached I will give a somewhat more special account in referring to the map, Pl. 49.

The Dala district. This district can shortly be characterized as a plain of Orthoceras limestone (about 180 to 185 metres above sea-level), within its western parts replaced by alum shales (about 170 to 160 metres above the sea). Towards the E. the ordinary eastern slope of Falbygden adjoins, E. of which the Archæan region extends (about 150 to 130 metres above the sea). Upon the limestone plain arise a series of hillocks of varying height and length and extended principally in a SW.—NE. direction. Most of them are terminal moraines, but in places is observed a nucleus of Orthoceras limestone, in NW. replaced by alum shale. These *terminal lines* are about eight in number (see the map, Pl. 49, where denoted as 1—1 to 8—8).

During the retreat of the ice-border this district was gradually overflowed by waters from the Wetter ice-lake, which eroded the originally more extended hillocks of rock and moraine, etc. to the above stated extent.

As appears from the map, the relation between the pauses of the ice-border, represented by the terminal moraines just mentioned, and the erosion valleys to be described is about as follows.

1—1. During the oldest stage of pauses of the ice-border here, the above-mentioned Planta outlet (VI) was developed.

From having previously (at the Tiarp outlet) been at a height of about 225 metres, the level of the ice-lake was gradually lowered to about 214 à 215 metres above the sea. This is evident from the erosion terraces in the NE. part of Plantaberget and in the southern slope of the valley in question, in some places worked out into limestone (cfr. fig. 16). The pass in the valley now being about 203 metres above sea-level, the erosion, therefore, lowered the outlet (and the surface of the ice-lake) here about eleven metres during that stage. The bottom of the valley declines slowly towards W., being near Skogastorp about 192 metres above the sea. Then a series of small steeps, only a couple of decimetres in height, represent the latest traces of this erosive work within the westernmost end of the valley (*a* on the map). Below this latest cataract the surface of the eroded Orthoceras limestone is about 185 metres above the sea.

2—2. The next marked pause of the ice-border probably ran along the line 2—2. During that recession there was principally one new tributary to the chief-valley VI, as is evident from the erosion phenomena between the hillocks of moraine and limestone (at *b* on the map).

During the recession from 1 to 2 the surface of the ice-lake in E. was lowered only about 2 metres.

Fig. 17. *The rapids-district* showing bare-washed limestone. S. of Djupadalen. In the background are seen some terminal moraines, viz. WSW. of Stenåsen (to the left) and at St. Vådeg (above the man). Photo by the author.

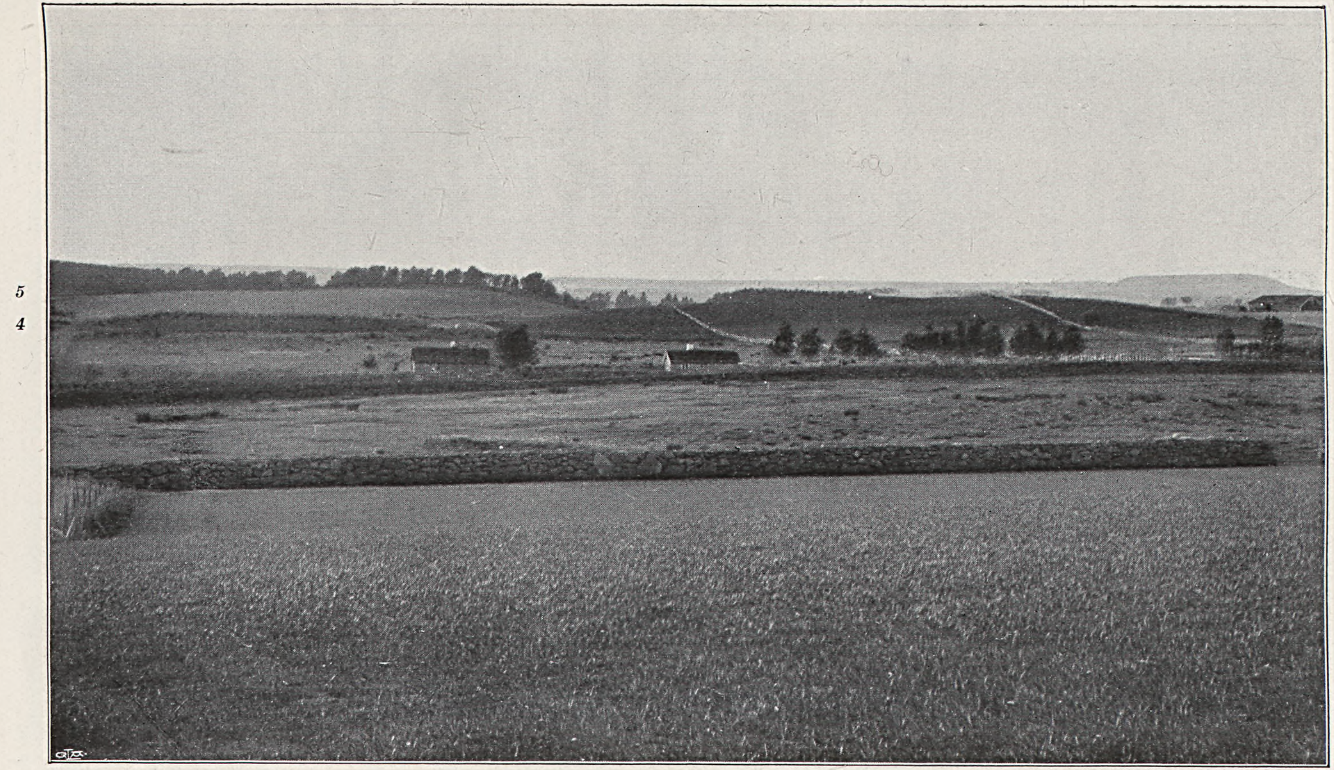

Fig. 18. A portion of *the rapids-district* + S. of Djupadalen, showing the moraine lines WSW. (4—4) and W. (5) of Stenåsen. Looking N. from St. Vådeg. — Photo by the author.

Fig. 19. *The mouth of Djupadalen*, eroded in Orthoceras limestone and Alum shale (below). — Photo by the author.

Fig. 20. *The middle and upper part of Djupadalen.* In the distance are visible portions of the terminal moraines, to the left that of the line *5*, to the right that of *4* (WSW. of Stenåsen). Cfr. fig. 18.— Photo by the author.

Then the ice-border retreated again a little to the North, to the line *3—3*. The water for a time took its course round the eastern hillocks and then discharged into the main-valley (VI). Further W. (at *c*) a little cataract indicates a somewhat later outlet. Still later the outlet moved to the places *d* and *e* representing small cataracts combined with erosion valleys towards the W and SW.

Then a slower but larger recession of the ice-border (from the line *3—3* to *4—4*) took place, which is evident from the relatively wide limestone area which is washed bare here, having become eroded by the overflowing and whirling waters from the ice-lake (see the map). This area, which from its W. to its E. side (E. and NE. of *g*) rises about 5 metres, might in fact be looked upon as a *rapids-district*, commonly showing eversion phenomena characteristic of such areas (fig. 17, see also farther on). Within the northern part of this area marked remains of the terminal moraine line are to be found (see fig. 18). Farthest to the West the area partly ends as small and narrow steeps or falls (at *f* and *g* on the map). These steeps are nearly the oldest marks of the stage, being the uppermost ends of small erosion valleys continuing towards the W. and indicating the commencement of an effective retrograde erosion, that gradually changed its place in a northerly direction.

A short time after the retreat of the ice-border from the line *4 b* the river seems to have commenced to erode the deep and narrow valley, called *Djupadalen* (»the deep valley»). See the map as well as the figs. 19 and 20. Its greatest depth, 12 to 15 *m*, is from the mouth and backwards to a point between *g* and *h*. More towards NE. it is commonly shallower. Within its western parts the valley has been eroded through Orthoceras limestone and alum shales, farther to the East only through the limestone.

To judge from the rapids-district just SE. of this magnificent valley as well as from some small fall-beds N. of it (see the map at as well as SW. and NE. of *h*), it is evident, that the water coming from the S. and SE. during this stage eroded also here at times. Possibly this erosion took place since the main-valley had been filled with ice during the winter as well as during the breaking up of the ice in the spring. More likely the shallow valleys N. of the main-valley (E. and N. of k on the map) were eroded in such a way. As water from the last-named rapids-district now-a-days sometimes finds a way to the small falls mentioned, and the erosion, therefore, has continued here at times since the late-glacial epoch, some of them possibly date their origin also from postglacial times.

When the ice-border had retreated to the northern part of the great terminal moraine (*5—5*) N. of Djupadalen, the water commenced to discharge here (at *l*). Its course was at first towards SW., as is evident from a series of steeps W. of *l* as well as from a couple of small erosion valleys N. and W. of the moraine hill in question. These small valleys join and open near the westernmost part of Djupadalen.

Then a valley called *Baggedalen* (»the tup valley») of about the same character as Djupadalen was eroded also in a retrograde direction. As appears from the fig. 21 its innermost part has a semicircular form and the uppermost parts show in places small steeps of Orthoceras limestone. Here the water as a cataract plunged into the valley at the very end of the existence of this outlet stage.

Round this end of the valley are seen several traces of the whirling motion of the escaping waters from the ice-lake (fig. 22). That is commonly the case also within the limestone district N. and NE. from *l*, where the waters seem partly to have eroded a long steep (n′—n″) chiefly into limestone and alum shales. Before that stage was reached the water escaped and eroded a short valley at *m* and flowed towards NW. and

Fig. 21. The semicircular uppermost part of Baggedalen (at *l* on the map) eroded in Orthoceras limestone. Photo by the author.

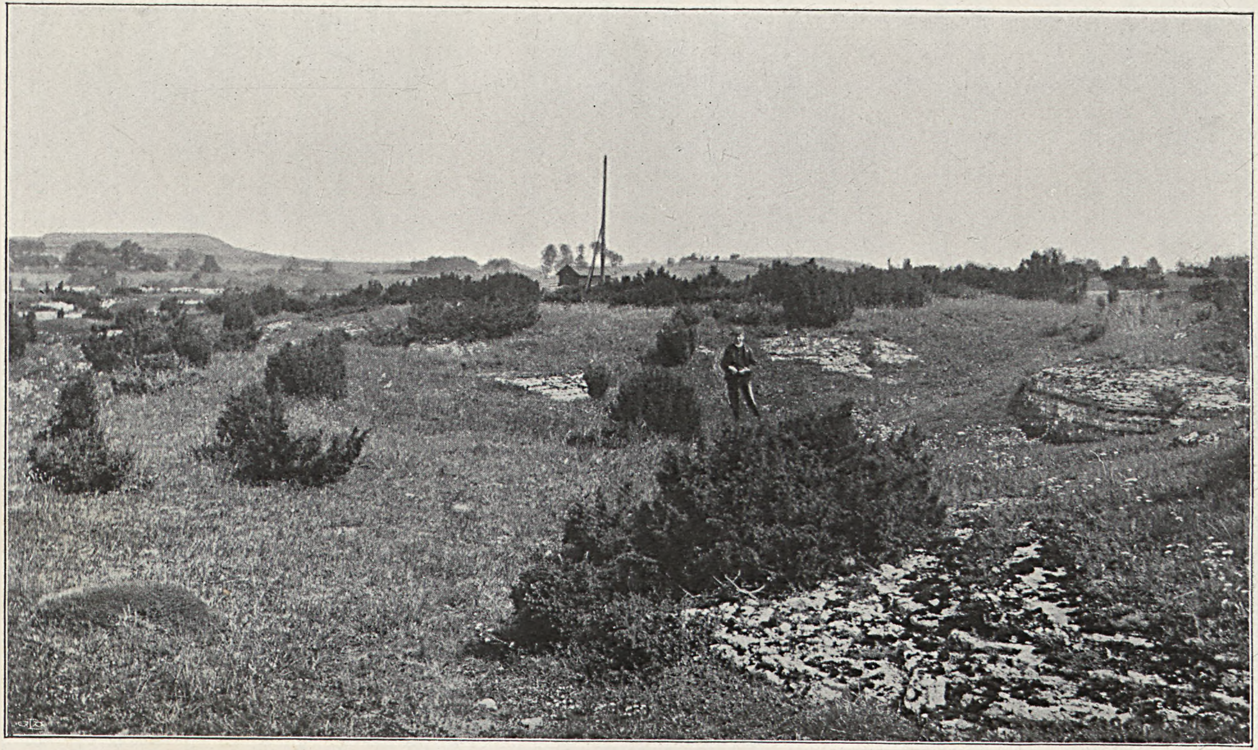

Fig. 22. *Evorsion phenomena in Orthoceras limestone.* E. of Baggedalen. — Photo by the author.

W., commencing the erosion of the broader valley there. As appears from the map, the bottom of this valley is sometimes rich in blocks. This erosion was continued by the waters passing the steep n'—n" and by those coming from a somewhat more northern stage.

During the stay of the ice-border at the line 7—7 *inter alia* indicated by marked hillocks of terminal moraines (partly with the rock as a nucleus), another valley like that of Djupadalen, but shorter and wider, was at last eroded NE. of the line *n'—n"*. This outlet, the pass of which is 190 *m* above the sea, is farther NE. indicated by masses of blocks (a residuum of the eroded moraine), while to the W. it divides into two smaller valleys running round an isolated hillock. The surface of this hillock was previously abraded to a plane, being about 183.5 *m* above the sea and NW. of it a terrace at the same height is eroded into the terminal moraine (see the map). N. of this terrace another plane, being about 177.5 *m* above sea, is worked out in the eastern and adjacent northern parts of the same hillock (see fig. 23).

Then the outlet of the Wetter ice-lake moved backward to the next and latest valley, i. e. to ***the northern Dala-valley, VII,*** a relatively broad and large valley extending WSW. to ENE. This valley held the water during a relatively long time, or while the ice-border retreated to the vicinity of Hjo (see the map., Pl. 47).

This northern Dala valley is of a pretty ordinary valley-type, without steeps and limited by commons lopes, which apparently depends upon the fact that it was eroded chiefly into moraine. It is now partly filled with peat. As seen from the map, Pl. 49, terraces are eroded at several places there, the most westerly one being about 176.5 *m* above the sea, i. e. at nearly the same level as the abrasion plane to the S. (fig. 23). The terraces within the NE. end of the same valley are developed at 178 to 179 *m* above the sea, probably being nearly contemporaneous with the terrace and plane just mentioned. As shown from borings the sandy and blocky bottom of this valley at the pass (a little SW. of its NE. end) is to-day about 174 *m* above sea-level, which indicates a lowering of the ice-lake by erosion here of about 16 *m* (190 at o minus 174) and of 5 *m* in the valley itself (179—174).

This valley has, like the Planta valley, been in use during such a long time *that it has cross-cut the district.* That was, on the contrary, not the case as to the smaller and narrower intermediate valleys, Djupadalen, Baggedalen, etc., *which, therefore, end suddenly or blindly into the limestone plain.* How long time it really took to erode these latter valleys one cannot tell, but, probably, a few years were sufficient for the formation of the largest of them.

As stated before, the Wetter ice-lake, while discharging through this northernmost outlet, maintained the levels it had during the erosion of the valley for a relatively long time, or until the ice-border had retreated about as far as the vicinity N. of Hjo. In consequence, *the lake gave rise to a marked set of gravelly beaches and erosion terraces approximately corresponding with the level of the pass just mentioned.* These shore phenomena, which are developed both to the North and to the South of the pass, will be shown during the excursion, for instance N. of Dala railway station, and near Ekedalen, E. of Hvarf church. As to the extent of the Wetter ice-lake of that stage see the maps, Pls. 47, 48 and 49. N. of the pass these shore marks are found at first on a gradually higher level than that of the lowest terraces of the pass (about 174 *m* above the sea), viz. 1.5 and 3.5 *km* farther N. 175.7 and 182 *m* respectively. At Skultorp gravelly plains indicate that the surface of the Wetter ice-lake was at about 188 *m* above sea-level there. This rise of the surface of the ice-lake was surely caused partly by the elevation of the pass while the ice-border was retreating N. of it, and partly because of the originally greater depression of land towards the North.

Fig. 23, showing *an abrasion plane* (177.5 *m* above the sea) in the moraine hill which forms a portion of the southern slope of the northern Dala valley, N. of Baggedalen. — In the foreground a peat-bog. — Photo by the author.

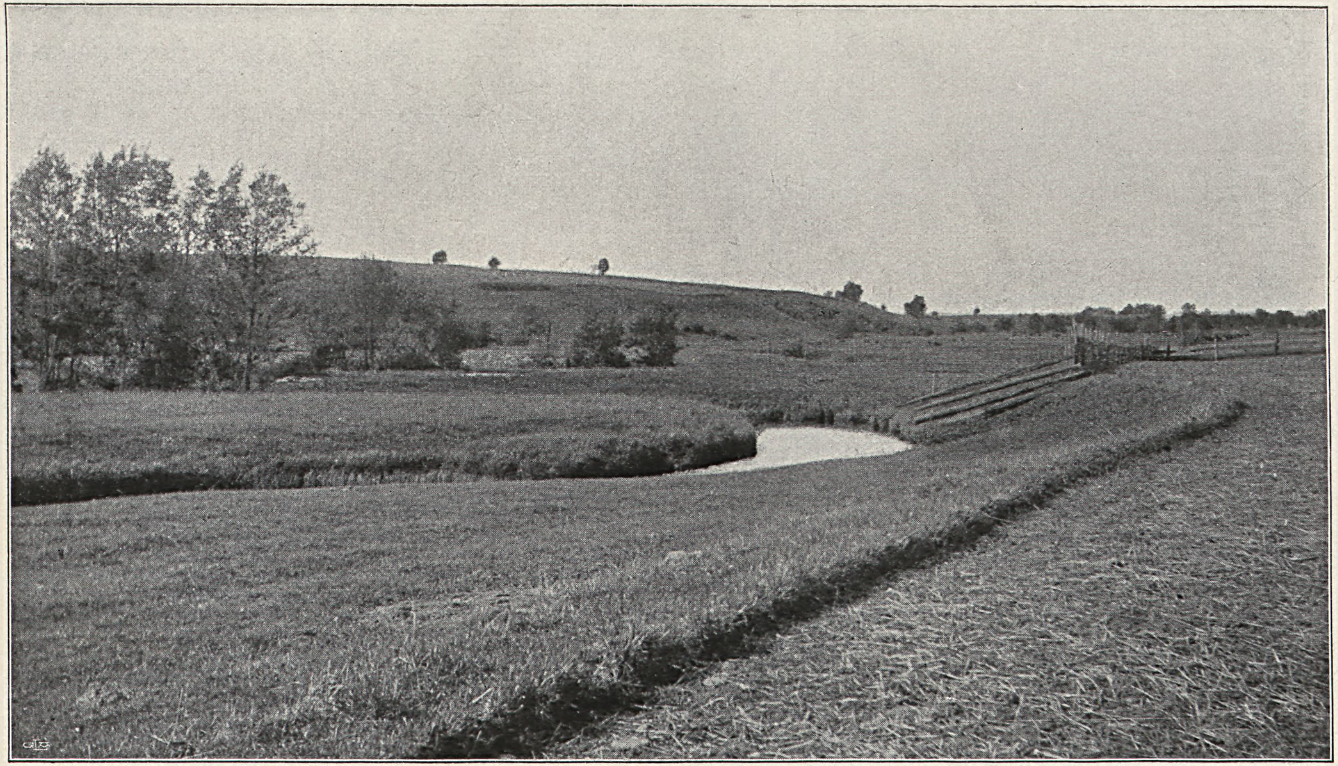

Fig. 25. A marked moraine slope being the westernmost boundary where the waters from the Wetter ice-lake deviated towards the S. — Photo by the author.

Later on, the lake was drained to the Baltic in the vicinity of Hjo (see before as well as the map, Pl. 47), and, in consequence, the uppermost marks of the ice-lake farther to the North are met with at lower levels, as, for instance, in the vicinity of Sköfde only about 150 *m* above the sea (see farther on).

S. of the Dala pass, however, these marks are met with at gradually lower levels, as, e. g., near *Ekedalen* and S. of Tidaholm (cfr. fig. 24) at approximately 170 *m* above the sea.

Fig. 24. Masses of clean-washed boulders marking the shore-line which corresponds to the northern Dala outlet. About 170 *m* above sea-level. Daretorp parish, S. of Tidaholm. (From the explanation to »Tidaholm»).

As is evident from the figures of the map, the whole sinking of the surface of the Wettern ice-lake during the recession of the ice-border from Plantaberget to the northern Dala-outlet was about 40 *m* (from 215 to 174 *m*), while the sinking from the Tiarp valley to the Dala-outlet amounted to about 64 *m* (238 to 174).

As appears from the map, Pl. 48, the first three western outlets of the Wetter ice-lake, viz. II, III, and IV, were tributaries to the Ätran drainage-system (see before and the map, Pl. 47), the Gerum-outlet (IV), partly also to the Åsle ice-lake (see farther on), which, moreover, received the waters escaping through all the other outlets in question, apart from the youngest of the Dala district.

As regards the marks of the waters West of this latter district, the erosion valleys at first, within the bluish dotted area, were only shallow, probably because the area in question, to judge also from the occurrences of sandy and gravelly plains there, was mostly under water, which highly diminished the erosive power of the running waters here. This district, without doubt, in times had the character also of a rapids-district. Farthest to the W. the map, Pl. 49, shows a steep and high moraine slope (fig. 25) which marks the limit, where the escaping waters at later stages deviated towards the S. Then their direction ran towards the SW., viz. into the northernmost part of the Åsle valley, which was previously filled with waters (see below).

Now a brief sketch of the development of the ***Åsle ice-lake*** etc. may be given.

In the vicinity of Wartofta (SE. of Falköping) ends the northernmost part of the above described Ätran system, here indicated by a wide plain of sand etc., approximately 230 *m* above the sea (cfr. the map, Pl. 48, and fig. 2, facing p. 1216).

N. of it the marked and deep *Åsle valley* extends being about 15 *km* in length (to the vicinity of Valtorp) and about three kilometres in width. When the recession of the ice-border took place here, this valley was filled by an ice-lake, which had its outlet chiefly through the marked erosion valley running from W and NW. of Wartofta towards the SW. and W. to the wide depression, now occupied by a peat-bog, called Mönarps-mosse, SSW. of Falköping.

Fig. 26. *The marginal plateau* named *Rännefalan*, from the distal side (SE.). Mt. Ålleberg is visible in the background. Photo by the author.

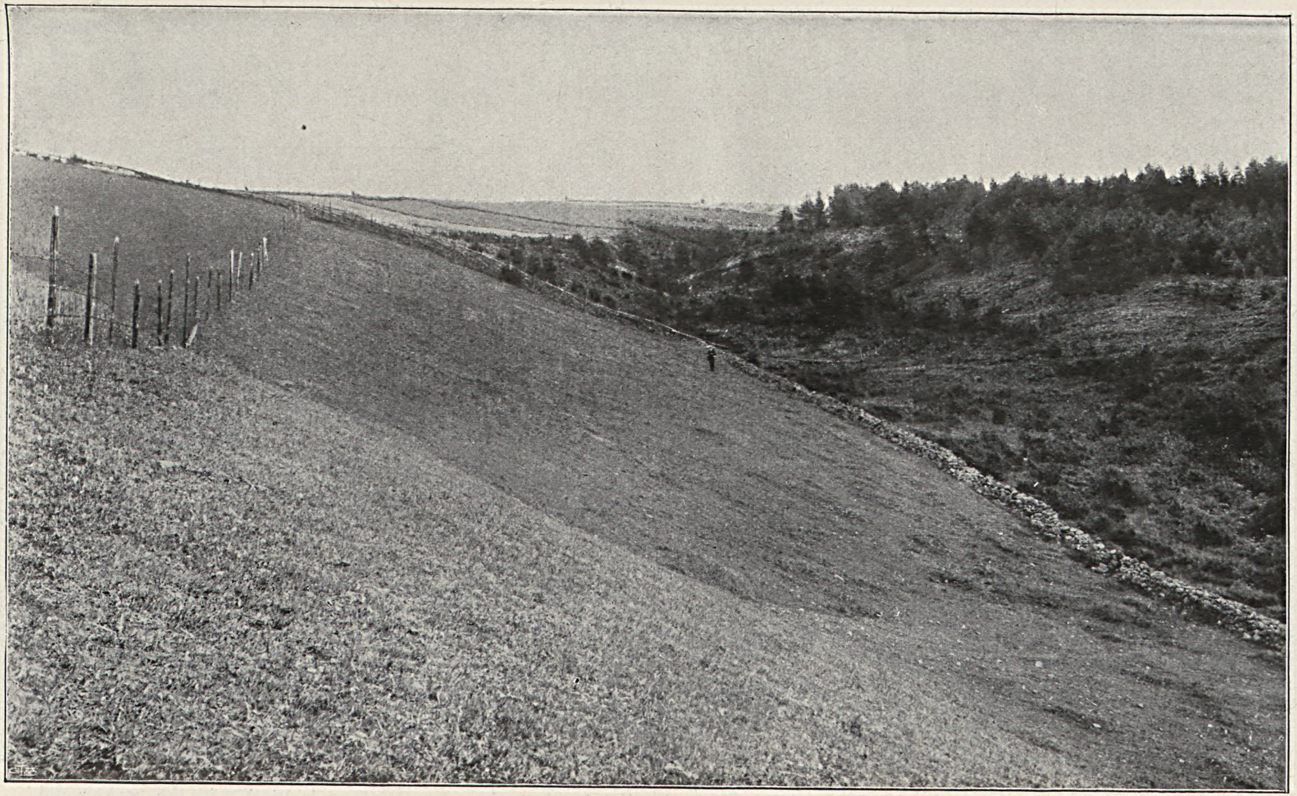

Fig. 27. *The transverse valley b eroded in moraine* (above, only to the left) *and in sandstone* (below). WNW. of Håkantorp church. Looking SE. from near the mouth of the valley. — Photo by the author.

However, the Åsle ice-lake at first discharged for a short time to the Ätran system, through a small pass SW. of Wartofta, and later on through another pass SW. of the church of Wårkumla (farther SW.)

The pass of the main-outlet is (NW. of Wartofta) nowadays only about 210 *m* above the sea, i. e. at a level about ten metres lower than the oldest surface of the southern part of the Åsle ice-lake. That relatively low level of this ice-lake is again in relation to the surface of the magnificent *marginal plateau*, called *Rännefalan* (216 *m* above sea-level), which extends NE. of the church of Slöta. (See the map, Pl. 48, and fig. 26, as well as the geological map-sheet of Tidaholm.) Its surface rises about 35 to 45 *m* above the bottom of the adjacent depressions to the South and West. Originally this marginal plateau was, without doubt, connected with the masses of gravel and sand NE. and N. of Slöta, erosion by the waters filling the marked depression S. and, later on, also N. of this line having broken the connection. This depression makes it probable that a remaining portion of ice prevented its filling out by sediments and the Rännefalan as well as several other such plateaus may, therefore, have been built up *marginally rather than terminally.*

It is worth mentioning that the deposition of glacio-fluvial gravels and sands was very inconsiderable within the Åsle depression N. of Rännefalan. Moreover the marks of the ice-lake itself are also very few and slightly developed. Not until we reach the northern part of the valley these marks are more distinct, indicating that the surface of the lake was at a height of about 205 *m* above the sea there, i. e. nearly at the same level as farther to the South.

When the ice-border reached the vicinity of *Rössberga.* another outlet from the Åsle ice-lake arose, viz. towards W., and through this outlet, therefore, the waters of the lake as well as, indirectly, those of the Wetter ice-lake discharged for a time. This pass is to-day about 205 *m* above sea-level

Later on a series of other passes were gradually laid bare at lower and lower levels. Thus marked and deep erosion valleys were formed in *moraine* and, in places, also in *the Cambrian sandstone*, the passes of these valleys being denoted as *a*, *b*, *c*, and *d* on the map., Pl. 48, which also shows their height above sea-level.

Among these passes are to-day those W. of Rössberga probably about 195 to 190 *m* and 180 to 177 *m* above sea-level respectively. WNW. of Håkantorp church there is a district, where the Cambrian sandstone to a relatively great extent is washed clean from the Quaternary deposits by the river in question, and E. of the same church plains of sand and gravel are met with at about the same level, or 150 *m*, indicating the existence of a local lake there at the time in question.

To the NW. of the sandstone plain just mentioned there are a couple of erosion valleys, the northernmost of them being the most important (see fig. 27). While the sandstone plain (= the pass) is about 150 *m* above the sea, the bottom of the 12 à 15 *m* deep valley descends to about 130 *m* farthest to W. That outlet kept the escaping ice-lake-water until the ice-border reached 2 *km* farther to the North, where the conditions again favoured the formation of a new outlet at a little lower level than the former, the pass (also here a clean-washed sandstone plane bordered by high slopes of moraine) being approximately 144 *m* above the sea. Then the outlet anew moved, viz. to the northernmost branch valley at Hornborga, the aspect of which valley is shown by the fig. 28. The highest marks of the stream here are about 145 *m* above the sea (the highest sandstone plane being at 134.5 *m*), and to the E. plains of sand at about 145 *m* seem to indicate that an enlargement of the river to a small lake took place also within this district. Near the bridge at Hornborga there are *a series of small erosion valleys* opening into the main-valley and illustrating the gradually lowering of the river bottom here. In the vicinity of Hornborga a pebbly beach situated about 128.5 *m* above sea-level, pos sibly mark the stage when the Yoldia Sea first entered this district.

As appears from the map, all the outlet valleys from the Åsle ice-lake, as yet mentioned, are transverse valleys. In contrast with them the long and marked *Håkantorp valley*, extending from near Valtorp church to Hornborga, was also eroded in sandstone, but chiefly during the latest stages of the Wetter and Åsle ice-lakes. Also afterwards the actual rivulet Slafsan might have deepened it to some extent.

Fig. 28. *View from the Håkantorp valley, eroded in Cambrian sandstone,* which is visible principally to the right. Looking W. from near the Hornborga bridge. (From the explanation to »Sköfde».)

Since the Cambrian sandstone is a hard rock difficult to erode, it is easily understood that the erosive action within the area of this rock has been very powerful, which was, also to be expected from the immense quantities of waters which at that time discharged there. However, the sandstone is commonly very rich in fissures (see fig. 29), which evidently at times hastened the erosion work.

All the valleys of the outlets *a* to *d* mentioned above seem to open suddenly into the plain area South of Hornborgasjön, no marked continuation of them having as yet

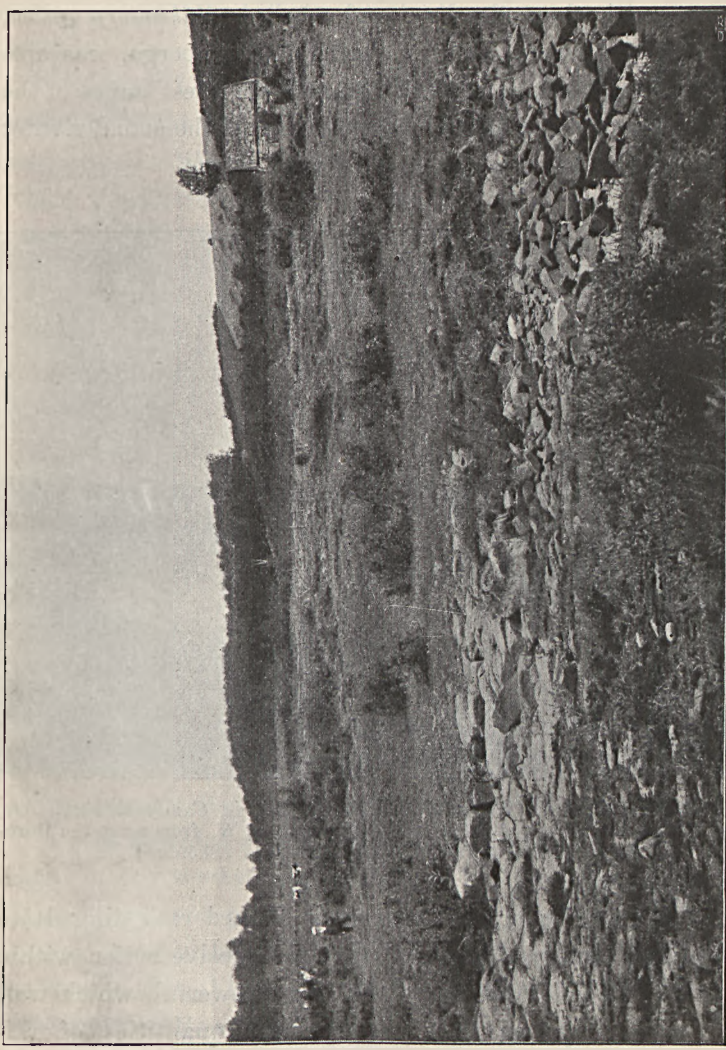

Fig. 29. The lowest part of the valley visible on fig. 27, to illustrate *the sandstone rock* (to the left in the foreground) and *blocks of sandstone*, in the rivulet of to-day (to the right). — Photo by the author.

been found. This is due to the fact that the Yoldia Sea at the same time occupied this area and, therefore, prevented the erosion there. On the contrary, large quantities of gravel and sand, heaped outside the mouths of the valleys might be looked upon as transported by the rivers in question; they are probably not glacio-fluvial deposits, as was thought previously (MUNTHE: the explanations to the map-sheets of »Sköfde», »Falköping» and »Skara»).

From the small quantities of late-glacial clay within the districts now occupied by the wide-extended Hornborga depression and adjacent areas it is, however, evident, that these regions at that time had the character of a shallow-water district. And, in consequence, the large quantities of clayey and marly products from the ice-lakes were brought farther, to the West, viz. to the districts W. of the line Skara to Wånga etc., where the true wide-extended clay-plain of Westergötland commenced. (Cfr. the geological map-sheet of »Skara».)

After this account of the late-Quaternary geology of Falbygden and adjacent districts I will give the plan of the excursion after the Hornborga village is reached and, in this connection, allude to some other features to be looked at during the excursion.

From Hornborga the route runs southwards, passing the above-mentioned outlet valleys *d* to *a*, and then to Valtorp.

At Valtorp we can see the two marked erosion valleys, opening into the grandiose Håkantorp valley, one, passing the church, from the Åsle depression, the other, coming from NNE., i. e. from the Wetter ice-lake outlets, belonging to the Dala system (VII).

Between ***Valtorp and Sköfde*** the following is to be observed. Between Valtorp and Stenstorp some os-ridges and, near the latter place, marginal oses with well rounded, isolated gravelly hills (»mammillated hills»). Between Stenstorp and Skultorp there are drumlin-ridges running about NE.—SW.

At L. Borgunda is to be observed, in the distance, a plain of sand, formed in a *nunatak lake*, about 208 *m* above the sea.

At Skultorp as well as somewhat N. of that place we pass the gravelly plane representing approximately the maximum level, 188 *m* above the sea, of the Wetter ice-lake when the ice-border retreated here. Farther to the N. this plane becomes gradually lower. Near Sköfde the plane is only about 150 *m* above the sea and here probably represents *the surface of the Baltic ice-lake*, which entered the district after the Wetter ice-lake had been tapped to the Baltic ice-lake through the above-mentioned strait near Hjo.

The plane N. of Sköfde has towards the East the character of a marked terrace, the foot of which (about 142 *m* above the sea) probably again marks a stage of falling of the Baltic's surface.

NE. of Sköfde and, more especially, N. of the railway to Karlsborg there is a series of well developed terminal moraines running W. to E., the higher parts of which rise above the surrounding clay and sand plains. In places sections show that also here glacial deposits (bottom-moraine and glaciofluvial gravel) cover clayey and sandy strata deposited within the Baltic ice-lake (cfr. the explanation to the geol. map-sheet of »Sköfde», p. 69, fig. 14), indicating that the ice-border oscillated when in retreat here.[1]

S. of the series of the terminal moraines the clay plain is more continuous and is in places covered by sand. These plains are often intersected by marked erosion valleys, lateglacial and postglacial in age.

Sköfde—Kymbo—Mösseberg—Jönköping.

Now a brief account of the route on the second excursion day may be given.

The first stop is at ***Skultorp***.

Just S. of the railway station of Skultorp there is a quarry in Orthoceras limestone covering Phyllograptus shale and alum shales. Upon the last-named rock in E. rests a series of supramarine strata including fossils, which illustrate the evolution of the late-Quaternary flora and land molluscan fauna. The first scientific description of this locality was given by Dr. HULTH (1899), and, besides, SERNANDER (1902) and I (in the explanation to »Sköfde», 1905) have published some supplementary notes. Recently (1910) N. ODHNER has re-examined this section in order to study more in detail *the evolution of the molluscan fauna;* and I may refer to his paper, since it contains also a review of the results previously obtained.

HULTH and SERNANDER think that the »humid» and »dry» layers (tufa etc. and humus resp.) represent the so-called boreal, atlantic, subboreal, and subatlantic periods of BLYTT-SERNANDER, but I have propounded the question (l. c. 1905, p. 119), whether the formation of the humus-beds cannot be interpreted by assuming that the water had locally eroded the layers and thus temporarily drained the basin. The question may be discussed during the visit.

During the journey *between the railway stations of Skultorp and Dala* chiefly the gravel beaches, representing the level of the Wetter ice-lake in relation to the latest Dala stage will be looked upon.

Then the Dala district will be visited more in detail. (See the description given above).

Farther on, the course chiefly follows the highway by Kungslena, Ekedalen, Dimbo, Kymbo, Rännefalan, Ålleberg to Mösseberg.

During this journey the following Quaternary phenomena are principally to be seen. Near Kungslena a glance at the mouth of the great valley between Plantaberget and Hvarfsberget, erosion terraces etc. Such terraces corresponding to the latest Dala outlet will be seen chiefly S. of the railway station of Ekedalen, about 170 *m* above sea-level.

NE. of the church of Hvarf there is a plain of sand (about 228 *m* above the sea), deposited in the Wetter ice-lake.

Near Dimbo is a marginal os, the flat surface of which is about 240 *m* above the sea and corresponds to the highest level of the ice-lake.

Between Dimbo and Hvalstad there is a hummonocky district of glacio-fluvial gravel etc. partly rising above the sandy ice-lake planes to the W. (S. of Anneberg etc.), about 240 *m* above sea-level. NE. of Kymbo among other things the wide marginal plateau called the *Wättak plateau*, will eventually be visited.

Then several outlets for the Wetter ice-lake, viz. n:is II, III, and IV b will be passed and the marginal plateau Rännefalan visited, from which one has a good survey of the Åsle valley etc.

At *Ållebergsände* (the northernmost part of Ålleberg) a peculiar phenomenon, probably caused by a fault of the Silurian strata and the diabase, after the ice-border had retreated from the place, will be looked upon (see fig. 9, p. 64 in the explanation to the map-sheet of »Tidaholm»).

Next morning first the Mösseberg will be climbed. From here we have, to the East, a wide view of the geological features, since nearly no forests are left.

Then we take the train from **Falköping-Ranten to Wartofta** and from here **to Mullsjö and Jönköping.**

During that journey the observations may partly be made from the train.

W. and NW. of Wartofta the chief outlet of the Åsle ice-lake will be seen. E. and NE. of Wartofta the sandy plain of the War ice-lake (the northernmost part of the Ätran-system) extends, the highest parts of which are about 230 *m* above the sea (cfr. fig. 2, p. 1216). NE. of Wartofta

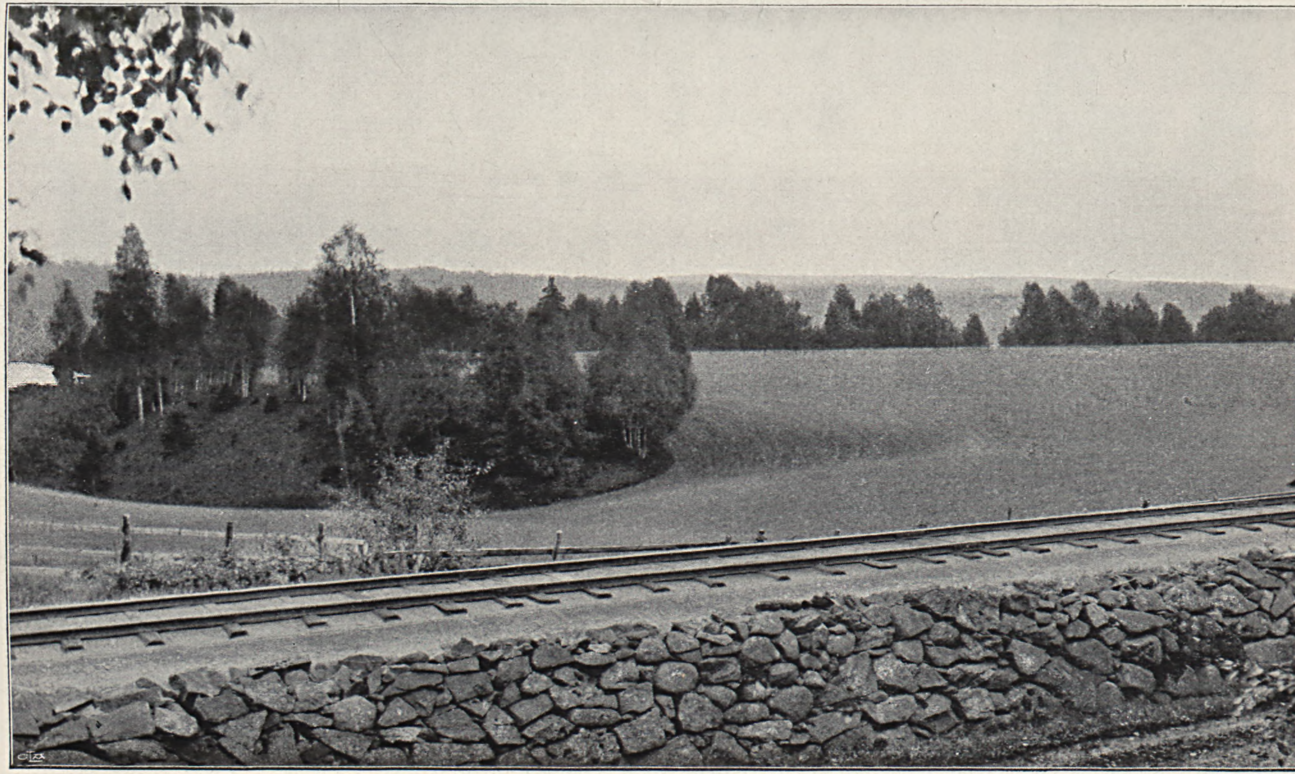

Fig. 30. A part of *the ice-lake plane*, near Margreteholm, W. of Lake Stråken. — Photo by the author.

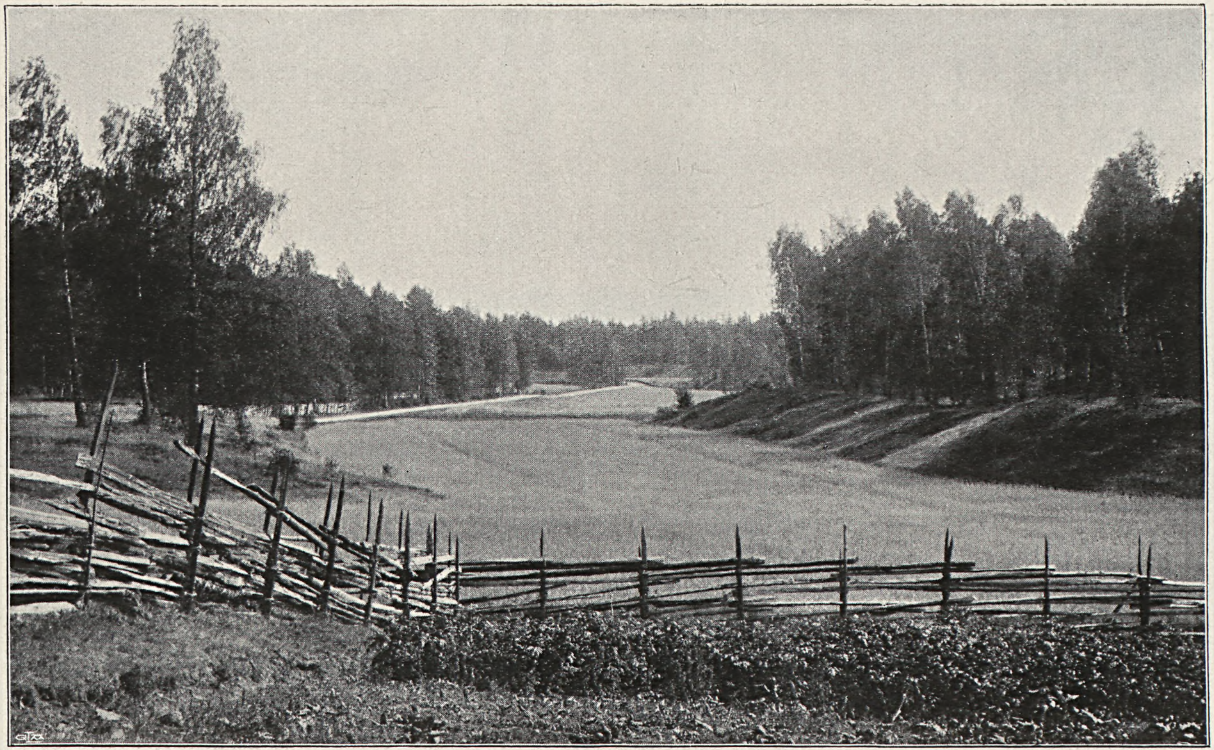

Fig. 31. A part of *the ice-lake plane, somewhat eroded.* Near Qvigeskedet, E. of Lake Stråken. — Photo by the author.

station the terminal line is developed as a highly hummonocky belt of gravel and sand, which E. of Löfberga ends into a marked »feeding esker».

Where the train reaches the boundary between the map-sheets of »Tidaholm» and »Ulricehamn» the earlier western chief outlet of the Wetter ice-lake may be observed from the train.

Near the railway station of Sandhem the *Stråk ice-lake* commenced. (Cfr. the geological map-sheet of »Ulricehamn».) Between Sandhem and Mullsjö the railway for the most part is built upon a flat plane of gravelly sand, indicating approximately the highest level of this late-glacial lake, or about 240 *m* above sea-level and 30 to 35 *m* above the present lake-level (cfr. fig. 30). On the left hand the surface of this lake, being 207 *m* above the sea, is now and then seen from the train. Beyond the lake, which extends 23 *km* in N. to S., there is a similar plain (fig. 31), sometimes visible from the train. This marked depression, no doubt, was originally, or when the surface of the late-glacial lake reached its highest level, filled with sand and gravelly sand. Later on this valley train during the upheaval of land and the regression of the ice-lake's surface was gradually eroded, partly transversely, but chiefly longitudinally, and this erosion still continued, after the rocky pass, being about 16 *km* S. of Mullsjö and about 200 *m* above the sea, i. e. about 7 *m* below that of the present Lake Stråken, was reached. Nowadays this lake, however, discharges its water towards the N., because masses of peat have been heaped within its southernmost part, where the just-mentioned pass is situated. The deepest parts of the recent Stråken being about 30 *m* below its surface, the vertical amount of the previous erosion was 60 to 65 *m*. That fact probably seems peculiar, but the same is, for instance, the case as to the Lule river in N Sweden, the surface of which between the pass at Hednoret (NW. of Luleå) and Edefors, or for a length of 37 *km*, declines only about 2 *m*, the late-Quaternary deposits, now reaching in places some ten metres above the river, having locally been eroded to about 30 *m* beneath the pass mentioned during the elevation of land in a late *postglacial* time.

The figs. 32 and 33 illustrate the character of the riant Stråken valley, which resembles as river-valley eroded in a common sediment district. Sometimes a series of terraces are eroded in the slopes limiting the lake (fig. 33).

Opposite the Mullsjö station is *the lake Mullsjön*, nearly round in form and of a maximum depth of about 20 *m*. This depression lying within glacio-fluvial and glacio-lacustrine deposits, may probably be looked upon as formed by the melting of portions of ice once buried beneath gravel and sand.

Between Mullsjö and Habo stations (cfr. the geological map-sheet of »Ulricehamn») the train runs through a hummonocky landscape of gravelly and sandy ridges and hills of irregular shape forming part of an uncommonly wide plain of glacio-fluvial material. This district, which is called *Svedmon*, extends for several Swedish miles in N. to S. on the highland W. of Lake Wettern. In the vicinity of Habo glacio-lacustrine clay and sandy clay, deposited in the Wetter ice-lake, commence, which deposits again are replaced by morainic soil and, at lower levels, of gravelly and sandy plains. From the train one has a good view of the southern parts of the grand and charming depression of the recent Lake Wettern and its surroundings.

b) Jönköping with environs etc.

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A. Blomberg: The geological map-sheet of »Vadstena» with explanation. S. G. U., Ser. Aa, N:r 130. 1905. Price 2 kr.

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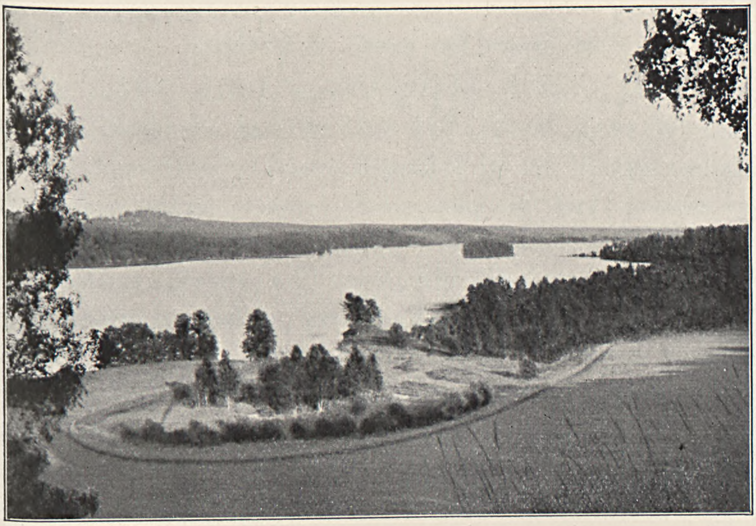

Fig. 32. *View over a part of Lake Stråken,* from Olofsborg towards the South. — Photo by the author.

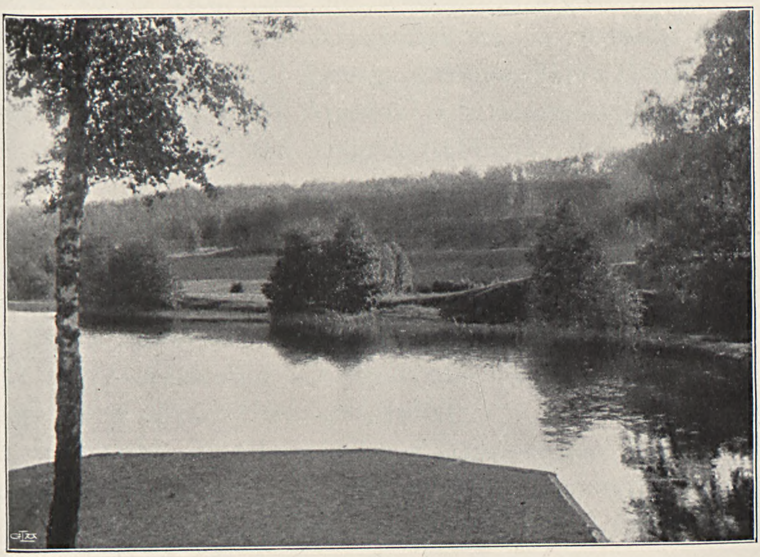

Fig. 33. *View illustrating the occurrence of terraces in the slopes of Lake Stråken,* S. of Olofsborg. — Photo by the author.

Jönköping to Taberg and return, etc.

W. and SE. of the town of *Jönköping*, on the highland lying 230—245 *m* above the sea and 140—155 *m* above Wettern, gravelly and sandy layers deposited in the Wetter ice-lake are widely spread, whereas the ice-lake clay has a greater extension chiefly at lower levels. The former strata together with bottom moraine, etc., originally filled up also the deep pre-Quaternary valleys extending SSW. and SSE. of the Wetter depression, but they have later on been to a great extent eroded away, as will be shown during the journey from Jönköping southwards to *Taberg*. From the top of this isolated mountain, rising high above the surrounding flat, the ice-lake plains will be roughly demonstrated. (Cfr. the figures 1, p. 6, and 2, p. 7, in the explanation to »Jönköping».)

The mount *Taberg* is for the most part built up by an iron ore containing only about 31 per cent of iron, but about 6 per cent of TiO_2. The ore, therefore, is a titano-magnetite with olivine. For fuller information see, for instance, A. G. Högbom: Jönköping and Taberg in Högbom, Gavelin and Hedström: Excursion in the Archæan of Southern Sweden. G. F. F. Bd 32 (also as a the Congress-Guide, N:r 18).

Eventually a short turn may be made from Jönköping to the railway station of Tenhult in order to look at the laminated and contorted ice-lake clay at the brick-yard of Heljaryd, about 220 *m* above the sea-level. (Cfr. fig. 37, p. 123 in the explanation to »Jönköping».) During the turn wa pass the grandiose Huskvarna vallay.

Sometimes in the vicinity of Jönköping occur plains of gravel and sand, which probably may be referred to the stage when the Baltic ice-lake came in here. (Cfr. Pl. 47.) On the other hand, traces of the Yoldia Sea are probably to be found near or even below the surface of lake Wettern here.

Jönköping to Hästholmen by steamer.

During this journey first the »Rosenlunds bankar» (the steeps of Rosenlund), E. of Jönköping, may be viewed from the steamer. (Cfr Pl. 1, fig. 2 etc in the explan. to »Jönköping»).

The 20 to 30 *m* high sections through the Quaternary deposits here show, on the whole, the following series:

a) (Uppermost) *Bottom moraine*, a few metres in thickness.

b) *Layers of glacio-lacustrine clay* (with *Salix polaris*, rarely), *sand and gravel* (in part also glacio-fluvial in origin). In places 10 to 15 metres in thickness.

c) (Locally) *Boulder clay.*

This series of strata indicate, like several similar examples within the districts round S. Wettern, that an extensive re-advance of the ice-border from an originally more northern line took place after mighty strata of glacio-lacustrine deposits had been laid down outside the ice-border. From that time originate also a fan-shaped system of glacial striæ radiating from the southern parts of the marked depression.

Balls of glacial clay, met with in sandy gravel between the two horizons of ground moraine at Rosenlundsbankar, indicate that the intra-morainic strata were eroded before the formation of the upper moraine bed.

During the journey Jönköping to Hästholmen we have a good opportunity of surveying the grandiose Wetter basin, a dislocation valley between mostly high slopes and steeps of Archæan rocks, principally to the East. The largest deep of the lake is (S. of Wisingsö) 120 *m*, i. e. about 30 *m* beneath the sea-level (the surface of the lake being 88 *m* above it). In places there are visible faulted strata of the socalled *Wisingö formation*, a series of sedimentary non-fossiliferous strata of sandy and marly shales etc., which have their most perfect development in the little isle of Wisingsö in the midst of the lake. Sometimes these strata are met with as rests hanging on the surrounding Archæan slopes, as particularly at the W. side of Mt. Omberg N. of Hästholmen. (See the map-sheet of »Wadstena».) To the S. and E. of this mountain horizontal Cambrian and Ordovician strata are to be found. The true age of the Wisingsö formation is not yet determined, but it is commonly thought to be post-Silurian.

The marked Wetter basin is to be looked upon as a fault district which later on has been highly eroded »(übertieft»), chiefly by the work of the land-ice, or, more exactly *its ice-rivers.* This is probable from the immense masses of rounded glacio-fluvial material heaped on the Archæan plateaus W. of the basin as well as S. of it, partly in its continuation there, partly also on the plateaus farther S. That the basin cannot have been eroded by current waters seems to be evident from its environs not allowing the existence of any such erosion, since, *inter alia*, its deeper parts are far below its rocky passes.

Finally, it is worth mentioning that the interesting glacio-marine fauna (*Cottus quadricornis* var. *relicta, Gammaracanthus loricatus, Idothea entomon*, etc.) was first found in Lake Wettern with its relatively cold and clear water and described (in the beginning of the 60:ies) by the late Prof. SVEN LOVÉN, the eminent Swedish zoologist.

Hästholmen to Alvastra in order to visit an interesting pile-dwelling place. (For a nearer account see O. FRÖDIN.)

The Pile-Dwelling at Alvastra.

a) *Archæological deductions.*

(By O. FRÖDIN.)

»In 1908, when draining the swamp about 400 *m* ENE. of Alvastra Station in the parish of Västra Tollstad, a number of objects from the Stone Age were met with, which led to the supposition that there had been a settlement here during that period.

On this account a systematic examination of the place was begun in the summer of 1909, and a shaft 13 *m* in length and 4 *m* in breadth was sunk. Under a layer of marsh-peat rich in *Phragmites*, from 1 to 1.1 *m* thick, followed a cultivated stratum of 0.2—0.35 *m* in thickness, which in its turn proved to rest on *a floor of logs* (of pine and birch) of unknown extent, since it continues into the four sides of the shaft. Inasmuch, however, as it occupies the whole of the shaft of 52 sq.-metres, we are evidently in the presence of what was a very considerable settlement.

On this floor have been exposed seven *hearths* of paved stones and *a seat* consisting of an oblong stone of granite, the upper side of which reveals traces of manufacture. Above the floor rise, moreover, a number of short piles, presumably remains of roof-supports. The construction of the house in other respects is at present unknown.

From geological investigations (see below) it has been deduced that the ground that surrounded the house consisted of a slightly sloping, spring-watered muddy morass of such loose consistency that the building must also have rested on piles. Such are also found in the place where the investigation has gone so far that the marl mud under the floor has been exposed to a considerable extent. In another part of the shaft it has been shown by borings that remains of culture are also found below the floor.

The pile-building at Alvastra — the first that has been discovered in Scandinavia — is consequently best comparable in plan with the well-known pile-building at Schussenried in Württemberg.

Among the objects of civilization met with here occur *axes of flint and greenstone, arrow-heads, borers, scrapers and knives of flint, knocking-stones of quartzite and grindstones of* *sandstone and quartzite.* It must be mentioned that all the flint is imported from Scania or Denmark.

While the objects of greenstone are highly affected by humic acid, *the bone and horn implements* are particularly well preserved. Among the latter may be noted a number of *chisels*, and above all a great number of *awls.* As ornaments were worn *beads* made of hogs' and elks' teeth. Of especial interest is the find of *an amber bead* in the shape of a two-edged axe, symbol of the sun-god, and of a little cut *hook of wood*, the first implement of this material from the Stone Age in Sweden that has been found during a scientific search. Fire was procured by striking specially shaped *stones of quarzite* (some 150 have been found) against *iron pyrites. Touchwood* (*Polyporus fomentarius* (L.) Fr.) has also been found.

The animal bones found in the settlement are those of the *pig* (wild boar and presumably also the domesticated pig), *cattle*, *sheep*, *goat*, *elk*, *stag*, *roedeer*, *hare*, *marten*, *badger* *wolf*, *dog* (presumably), and *bear;* also *pike* bones.

The Stone Age dwellers at Alvastra consequently had domestic animals. A number of charred grains of *Hordeum hexastichum* show that farming was also practised. Still more remarkable are, however, the charred *apples* that were found at several places. An examination has revealed that these were gathered in a fully ripe state, cut in two and dried in the air, evidently to serve as winter stores, and that they belong to two different types in size, a larger and a smaller, quite corresponding to the results arrived at by Oswald Heer in his examination of the apple finds from the pile-buildings of Switzerland and N. Italy. The larger variety of apple may possibly point to a primitive fruit-culture.

It follows from the finds made that the pile-building at Alvastra belongs to the period of the *later Stone Age*, which is usually called the age of the »passage-graves»; according to the chronology of MONTELIUS about 2,500—2,000 B. C.[1]

The communication on the geological nature of the spot in question is from the pen of L. VON POST.»

b) *Geological deductions.*

(By L. VON POST.)

The pile-building at Alvastra was not, like its well-known Swiss analogies, built along the edge of a lake; for the hillock-shaped stratum, consisting of calcareous tufa, marl-mud, lake-marl, and peat, in which its remains were discovered, does not belong genetically to the neighbouring Dagsmosse — the SW. quarter of the basin of Lake Tåkern, now filled up with peat formations — but belongs to a type of peat strata related to the North Scandinavian »backmyrarna», to which little attention has been paid in our country, but which is well known in North Germany under the name of »Quellmoore».

The chief formations in the stratification of these spring-mosses are, from below (fig. 34), the following:

Calcareous tufa on a good water-bearing substratum consisting of sandy moraine and very loose clay; not exceeding 4 *m* in thickness.

Cladium peat, more or less mixed with mud, especially in the upper part; it forms as a rule a connected bed 2 or 3 *dm* to 1 *m* in thickness and rests on the calcareous tufa, but is here and there broken up into larger or smaller irregularly lying lenses.

Marl-mud, here and there with ledges of *calcareous tufa* and *Cladium peat*, and everywhere with scattered rhizomes of *Cladium* and *Phragmites*.

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[1] For further information we refer to the work of FRÖDIN: En svensk pålbyggnad från stenåldern, Fornvännen 1910, Stockholm, of which a German translation appeared in *Mannus* 1910, in the »Organ der deutschen Gesellschaft für Vorgeschichte».

Marsh-peat with *Phragmites* and occasional stumps of alder, 1—1.3 *m* in thickness.

All these strata dip towards the South, West, and North, i. e., from the moraine-hillock at Broby radially outwards towards the Dagsmosse. The contact between the marl-mud and the peat, which is everywhere very distinct and quite rectilinear in the profile taken, has, just at the present peat surface, a slope of about 1 in 50. The outpinch of the peat at Broby hillock lies 6.2 *m*, and the peat surface at the place where the pile-building stood lies 3.9 *m* above the highest (recent) shore-line of Lake Tåkern, the floor of the pile-building itself being on an average 2.6 *m* above the level mentioned.

The relics are all to be met with in the contact between the marl-mud and the peat, or more correctly in the uppermost stratum of the former. The ground on which the pile-dwelling was built up, consisted of a loose, sloping mud-surface, permanently irrigated by spring-water, sparsely overgrown with *Phragmites* and *Cladium Mariscus*.

The pile-building was here still better protected than if it

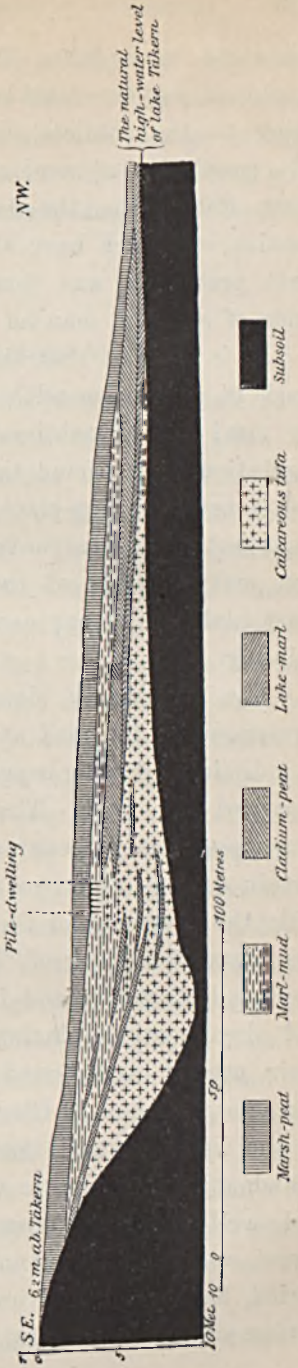

Fig. 34. *Section illustrating the different layers of the Dagsmosse near* Alvestra in relation to *the levels of Lake Tåkern.*

had stood in a lake. The loose mud would not bear the weight of anyone walking on it, nor could it be navigable, owing to the shallow depth of the water (a few *cm*). The only possibility of reaching the building, which was situated about 100 *m* from the then land, was by laying out planks, remains of which have already been found. A splendid natural protection was thus gained against the attack of all kinds of enemies, man as well as beast.

It is evident that the abandoning of the dwelling-place stood in connection with the rise of the peat-covering above the marl-mud. Doubtless also the advance of a connected vegetation-cover round the building forced its inhabitants to seek a new dwelling-place, the spot having now lost its most important protective nature, i. e. its inaccessibility. On the firm mat of roots of the newly formed bog, both man and beast could easily approach the hitherto perfectly inaccessible building.

The presumably simultaneous appearance of close plant formations on the mud at Broby, undoubtedly owed its origin to a diminished water supply from the springs whose water had deposited the mud. The development of Tåkern and the Dagsmosse clearly bear witness to a similar drying up. At a certain date — as far as can be judged, about simultaneously with the lessening of the supply from the Broby springs — the low-water level of Tåkern sank to 1.9 *m* below recent average high-water, and large parts of the Dagsmosse which had already existed during the pile-building period with about their present extent, and which in their phyto-physiognomic character had been a *Cladium-Carex* swamp of the same type as the well-known Gotland marshes, were covered over with abundant pine-woods, to whose former existence an extensive and well developed stump stratum bears witness. *The sub-boreal age*, the dryest and warmest phase of the postglacial period, had begun, and under the influence of its climate the surface of the lakes sank, the moist peat-grounds were covered with woods, and the springs grew weaker, not only round Lake Tåkern, but likewise over the whole of Southern Scandinavia; and, as shown above, the climatic change extended its influence even to the habitations of man, this being without doubt the primary cause of the abandoning of the dwelling-place at Alvastra.»

Hästholmen—Norrköping—Visby.

Hästholmen to Mjölby. During this journey the train passes principally an Archæan, pre-Cambrian denudation plain, the Cambrian strata being met with farther to the North (round and N. of the shallow Lake Tåkern, of the same character as Hornborgasjön W. of Mt. Billingen). The plain is commonly overlain by Quaternary deposits, which are of but little interest until we reach Mjölby. Here, in NW., an imposant *marginal plateau* (fig. 4, p. 1217), partly covered by a thin deposit of moraine, is met with, the proximal side of which continues as *a series of »feeding eskers»*. The surface of the plateau was approximately at the level of the Baltic ice-lake when the ice-border was there. Round the plateau glacio-lacustrine clay has a wide extension.

Between *Mjölby and Norsholm* the train passes at *Mantorp* a gravelly and sandy *mariginal os including portions of glacio-lacustrine clay, indicating a re-advance of the ice-border also within this district.* The same is the case at *Malmslätt*, a terminal (outwash) sandy and gravelly plain being at a lower level than the Baltic level of the late-glacial time.

Shortly after leaving the Malmslätt station the train passes a marked erosion terrace. That is *the uppermost limit of the transgressed Ancylus Lake* within this district. Farther to the NW. is an occurrence of a gravelly and sandy Ancylus beach, resting upon a peat layer. As this latter phenomenon will be better studied in the isle of Gotland, no stop will be made at Malmslätt.

Between Linköping and Norsholm a series of terminal moraines, ice-worn Archæan hills, drumlins, etc. are visible from the train.

Near Norsholm is the brick-yard of Tångstad showing sections through *Litorina clay resting upon Ancylus clay* with plant remains etc. which latter layer in its turn rests upon *late-glacial clay*. Here the before mentioned boneimplement from the Palæolitic age was found into the Ancylus clay (MUNTHE 1895).

Norrköping to Wisby. When passing Bråviken we observe the steep Archæan slope bordering it to the North and the flat Archæan plain to the South. This slope is a E.—W. fault-line, the faulted district to the South being the old pre-Cambrian denudation plain, probably during the Ice-age deprived of its Cambrian-Silurian strata, which are met with farther to the W. (round Mt. Omberg as well as E., NE. and N. of it). At »Marmorbruket» the light-coloured rock is an Archæan limestone, the so-called »Kolmorden marble», with »Eozoon».

4. The island of Gotland.

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The late-Quaternary history of the isle of Gotland being described in my above cited paper, to which is appended an English summary of the contents of some length, I may confine myself to giviny a brief account chiefly of the course of the planned excursion and some more important places to be visited.

Before entering upon my real object it is thought proper to say a few words as to the rock-ground of the island in relation to the topography.

The rock-ground of Gotland consists for the most part of marl shale and limestone, the former commonly forming a lower bed, upwards partly replaced by thin banks of limestone, which latter rock, in several varieties, forms the upper parts of the Gotlandian series. During the excursion an opportunity will be offered of seeing in places nearly the whole series represented in the steep cliffs (»klintar» in Swedish) between Visby and Stafs klint (SW. of Visby), and, besides, parts of it in the inland cliffs, as at Klinteberget, Fröjelberget, and Karlsöar.

The shore-cliffs have in places an absolute height of 35 to 50 *m*. Sometimes the cliffs are divided into two steps, as along the shore between Visby and Stafs klint. The highest point of Gotland, situated in the parish of Träkumla, is not more than 82.3 *m* above sea-level. Apart from the steep cliffs the districts which will be visited during the excursion form, on the whole, a plain covered by Quaternary deposits.

Visby to Klintehamn by carriage, with stops at Halsjärnet (SSW. of Visby), Högklint—Röfvar Liljas håla, Tomtemyr (in the parish of Tofta), the church of Eskelhem etc.

Halsjärnet. A little SSW. of Visby a stop may be made for inspecting a section through *a marginal os* (according to H. HEDSTRÖM, G. F. F. 1906, p. 421), showing strata of sorted gravel and sand *resting on a bed of boulder-marl* and also *covered by a bed of boulder-marl.* (See MUNTHE in G. F. F., 1886, where it is described as an os proper).

The *glacial striæ* on the polished limestone under the lower boulder-marl run approximately from NE. to SW., as also appears from the well developed striæ NE. of the section, whereas the ice which gave rise to the upper boulder-marl came about from NW. This is evident from the different kinds of blocks and gravel found within the younger beds here, since they for the most part arise from the strata of the adjacent shore-belt. Among other rocks represented here may be mentioned *Rapakivi granite* (chiefly from the isle of Åland), *porphyries from Dalarne* (Dalecarlia), »*Östersjökalk*» (»Baltic limestone») which is an *Ordovician limestone* from the sea-bottom N. and NW. of Åland, »*Östersjö-kvartsporfyr*»

(»Baltic quartz-porphyry») from the sea-bottom between Åland, the Stockholm archipelago, and Gotland (cfr. HEDSTRÖM 1894).

Riding along the highway south-west from Visby to the Högklint we see, to the left, the continuation of the marginal os, replaced near Wisborg by a gravelly field, and, to the right, a limestone plain washed clean by the waves except of a marked gravelly beach, *the uppermost Ancylus beach*, which runs SW. to Högklint etc. In a couple of places a stop may be made for visiting this beach and for surveying the topography in correlation to the Gotlandian rock-ground, principally the coast-cliffs between Visby and Högklint.

At that last-named place is to be seen the wide cave, called »*Getsvältan*» (the goat-starving cave), worked out by the waves of the Ancylus Lake. Farther to the SW. there are *a lower* and *an upper cliff*, the latter one showing *caves* and, in places, some »*raukar*» (stone pillars). At »Röfvar Lilja's håla» (»the cave of the robber Lilja») and its neighbourhood there is an instance of a sliding out of Gotlandian strata along old fissures, that took place in postglacial time (se MUNTHE l. c., figs. 42 and 43, facing pag. 164).

Between Högklint and Tometmyr (in the parish of Tofta) no Quaternary phenomena of special interest are visible. At Tomtemyr (the peat-bog of Tomte) there will be demonstrated the *Ancylus beach resting upon lacustrine deposits, marl-mud with Anodonta* and other molluscs, and plants, among which *Pinus silvestris* ought to be mentioned in the first place. (See MUNTHE, l. c., figs 5, 6, and 7 pp. 17—18.)

Then on foot along the Ancylus beach towards SE. to the way. A little southwards *a locality for Ancylus fluviatilis* etc. in sand with pebbles. Near the church of Eskelhem we reach *the uppermost Litorina beach*, on which the way runs towards the South to the vicinity of the railway station of Tjuls etc., resting in places upon old peat-layers.

From Tjuls towards SE. to Ejmunds, where the *Ancylus* *beach* again occurs, which will be followed farther to the South to the church of Klinte, here replaced by an erosion terrace in the hill called Klinteberget. Then to Klintehamn.

Klintehamn—Mölner—Göstafs—St. Karlsö—Visby.

The second day by carriage from Klintehamn to Mölner, where a section will be studied, which shows *the uppermost Litorina beach, partly overlain by lake marl, and, besides, resting on lacustrine deposits* (*lake marl, peat*) and *Ancylus sand* (MUNTHE 1910 a, fig. 25, p. 80).

Near Botarfve Dr. HALLE vill review the interresting section through calcareous tufa etc. (including *Cratægus oxyacuta, Hedera helix*, etc.) described by him in 1906. It is situated beneath the upparmost Litorina limit.

Then by carriage towards the South to Göstafs in the parish of Fröjel. Here a section through *the uppermost Ancylus beach*, resting on *mud* with *Corylus*, *Cladium-peat*, *marl-mud* with *Pinus* etc., and *sandy clay* (with *Salix polaris* etc.) ought to be studied (MUNTHE, l. c. a, fig. 4, p. 15).

The beach continues further to the South along the way, until the road turns towards the W. to the fishing-place Djupvik. From here or from Klintehamn, we might, if the wind admits it, take a steam-boat to St. Karlsö in order to see the important steep cliff phenomena, the uppermost Litorina and Ancylus beaches, etc. as well as the cave »Stora Förvar» (Great Safe), which was once nearly filled with culture layers, mostly from the *Stone age*, but many years ago became the object of scientific investigations (MUNTHE, fig. 34, p. 153).

In passing Lilla Karlsö cliffs, caves (both from the Lateglacial, Ancylus, and Litorina times) as well as »raukar» are visible from the steam-boat.

Between Nyrefs udde and Visby we have also a good opportunity of inspecting at some distance the steep cliffs, forming the shore-line.

On the third day, by train from **Visby to Stånga,** and by carriage from Stånga through the parishes of **När, Lau** and **Garde** to **Etelhem**; by train back to **Visby**.

SE. of Stånga (here the *Ancylus beach*) we soon enough reach the *Litorina beach* (at Tällungs), upon which the way runs towards the South to Vidringe, resting on peat at Österlings.

SE. of the church of Burs, a rocky ridge, named Burgen, extends in W. to E. It shows the *Ancylus and Litorina limits*, the former being developed as a beach, the latter chiefly as an erosion terrace. On the northern slope of Burgen *a dwelling-place of Neolithic age* ought to be visited. It lies in a height of about 70 percent of the Litorina limit (See MUNTHE l. c., pp. 153—154).

Then from Burgen to Lau backar for studying *the Ancylus and Litorina limits* there, the former being developed as an imposing *top-beach* (MUNTHE, l. c., pp. 48 to 50 and 102 to 103 as well as the map, fig. 17, facing p. 48).

A little SE. of the church of Lau the Litorina beach rests on peat etc.

From Lau to Garde (passing again the Litorina and Ancylus beaches) and Etelhem.

By train Etelhem to Visby.

During the next day eventually an excursion in the vicinity of the town.

5. The surroundings of Kalmar.

From Visby to Kalmar and excursion in the vicinity of the latter town.

As to the ***Bibliography*** see especially:

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Munthe, Henr.: The geological map-sheet of »Kalmar» with explanation. S. G. U., Ser. Ac, N:o 6, 1902. Price 2 kr.

The district round Kalmar may shortly be characterized as follows. The *rock-ground* consists of Cambrian sandstone, towards the West replaced by Archæan granite etc. forming the old denudation surface from which the Cambrian-Silurian strata are removed. Upon these rocks rest a series of glacial and late-Quaternary layers. Among them the glacial ones are represented by *till* and *oses*, the former commonly having the character of terminal ridges or a hummonocky terminal landscape. As previously mentioned (p. 1216), the moraine also in places includes portions pf seasonal clay or rests upon those deposits. The oses partly run in a SW., partly also in an approximately E. direction. Sometimes they also unite. As to the late-Quaternary deposits of the Kalmar district Dr N. O. Holst in 1899 described the following interersting series of layers (from younger to older):

a) *Younger alluvial deposits.*
b) *Sand.*
c) *Litorina clay and mud.*
d) *Sand.*
e) *Peat, mud,* etc. with the *oak flora.*
f) *Sand.*

g) *Ancylus clay and mud* with numerous fresh-water Diatoms.
h) *Peat* (»The sort stripe») with plants belonging to the *aspen*, *birch*, and oldest *fir* floras. In this layer remains of *Bos primigenius* are also met with (HOLST 1888).
k) *Sand with marine Diatoms* (sparsely).
l) *Clay with Dryas* etc.
m) *Sand and gravel with Zanichellia polycarpa.*
n) *Seasonal clay or marl.*
o) *Glacial sand.*
p) *Moraine* (till or boulder-clay).

In order to illustrate the late-Quaternary development of the district I published in 1902 and 1904 a diagram (see fig. 35), which may be reproduced here to elucidate also the changes of level (cfr. MUNTHE, 1910 a, p. 205, fig. 63, as an illustration to the analogous development of Gotland).

Only the following explanation of the figure may be given here.

The line H. Y. (the Sea- or Ocean-level) is thought to have been constant during the whole of the late-Quaternary time. This line is *dotted* for times when the Baltic's surface (= B) was not in connection with, but above that of the Ocean, i. e. during the ice-lake stage, or, more correctly, stages, interrupted by a marine stage, and *unbroken* when in connection with the Ocean across the Ladoga district to the White Sea (cfr. MUNTHE 1910 a).

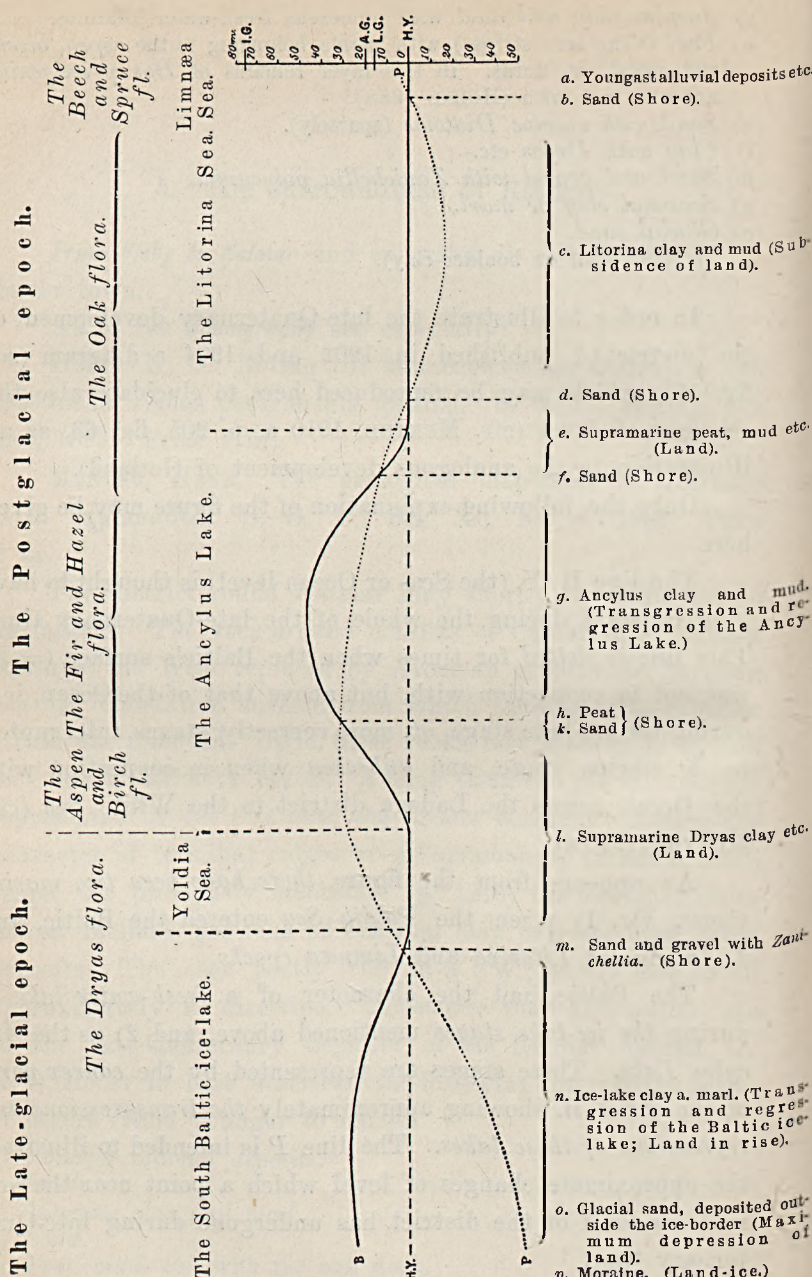
As appears from the figure, *there have been two marine stages*, viz. 1) when the *Yoldia Sea* entered the Baltic, and 2) during *the Litorina* and *Limnæa epochs.*

The Baltic had the character of a *fresh-water lake* 1) during *the ice-lake stages* mentioned above, and 2) as the *Ancylus Lake.* These stages are represented by the *convex parts* of the curve B, showing approximately *the transgressions and regressions of these lakes.* The line *P* is intended to illustrate the approximate changes of level which a point near the present sea-level of the district has undergone during late-Quaternary time.

I. G. (= *the uppermost Late-glacial limit*), A. G. (= *the*

Fig. 35.

The evolution of the Kalmar district during Late-Quarternary time, graphically illustrated.



uppermost Ancylus limit), and L. G. (= *the uppermost Litorina limit*) on the scale of the diagram represent points which once coincided with the lake and sea surfaces in question. Their present height above the sea appears from the scale.

To study these geological features we take the train from Kalmar to Läckeby and then we go by carriage first to Svartingstorp and later on to Mossberga. Near these places sections will be studied. By train back to Kalmar and then to Alfvesta and Skåne.

Between Kalmar and the railway station of Trekanten we pass the above-mentioned hilly moraine landscape. W. of Trekanten the first Archæan hills will be visible. At Nybro plains of sand and gravel, partly eroded, mark approximately the uppermost limit of the Baltic ice-lake, about 85 *m* above the sea.

Between Nybro and Alfvesta the train passes in places late-glacial lake and river systems represented by plains of sand and gravelly sand, as at Örsjö, Lindås, Skruf, Hofmantorp, etc. In the vicinity of Alfvesta such a system has a wider extent, being represented also by ice-lake clay. Such other systems are to be seen between Alfvesta and Lund as at Wislanda, Elmhult, Hör, etc.

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Contents.

82*—*100170. G. F. F. 1910.*

The Långban mines.

By

HJ. SJÖGREN.

(With two Pls. 50—51)

Introduction.

It is not known when the Långban mines were first worked, but they are certainly, together with the Nordmarken and Persberg mines, among the oldest in Värmland.[1] FERNOW states that the »Långban mines are said to have been discovered before the Black Death. The smelting-houses of Born, Saxå and Gåsborn are the oldest there». He goes on to mention that the Långban furnace was established in 1550 and that at that time the iron-mines of Nordmark, Persberg and Långban were in full swing. The report of the Bergmaster for 1658, however, states that the owners of the Långban furnace at that time fetched their ore from Persberg, which indicates that the Långban mines were then shut down. This is also confirmed by the reports of the year 1711, which state that the Långban mines were discovered 200 years before, but had lain waste until the spring af the year mentioned.

[1] Finds from the Stone Age have proved that the district around what is now Långbanshyttan was inhabited earlier than the rest of this part of Värmland. This certainly stands in connection with the rich vegetation and fertile soil which is due to the dolomite rock in that part. Cfr. H. V. TIBERG, Värmland förr och nu. 1908.

From that time we have reports that show that mining went on without interruption. During the period when the iron-mines were deserted, however, the silver-mines seem to have been working, for the report of 1658 states that the Bergmaster ERIK JOHANSSON worked up the silver ore that was broken in the neighbourhood of the smelting-house, in the silver-foundry situated at the Långban works. That ore certainly came from some of the insignificant deposits of galena and sphalerite that occur in several places in the dolomite.

The Långban mines have been worked all the time on iron ore, chiefly hematite, which is smelted by the proprietors of the mine. The richer iron ore contains silica, the poorer, on the other hand, is rich in lime, and the mixture is suitable for smelting without flux. The percentage of phosphorus is throughout low.

Of the manganese ores the hausmannite was discovered first, and the braunite in 1878; the manganese ores now first began to be turned to account. The Långban manganese ores are used either as they are mined or after concentration, partly for metallurgic purposes, mainly for bessemer, partly in the glass industry. But the chief production still consists of iron ore. During 1908 there were mined 6,442 tons of iron ore, with a value of about 74,000 kronor; the same year 3,179 tons of manganese ore were mined, with a value of only 47,000 kronor. It is, consequently, not correct to designate Långban, as has sometimes been done, as only a manganese mine.

The oldest geological description of Långban occurs in TILAS' »De värmländske malmfältens system» (MS. 1760).

TILAS begins by holding forth that the »ore district»[1] of Långbanshyttan might be compared with that of Persberg,

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[1] By »ore district» TILAS means such areas of ore-bearing rocks, hälleflinta, limestone etc., which are everywhere surrounded and bounded by none metalliferous granites. The various groups of ore deposits in each »ore district» he calls »ore fields».

since it is not proved that they are separated by any granite. Since, however, the ore district of Långban »has not the remotest connection or similarity with all the remaining ore fields in the whole parish of Fernebo», he has described it as a special ore district though it does not enclose more than one single ore field.

He describes the country rock (»Hällearten») as a light limestone, almost as compact as marble, blackening on exposure, »whose veinage proves to run from east to west».

The gangue consists of a reddish brown hälleflinta, called »Rödbinda», which evidently refers to the ferruginous quartz. He also calls it »a reddish brown jasper standing in venous nodules and following the veinage of the limestone east-west. . . . Sometimes this brown jasper is heightened in colour and stands in patches and nodules of vermilion jasper». Another gangue is referred to as a yellowish garnet.

As to the ore deposits themselves, TILAS says that on the surface and a good way down they appear as veined spots extending east and west, like the gangue and the veinage of the limestone. These scattered spots collect towards the depth into ore-stocks made up of several ore-bodies of varying size. TILAS states that the uniform pitch is westerly. He then describes the two mines that were working at that time, the Stora grufvan and Collegiigrufvan, of which the former had reached a depth of about 40 fathoms, the latter 15 fathoms. He mentions that although both these mines lie lengthways one after the other, they do not lie in the same line.

No geological description of the Långban mines seems to have been published since TILAS' time besides the note by H. V. TIBERG, 1897 (see below).

HISINGER [1] published a number of mineralogical statements, but he throws very little light on the geology of the ore-field;

[1] Mineralog. Geographie von Schweden, translated by WÖHLER. Leipsic 1826.

still he mentions that the so-called limestone consists of dolomite, in which the ores occur as nodules. And neither HAUSMANN nor DUROCHER, who have given such excellent descriptions of many Swedish mines, have anything to say about Långban. On the other hand, the mineralogical literature on Långban is especially abundant from the beginning of the seventies (19th century), when the manganese deposits began to be worked, which led to the discovery of a large number of rare minerals.

IGELSTRÖM's and TÖRNEBOHM's geological maps of the mining district of Filipstad, of which the former was carried out in the sixties, the latter printed in 1877, threw light on the geological relations in the vicinity of the mining field. For a knowledge of the geology of the ore deposits themselves, however, one is almost exclusively thrown upon the studies and reports carried out by the manager, H. V. TIBERG, and published in »Värmländska Bergsmannaföreningens Annaler» and in »Brytningsberättelserna till Grufveaktiebolaget Långbans bolagsstämmor». The observations conveyed in the following are consequently drawn to a very great extent from these publications. The manuscript of the Guide that follows has moreover been looked over and amplified by TIBERG.[1] The geological map appended was drawn up in 1901 by BJÖRN TIBERG, mining engineer, on the basis of TÖRNEBOHM's map.

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[1] H. V. TIBERG's most important works with reference to the geology of Långban are:

Om kalkstenar och dolomiter etc. Värml. Bergsmannaför. Ann. 1901.

Beskrifning till en vid Industriutställningen i Karlstad år 1903 anordnad kollektivutställning etc. 1903.

Beskrifning till H. V. TIBERGS utställning: »Belysning af malmbildningsproblemet». Karlstad, 1903.

I malmbildningsfrågan, Värml. Bergsmannaför. Ann. 1907.

Several notes and reports in Värml. Bergsmannaför., especially 1897—1899.

Mining reports for Company meetings, especially after 1900.

Moreover, Tiberg has written a description of the Långban field in G. NORDENSTRÖM's descriptive catalogue of the Mining Exposition of Central Sweden (Stockholm 1897), which is in fact the first description published since TILAS' time.

Rocks.

The crystalline schists, which here, as throughout the ore-bearing district of Central Sweden, constitute the oldest and at the same time the only ore-bearing formation, are represented in the tract around the Långbanshyttan by granulite and dolomite. Closely allied to these rocks is a gneiss-granite. Younger than this oldest division of the Archean rocks are two intruded granites, Filipstad granite and one probably still younger, fine-grained granite; to these are added a diorite, which appears in huge intrusions or also in narrow dikes, and finally diabase in dikes. The number of rocks that take part in the structure of the district is consequently somewhat large, and the geological structure of the district is on the whole rather complicated.

Granulite (leptite). This rock is the same here as in other parts of east Värmland. It stretches in a continuous area W. of the lakes Hyttsjö and Långban, down to Yngen, and is consequently connected with the granulite field that almost entirely surrounds the last-named lake, and which here *inter alia* contains the largest ore-field in Värmland, Persberg.

The granulite district between Yngen and Långban, moreover, presents a large number of minor ore deposits, of which the majority are worthless.

The granulite of Långbanshyttan, such as it crops out W. and S. of L. Hyttsjö, is a light plagioclase rock. In a fresh condition the rock shows light ruddy, light gray, or yellow colours. The weathering crust is almost white.

The microscopic picture shows a rock that reveals few chemical transformations, but on the other hand bears traces of strong mechanical destruction. The felspar is on the whole fresh, without sericitization, and the femic constituents, of which biotite is always present, though in varying quantities, are equally little affected. The zones of coarser albite and quartz material occurring in the fine-grained homogeneous ground-mass, which obviously consist of crushed and laminated porphyritic phenocrysts, witness to the mechanical stretching or laminating process to which the rock has been subjected.

In the N. part of the granulite district the rock assumes another appearance and resembles more the granulite which is designated by Törnebohm as dark, gray or green granulite and is referred to the upper granulite division.

Quite different is the granulite appearing in the Storgrufvan and the Collegiigrufvan. It occurs there as a thick wall, enclosed in the dolomite and upwards decreasing in size. At the 110 *m* level in the Bergmästare drive, which is the highest level where it is observed, it is quite narrow; it then widens deeper down, so that already at the Räms drive at 130 *m* it is more than 20 *m*, and in the Botten drive at 150 *m* its intersection reaches 65 *m*. At the 130 *m* level and, moreover, at several other places it is bounded on the E. by a thick »sköl» [1] of chlorite, which seems to be no more than a transformation of the granulite. This granulite differs from the common country rock by its darker appearance owing to a greater amount of biotite. The composition is shown by the following analyses, executed by G. Nyblom. [2]

A. Granulite (lamprophyric) in the working »Japan» from an apophyse from the main granulite stock;

B. Granulite (lamprophyric) from Bjelke's shaft, 150 *m* level;

C. Granulite from the Lesjöfors drive, 150 *m* level.

D. Granulite from the Smedje drive, 150 *m* level.

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[1] The Swedish word *sköl* indicates mineral formations of secondary origin chiefly consisting of minerals from the amphibole-, mica-, chlorite- and serpentine-groups and occurring closely connected with the ore deposits.

[2] These analyses, not before published, belong to the series of analyses, which the author of this paper has had executed for the purpose of an investigation of the rocks connected with the ore-bearing formation of Central Sweden.

	A.	B.	C.	D.
SiO_2	52.91	56.12	66.67	69.47
Al_2O_3	23.04	20.20	18.01	13.67
Fe_2O_3	1.20	3.05	0.84	1.35
FeO	0.54	2.47	1.22	2.47
MgO	6.37	5.61	3.54	5.71
CaO	0.78	1.05	0.21	0.76
Na_2O	2.72	1.87	0.84	2.07
K_2O	9.95	7.83	6.91	2.97
H_2O	1.31	1.35	1.27	1.11
TiO_2	0.12	0.30	0.23	0.23
P_2O_5	0.28	0.02	0.02	0.03
S	0.09	0.02	0.06	0.06
MnO	0.19	0.10	0.06	0.06
Totals	99.50	99.99	99.88	99.96

It is evident from these analyses, that the chief felspar constituent in this granulite is a kali-felspar in contrast to the surrounding country rock. Remarkable is also the great amount of magnesia. The composition of this rock is in the main lamprophyric; in some varieties the felspar constituent decreases and the rock is chiefly composed by quartz and mica (the Smedje drive, 150 *m* level).

The ***Dolomite.*** The main distribution of this rock is on the neck of land between the lakes Hyttsjön and Långbansjön; but it also occupies some of the points of land on the E. side of the last-named lake. The largest extension of the dolomite area in the N. and S. is about 4 *km*, the greatest width reaches 1 *km*; a part of the dolomite area, however, lies beneath the lakes.[1]

[1] The extent of the dolomite also reveals itself by essential changes in the flora, as was already pointed out by M. Larsson (1852) and afterwards emphasized by Tiberg. It seems as if the flora on the dolomite differed somewhat from that on the limestone ground. The flora of Långban has been famous since olden times. Among lime and dolomite plants may be named *Anemone hepatica, Primula veris, Daphne mezereum, Vicia silvatica, Lonicera xylosteum, Orobus vernus* and several orchids, including the magnificent *Cypripedium Calceolus.* Also the woodland produce of the soil is very much increased. Tiberg's investigations show that while the yearly timber growth on the granulite ground at Långban comes to 1.6 *cbm* of compact mass, on the dolomite ground it amounts to 8 *cbm.*

Within the area in question the rock has almost a normal dolomite constitution, and seems to be fairly homogeneous. In contrast to what is the case on the peninsula of Persberg, on Getö, and elsewhere, the dolomite does not occur, consequently, within the Långban district in combination with limestone.

The dolomite is frequently striped owing to the occurrence of lime-magnesia-silicates, which are distributed in stripes. The stripes are easy to observe on weathered surfaces, since the purer carbonate stripes have there been attacked by the atmospheric agents to a greater extent than those richer in silicates, whence these latter stand out like little ridges; at other places the striping is distinguishable through differences of colour. These edges are mostly between 1.5 and 5 *mm* in thickness, sometimes more.[1] Often the dolomite is spotted by serpentine.

An analysis of the ordinary striped dolomite shows that this, too, is of comparatively great purity, and that the proportions between lime and magnesia nearly correspond to those of the normal dolomite.[2] The dolomite spotted by serpentine is more impure and contains more iron and silica.

	Dolomite	
	striped.	serpentine spotted.
Insoluble in acids	2.63 (SiO_2 2.42)	7.11 (SiO_2)
Iron oxide	1.18	2.34
Alumina		0.78
Lime	30.70	33.82
Magnesia	20.80	19.81
Manganous oxide	0.51	0.62
Carbonic acid	44.33	35.02
	100.15	99.50 %

[1] The striping in the dolomite is sometimes so regular that is has been compared by H. V. Tiberg to annual strata. He calculates that the average thickness of the stripes is about 2.2 *mm*, from which the conclusion is to be drawn that the deposition of the whole mass of Långban dolomite should have taken about half a million years.

[2] The analysis is taken from H. V. Tiberg: »Om kalkstenar och dolomiter» (V. B. Ann. 1901, p. 23).

In the mines it can be observed how the dolomite, when struck by the hammer, phosphoresces intensely with large flashes.

In the ordinary dolomite territory there occur frequent small immigrations of gangues especially in fissures, as well as sometimes iron ores; they are of the same nature as the large ore deposits, only developed on a smaller scale; in several places they have given rise to exploratory working. But on the whole it may be said that as long as the dolomite retains its primary striping or is spotted with serpentine, it contains neither ore nor skarn[1] deposits worth considering. These appear as evident fissure-fillings. Of the same kind are the sulphide ores, copper-pyrites, zincblende, and galena, which appear in the Långban dolomite and have given birth to the mines at Getberget, Lahäll, and elsewhere.

Different from the usual, striped dolomite is the so-called pure dolomite, which occurs together with the ores and the »sköls». It is marked by an absence of silicate compounds; as consequently the silicates, which give the usual dolomite its striping, are absent, the pure dolomite is quite massive.

It is known by experience that pure and unstriped dolomite does not occur save in combination with ore or »sköl» formations. The dolomite which most nearly surrounds the ores and gangues is as a rule either pure or irregularly interspersed among ore or skarn, but it is clearly distinguished from the striped dolomite described above.

The occurrence of such pure dolomite is, however, very irregular. As a rule it occurs in the foot-wall of the ores, e. g. in the Norbottensrummet under and beside the manganese ores at the 96—116 *m* level; in other places it occurs in the ore, surrounded on all sides by iron or manganese ore. The

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[1] *Skarn* is a Swedish term given by miners to the mineral associations that in many of the Swedish iron ore deposits are mixed with the ore and separates it from the country rock.

pure dolomite is also in several places connected with »sköl» formation.[1]

The average composition of the pure or unstriped dolomite is shown by the following analysis, carried out on samples taken from various workings in the Långban mines.

Insoluble in acids	0.69
Iron oxide	0.71
Alumina	0.10
Carbonate of lime	54.20
» of magnesia	44.39
Phosphoric acid	0.014
Sulphur	0.004
	100.108

It will be noticed that this almost corresponds to the constitution of pure, normal dolomite. The nature of the pure dolomite, as compared with the primary, shows that the injection of the ores has been accompanied by certain changes in the character of the dolomite. This is still more evident, if we compare the constitution of the carbonates accompanying the ores with the surrounding dolomite. TIBERG[2] has pointed out that the average of 7 analyses of dolomite from Långban give the relation MgO : CaO = 1 : 1.48. In a general sample of all the Långban iron ores the same relation comes to 1 : 1.55; in hausmannite ore 1 : 1.65, and in four analyses of manganese ores, both hausmannite and braunite, on an average 1 : 2.35. In the Långban tailings after concentration of manganese ore the relation is 1 : 2.6. These figures show that the amount of magnesia diminishes in connection with the immigration of the ores, but the decrease is much greater in the manganese ores than in the iron ores. In the manganese ores, however, there is always found barium carbonate, which

[1] TIBERG. Mining report for 1907, in the annual report presented at the meeting of the shareholders of Långban, June 9, 1908, p. 24.

[2] TIBERG. Om kalkstenar och dolomiter, Värml. B. Ann. 1901, p. 33.

seems to enter and substitute part of the magnesia carbonate; the percentage of baryta in this ore sometimes amounts to about half of that of the magnesia. To this is added in the maganese ores also a variable percentage of lead carbonate, which usually amounts to about half that of the barium carbonate.

Archæan Granite. With the crystalline schists are closely connected the gneiss-granite or »katarchæan» granite which bounds the granulite district on the W. This is the same rock which TÖRNEBOHM called Horrsjö granite, and which also appears N. of Persberg. The boundary at the granulite formation is as usual uncertain; the granite nearest the contac exhibits pressure structures, while nearer the centre of the district it shows more granitic characteristics. On the whole this rock is distinguished by strongly dynamo-metamorphic characteristics, such as mortar structure in the ground-mass consisting of quartz and felspar etc.

The ***Diorite.*** Most closely connected with the crystalline schists come rocks of dioritic composition, which appear in several places around Långban. A large diorite sill or intrusive sheet stretches NE. of Lake Långban and a smaller one is situated N. of L. Hyttsjö. A diorite dike with a length of about 6 *km* intersects the granulite district W. of Hyttsjön and Långban and reaches as far as Lilla Horrsjön. To what extent these masses and dikes of diorite are mutually connected geologically, cannot at present be decided.

The microscopic picture reveals that all these dioritic rocks, both the dike-shaped and those occurring as sheets, are composed of strongly dynamo-metamorphically transformed rocks, marked by secondary structures and new mineral formations. The amphibole that constitutes the main mass, occurs in clusters, radiated masses or irregular spots, surrounded by a ground-mass of secondary plagioclase. Yet at times there may be observed relics of an ophitic structure: lath-shaped plagioclase, finely twinned, is interspersed in large individuals of green amphibole. A part of the amphibole has obviously arisen through transformation of a primary pyroxene mineral, of which small, unaltered relics are to be met with surrounded by amphibole. To the diorites we may probably refer the dike-shaped rocks that appear in many parts of the mines, even if the original nature of these rocks must be considered as not decided. The most remarkable are those that in the form of almost horizontal dikes occur in the Gustafsgrufvan at a depth of 54 to 60 *m.*[1] The peculiar relation of the ores to these diorite dikes is dealt with below.

The trap dikes in the Gustafsgrufvan are considerably transformed. In places an epidotization has taken place on a large scale. In the first stage the rock is intersected by narrow yellowish green stripes of epidote; in the end the rock may be almost completely changed to epidote. At other places the rock is so altered that it resembles a dark-green earthy mass, or it may be completely dissolved, so that of the whole trap dike there is only left a white clayey mass, which in the air hardens into a kind of mountain-leather-like substance. On the whole these trap dikes illustrate in a splendid way the various changes to which old basic eruptive dikes may be subjected. Even where the trap is least changed, yet at the edges and sides it is transformed into a chloritic »sköl». The two following analyses give the composition of the trap from the Gustafsgrufvan:[2]

A. Black, comparatively unaltered.
B. Largely epidotizied.

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[1] H. V. Tiberg. »I malmbildningsfrågan». V. B. A., 1904, p. 16 and elsewhere.

[2] Compare note 2, page 6.

	A.	B.
SiO_2	49.47	43.22
Al_2O_3	17.47	18.95
Fe_2O_3	2.56	10.73
FeO	6.70	1.72
MgO	6.11	2.08
CaO	9.36	18.40
Na_2O	2.52	0.41
K_2O	2.31	2.09
H_2O	1.58	1.04
TiO_2	0.70	0.50
P_2O_5	0.18	0.12
S	0.10	0.27
MnO	0.20	0.70
CO_2	0.75	—
Totals	100.01	100.23

The chemical alteration thus consists in loss of SiO_2 and Na_2O, oxidation of FeO to Fe_2O_3 and exchange of MgO for CaO.

Similar transformed dikes are met with also in the Storgrufvan and the Collegiigrufvan; thus, e. g. in Bjelke's shaft or the Konst shaft a narrow dike of 0.4 *m* in thickness was passed through at a depth of about 180 *m.*[1] This too was in part so decomposed that only a little mountain-leather and a dark earthy mass was left. A cavity so large that a man could creep in was formed in the dike, and contained masses of large calcite crystals.

The ore deposits, their form and position.

A study of the map of the mines already shows that the Långban deposits are divided up into several parallels or zones which with a main strike WNW. to ESE. traverse the dolomite. The most important parallel is the one in which are situated the Storgrufvan and the Collegiigrufvan, which have

[1] It is doubtful if this rock belongs to the diorite or to the lamprophyric rocks described above.

been worked since olden times; to the same parallel also belongs the Norrbotten ore, which has been worked during the last twenty years. The zone of the Gustaf mine is situated about 600 *m* more to the north.

However, these zones or parallels are themselves made up of subordinate ore-shoots, which lie somewhat obliquely towards one another. In the first named zone, which has a general strike from WNW. to ESE., the three ore-stocks, the Stor-, Collegii- and Norrbotten mines, have each their separate strike E.—W. Besides these main stocks there are several smaller stocks belonging to the same zone.

The dip is sheer on the S.; the pitch is constantly to the W., but varying in degree of inclination.

It is characteristic of the Långban ores that on the surface they have been of comparatively small dimensions, but increased towards depth, so that at about 110 *m* they have united into one continuous ore body of over 360 *m* in length. The largest ore area is at a depth of from 70—110 *m*, where it has reached 9000 m^2, the manganese ores included. Similarly the manganese ore-bodies at the higher levels are small and scattered; they were scarcely observed until a depth of about 30 *m*. In the Gustaf mine the largest ore area was hitherto 2000 m^2, at a depth of 40—50 *m*.

The forms of the ores at Långban are much more pronouncedly stock-shaped than at the granulit deposits, e. g. Persberg, where the lens-shape is predominant. In the Långban mines the shoots have an almost round or oval intersection. This shoot-shape may probably be regarded as connected with the more massive structure of the surrounding rock, the dolomite. In the ores situated in the granulite, on the other hand, there is a lateral extension, corresponding to the parallel structure of these rocks. What is most characteristic of the shapes of the Långban ores is their pronounced stock-shape; each one of the chief mines, the Collegii-, Stor- and Norrbotten, are mined on a complex of several larger or smaller stocks lying beside each other, of which some contain manganese and others iron ores; most of the stocks contain both iron and manganese. An example of such a stock, or more correctly speaking, complex of stocks, is the one, chiefly consisting of specular iron ore (hematite), which was mined from the surface in the Collegii mine and which continued below the Botten level (150 *m*) and is even known at the 200 *m* level. The ores worked in the Bergsråd pit are manganese ores belonging to the stock of the Collegii mine; this working is especially known for the numerous rare minerals that occur there.

The Storgrufva ore forms another complex of stocks, which as far as is known, cease to be worth mining at 110—120 *m*. It is also known at lower levels, but it occurs there sporadically and is not worth mining The iron and manganes ores in these stocks, put together, have a thickness of up to 20 *m*.

The Norrbotten stock is very inconsiderable at the surface, and begins to be minable at 50—60 *m* below the surface. This ore-body, as also the ore body of the Storgrufvan, for a distance of 120 *m* or more lies almost horizontal. The width of the ore reaches 20 *m* and more. At a depth of about 110 *m* the ores in the older workings, as well as in the Norrbotten mines, have a tolerably flat position, but at about 120 *m* the Norrbotten ores dip down steep, while the ores of the older workings below this depth decrease rapidly. The deepest workings in the Långban mines are now development works, which at a depth of 187 and 200 *m* have opened up iron as well as manganes deposits in the extension of the Collegiigrufvan at the 163—166 *m* level, situated entirely in dolomite.

The ores of the Gustaf mine also begin with small dimensions on the surface, but expand considerably with depth, and have their greatest extension at the 50 *m* level, where they spread out on the top of the system of almost horizontal trap dikes of which mention was made before. Above these trap dikes the ore has a width of 26 *m* with a length of 85 *m*.

Below the trap dike the new ore has a width of only 2—3 *m* but increases somewhat with depth.

The main mass of the Gustaf mine deposits consists of hematite with some magnetite. Manganese ore (hausmannite) only occurs insignificantly. On the other hand the percentage of manganese in the iron ore is almost double as much as in the other Långban mines.

The gangue rock of the Gustaf mine consists principally of garnet. It is characteristic that the top end of the new ore-shoot, which was met with under the trap dikes, contained a good deal of ferruginous quartz, which is otherwise uncommon in this mine.

Mineralogical character of the deposits.

As is well known, the deposits that are mined in the Långban mines consist of both iron ore and manganese ore. The iron ore was exploited exclusively up to the beginning of the seventies of last century and continues to constitute the main product. From a geologic point of view the ore deposits of Långban belong to the same large group of deposits as all the other mines within Filipstad's Bergslag.

It is characteristic of the Långban deposits that iron ores and manganese ores occur, on the whole, separated and independent of each other, although so close that they are mined in the same workings.

The iron ore generally contains less than 1 % of maganese and the manganese ore only about 1 % of iron. The circumstance that the iron and mangenese ores do not occur as a mixture but separately, seems to indicate that they are independent of each other and probably formations of different age. This is proved also by the circumstance that their gangues differ with regard to the mineral association. This separation of iron and manganese, which is so characteristic of the main deposits at Långban is only true to a smaller extent of the Gustaf mine, the iron ore of which contains almost double as much manganese as the Långban ore. The iron and manganese are consequently not separated in the same degree in the Gustaf mine as in the other Långban mines, which makes itself known by the fact, that

Fig. 1. Braunite in dolomite.

in the Gustaf mine scarcely 100 tons of manganese ore were mined during the time that more than 60,000 tons were mined in the other Långban mines.

The iron ore consists of both magnetite and hematite; but the latter predominates so greatly that it claims 70—80 % of the whole iron ore production. The hematite of Långban has, when pure, a characteristic fine grainy structure. Like all Swedish hematites it has some magnetite in it, as revealed by the analyses; sometimes the magnetite is separated off as large crystal individuals in the hematite.

The manganese ores appear in two kinds: as hausmannite and braunite. The occurrence of braunite was not established before 1878; it had earlier been mistaken for magnetite, and some of the so-called magnetite of Långban had consequently not enjoyed a particularly good reputation. The manganese ore-shoot chiefly containing braunite, discovered in 1878 as constituting the foot-wall of the Collegii mine, has since been developed and mined to a maximum width of over 20 *m* and a length of more than 65 *m*. The braunite predominates in the shoot of the Collegiigrufvan and in the Norrbotten shoot; in the Storgrufva shoot, on the other hand, the manganese ores are represented exclusively by hausmannite.

The poorer hausmannite often shows a fairly evident striping by parallel arrangement of the ore grains and the accompanying minerals, which almost exclusively consist of lime or dolomite without any admixture of silicates. The richer hausmannite can by hand dressing be brought to a percentage of as much as 47 % Mn. The braunite, which in itself contains silica and besides often is mixed with silicates, never exceeds 45 % Mn.

The ores in their relation to each other. Relation of the manganese to the iron ores.

In Långban the iron and manganese ores occur separated, yet side by side. At a number of places, e. g. the Hörken (22—40 *m*), President pit (40—58 *m*) and Bergsråd pits (20—95 and on 187 *m* level), the Storgrufvan (26—45 *m*), Garibaldi (56—74 *m*), Pumphålet (110—115 *m*), the Norrbotten shoot (110—150 *m*), the manganese ore has as a rule been found in the foot-wall, the iron ore in the hanging-wall. As long as the sedimentary theory prevailed, this led to the assumption that in the supposed stratification the manganese ores should occupy a lower level than the iron ores.[1] The fact that the iron ores in several places in the mines are situated in the hanging of the manganese ore can, however, have no importance for the question of age, since stratification is out of the question, and even if such were not the case, it is impossible to say what is the actual hanging, since the position of the strata is so highly raised. In many places iron ore occurs without any manganese ore near it; sometimes even the opposite is the case. Ore of one kind can also occur as portions enclosed in the other; thus TIBERG[2] states that in the middle of the large braunite shoot of the Bergsråd pit lie two quite large, pure horses of hematite; one of these lies in the margin of an untransformed section of dolomite, which is likewise surrounded by manganese ore.[3] There is no universal rule for the position of the manganese and iron ores in their relation to each other. It often appears as if the iron ores were surrounded by manganese ores; but the opposite can also be the case, e. g. in a part of the Norrbotten working, where a sheet of iron ore has almost entirely surrounded the manganese ore shoot.[4]

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[1] Descriptive catalogue, p. 43, 1897.

[2] On limestones and dolomites etc.

[3] To some extent comparable with these enclosures of iron ore in the manganese ore shoots are the enclosures of large lumps of other metallic minerals that occur occasionally. In the pure braunite-shoot of the Norrbotten working an isolated lump of at least a ton of melanotekite (a silicate of lead and iron with about 58 % of lead oxide) was found. In the iron ore shoot of the same working was found, in 1901, a lump of nearly a ton of chalcocite entirely enclosed by magnetite; a similar but smaller nodule of chalcocite had been found a few years earlier in the Lesjöfors working, at a somewhat higher level. No trace of copper could be found in the surrounding iron ore.

[4] Mining report for 1908.

Relation between hematite and magnetite, and between braunite and hausmannite.

The hematite and magnetite of Långban stand on the whole in the same relation to each other as at other Swedish hematite mines, viz. that the hematite occurs in the core of the ore-shoots, the magnetite with its characteristic gangue of pyroxene and amphibole, garnet, etc., in the points or peri-

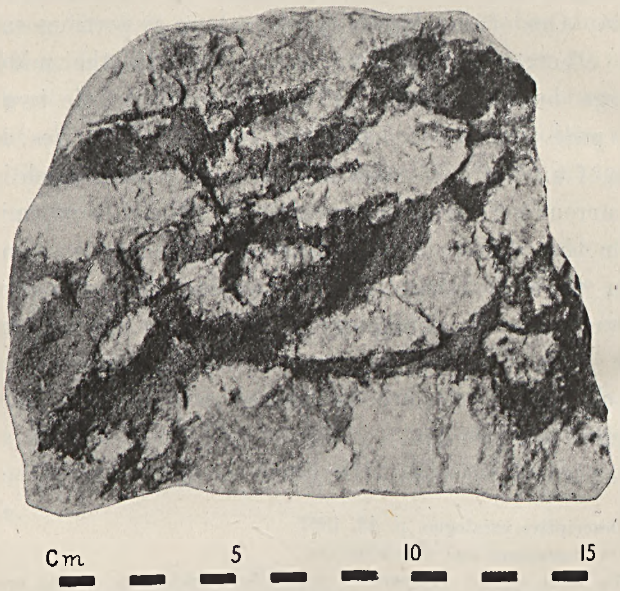

Fig. 2. Magnetite invading the dolomite, and enlarging the fissures through solution causing a pseudo-brecciated structure.

pheric parts of the ore-shoots. This is also repeated on a small scale, so that quite little nodules or stripes of hematite are always surrounded by a narrow zone of magnetite. It is especially the upper parts of the ore-stocks that are rich in magnetite. Above occurs skarn of malacolite and ferruginous quartz as gangue.

The braunite and hausmannite appear in quite an analogous manner, in that the braunite, which corresponds to the hematite, occurs in the interior of the manganese ore-shoots, the hausmannite, on the other hand, in their outskirts; when it is poor and mixed with lime and dolomite, it is sometimes striped. The hausmannite therefore often appears in bands of from a few decimetres up to a metre in width, while the braunite appears in shoots up to 20 *m* and above. When the ores, especially the iron ores, occur directly in the dolomite without interspersed gangue, we can often observe

Fig. 3. Braunite invading in the dolomite through fissures and later enlarging the fissures, through solution causing a pseudo-brecciated structure.

a kind of brecciated structure, the ores appearing as fissure-fillings in a pseudo-breccia composed of remnants of untransformed dolomite. Yet the brecciated structure is false, since the fissures are enlarged by solution, so that the fragments can no longer be fitted together; they have also assumed rounded forms, which is more and more conspicuous with advancing transformation. However, it is evident that the first invasion of the ores followed fissures in the dolomite. Proceeding further, it penetrated the whole dolomite mass, and large portions of the dolomite have in this way been transformed into ore. In finer fissures, which are filled with hematite, we can see that the latter is transformed at the edges into magnetite.

If we compare larger pieces of ore-bearing dolomite from Långban with such pieces from Sala, it is impossible to doubt that the way of formation is the same in both. The pseudo-brecciated structure in the ore-bearing dolomite is quite similar in both places. The only difference is that while the ore-shoots in Långban consist of iron and manganese oxides, those in Sala are galena and zincblende. Certain pieces of ore from Långban showing the invasion of galena in the dolomite present a confounding likeness to those from Sala.

The gangue.

In connection with the ore-shoots various kinds of gangue appear; the gangue of the iron ore, the so-called »green skarn», consists mainly of compact, grayish green malacolite. The green skarn appears in large masses in the vicinity of the deposits, especially above the ore-shoots. The black calcareous iron garnet (andradite) is a companion of the ores and is used as a guide in searching for them; the brown lime-alumina garnet belongs to the not ore-bearing parts of the skarn. The black garnet at Långban, as at the other places, is younger than the ore and skarn formation for the rest, as is evident from the fissures filled with black garnet of varying dimensions up to a metre in size which intersect the ore. It is noteworthy that the green skarn appears by preference in the roof of the ores, in the tops of the ore-shoots, or in their hanging.

Among the gangue that is especially characteristic of the hematite may be mentioned the ferruginous quartz, which is composed of quartz and microscopic scales of hematite, in which case it is red, or of magnetite, in which case it is dark gray. In olden times i. e. on higher levels, it enjoyed great repute as an indication of the continuation of the hematite and as a guide in finding it; it has been pointed out that the ferruginous quartz is incomparably more common in the upper than in the lower parts of the mine.[1] However, the fact seems to be that the ferruginous quartz and the quartz-bearing gangue are limited to the tops of the ore-stocks or, when they have a horizontal position, to their upper edge, so that when at greater depths ore-stocks are found which do not crop out, they contain ferruginous quartz in the upper ends or edges. Such was the case, for instance, with the Norrbotten ore, which at a depth of 105—110 *m* contained ferruginous quartz and quartz-bearing gangues. Similarly with the ore-shoot that appears in the Gustaf mine under the system of trap dikes. The richer hematite is always somewhat quartz-bearing, but not quartz-striped; the poorer varieties may be mixed with lime or dolomite. It is consequently an universal rule that the gangue, whether it has a more basic constitution, as the green skarn, or a more acid as the ferruginous quartz and the masses of the quartz that accompanies it, appears especially in the tops or in the roof of the ores. In the foot-wall and at the lower ends the ore-stocks terminate, as far as has been ascertained hitherto, directly in the dolomite, without interposed skarn masses.

The gangue that occurs in connection with the manganese ores plays a smaller part quantitatively than is the case with the iron ores. It scarcely appears as large independent masses of skarn, but rather as admixtures in the ore-shoots. The manganese pyroxene and amphibole species schefferite rhodonite, and richterite, and the manganese garnet are the most important. Tephroite also occasionally occurs to such an extent that it can be counted with the constituents of the gangue.

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[1] TIBERG. Värml. Bergsmannaför. Förhandl. 1898, p. 21.

Sulphide ores.

As in the majority of other iron-mines various sulphides occur in Långban in connection with the iron ore. As has already been said, there appear in the vicinity of Långbanshyttan, within the dolomite area, several minor zinc, lead and copper deposits, of which some, e. g. Lahäll and Getberget, have been mined.

In the Långban mines sulphide ores occur in greater amounts at the deep parts than in the upper levels of the mine. In the so-called Blyglansorten (galena drive) at the 146 *m* level and in the W. end of the Bade drive at 165 *m* level galena occurs abundantly in the dolomite as irregular crevice fillings. Copper pyrite occurs commonly together with magnetite and green skarn. The lumps of chalcocite occurring in the Norrbotten, Lesjöfors and Rämmen workings have already been mentioned.

The mode of occurrence of the sulphide ores shows that on the whole they are formations contemporaneous with the other ores, or at least that the have the same origin as the ore formation as a whole. In several places there have been observed immigrations of copper pyrite, bornite and magnetite filling the crevices in the dolomite. Also the sulphides are accompanied by gangue, so that in this case, too, there is a conformity with the iron ore formation.

Nevertheless in some places it seems as if the sulphide ores were the youngest of the ore-minerals or at least that they have occupied their present positions later than the rest of the ore-formation.

»Sköls» and faults.

»Sköls» of, on the whole, the same nature as are found in company with other iron ores in Central Sweden occur in numbers at Långban. Often these »sköls» run parallel with the ores and form their boundary against the dolomite, or again the

»sköls» divide two heterogeneous ores, e. g. iron and manganese ore from each other. Such »sköls» as penetrate the manganese ore or appear near it, often consist to an essential extent of manganophyllite.

It is common for the »sköl» rock to occur in the form of irregular isolated lumps in the dolomite. There is a good opportunity of observing this in the lower part of the Loka

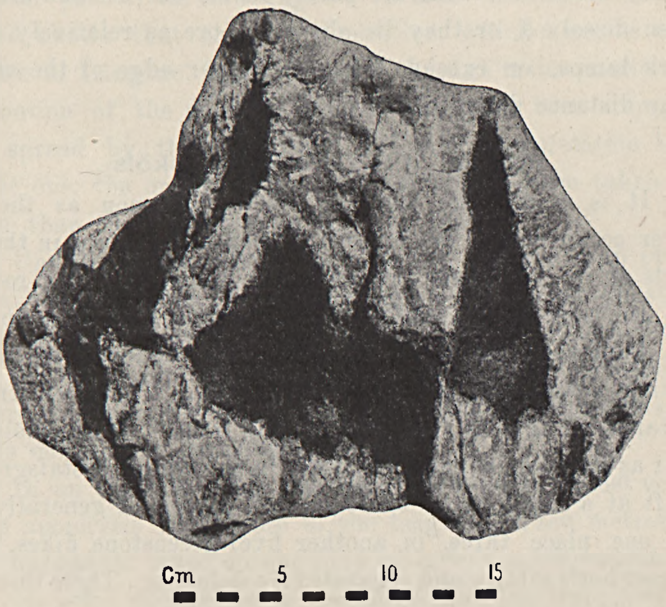

Fig. 4. Sköl-rock, probably a lamprophyric granulite, occurring as irregular dikes and inclusions in the dolomite; from the Botten level.

shaft, and a still better in the Hiss drive between the shaft named and the Botten level. The »sköl» mass sometimes assumes shapes resembling transformed fragments of dikes.

Already in the last decade of last century A. Sjögren proved that a great part of these »sköls» consists of transformed granulite, more or less micaceous; other »sköls», however, seem to have arisen through the transformation of intrusive greenstones. As a matter of fact, the term »sköl» at Långban includes several heterogeneous formations, all of which, however, seem to consist of derivatives of granulite or basic eruptives. A number of these »sköls» have a considerable length, and can be followed continuously for 100 *m* or more. This is the case, for instance, with the »sköls» that extend below the metalliferous deposits of the Gustaf mine on 50 *m* level and which probably derive from greenstone-dikes. Other »sköls» or »sköl» masses lie partly inside the ore and are then often dissolved, or they lie above the ore as relatively short, thick lumps, or extend from the upper edge of the ore for some distance down into it.

Relation of the ore to the »sköls».

It is remarkable that the »sköls», common as the are, never occur within the ore bodies proper, but only in the outparts or in the poorer ore, or in the not ore-bearing rock.

In most places »sköls» appear in such a way as to give the impression of being older than the ore-formation and of having determined the extent of the ore. The most striking instance of this is from the Gustaf mine.[1] The »sköls» appear as a system of intrusive dikes in the Södra Gustafsgrufvan shaft at a depth of 54 to 60 *m*, and consist of generally four (in one place three, in another five) greenstone dikes, lying almost horizontally and separated by dolomite. Their thickness varies from a few decimetres up to about 1.3 metres; they all vary in thickness. The four trap dikes together with the intervening parties of dolomite are about 6 *m* in thickness. Besides the horizontal main dikes one sometimes sees some apophysis of a few decimetres in size, which connects the main dikes or here and there extends a metre or two above the uppermost of the horizontal dikes. These dikes have as yet been exposed for a distance of 140 *m* and partly to a width of 36 *m*.

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[1] TIBERG: I malmbildningsfrågan, Värml. Bergsmannaför. Ann. 1904. The following description of the conditions in the Gustaf mine is largely taken verbally from TIBERG.

The deposit in the Gustaf mine, which consists of hematite and magnetite with gangue of pyroxene, amphibole, and garnet and a small amount of ferruginous quartz, is very characteristically related to these trap dikes. The deposit, which has been followed from the surface down to the trap without interruption, though varying in thickness, here extends as a sheet lying spread on the uppermost trap dike over the greater part of its now exposed surface. The mode of occurrence shows that the ore deposition, which here, as everywhere in Långban, has originated through metasomatic transformation of the dolomite from fissures, has been stopped in its spread by the trap dikes. If this interpretation is the right one, the ore formation must evidently have taken place later than the formation of the trap system.

Underneath a minor part of the exposed trap ore has been found in the underlying dolomite, though mostly in such places where the trap is fissured, as though perforated, or else thinner than usual, less than a decimetre, and where consequently one can imagine that the ferriferous solutions could have penetrated the trap.

In an other working has been observed an almost vertical trap apophysis which rose to the height of a few metres from the horizontal trap; on one side of it was a concentration of ore of some decimetres in thickness, and the trap itself was transformed nearest to the ore into a micaceous »sköl»; on the other side of the trap pure dolomite occurred. It looks here as if the trap had determined the extension of the ore, and where the trap ceased, the ore spread in the dolomite in its usual irregular manner.

It is of interest to observe that the uppermost horizontal trap dike in places reveals a kind of apparent faults, in that pieces of the same lie so that the upper edge of one piece lies about on a level with the lower edge of the adjoining part. The apophysis mentioned above, which is invisible at several places, sometimes lies free in the dolomite, in other places one can observe small pieces of trap lying free in the dolomite. These phenomena which fully correspond to those which in the Sala mine and thereabout can be observed on the diabase dikes that intersect the dolomite, are by no means faulting phenomena, but depend on the irregular cleavage of the dolomite, which has caused the dolomite to open along irregular cleavages at the injection of the eruptive mass. Of particular interest it is to follow the various transformation stages in the trap of the Gustaf mine, which give a good insight into the development of the many different kinds of »sköls» that appear in the iron mines of Långban and elsewhere.[1]

A state of things similar to that in the Gustaf mine can be observed at several places in the Storgrufvan and the Collegii mine, though with this difference, that the »sköl» formations occurring there cannot be proved to have their origin from any trap, but probably from the granulite, possibly in part from the gangue masses. That the composition of the »sköls» depends much on not only the rocks from which they derive, but also on the ore formations that they border, follows from, for instance, the character of the micaceous »sköl» that appears in the Säve working (137 *m*). There iron ore and manganese ore occur beside each other. Both ores are bounded in the footwall by a »sköl» which within the iron ore consists of biotite, but in the manganese ore of manganophyllite.[2]

Another interesting fact can be observed in the Myhrman working, where a »sköl» appears bounded on one side by rich hematite and on the other by a thin sheet of lean hausmannite scarcely one metre broad; the »sköl», thus, here separates these two ores.

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[1] These transformations are described by H. V. Tiberg: I malmbildningsfrågan, Värml. Bergsmannaför. Förh. 1904, p. 19.

[2] In Dec. 1909 when I visited the place, the greater part of this »sköl» was mined away, so that only a »sköl» formation, a few *cm* broad, was visible; it consisted of a granulite ledge in the middle with manganophyllite on each side, all surrounded by hausmannite. Before that the »sköl» was a broad manganophyllite »sköl» of several *dm* in breadth.

The true nature of the »sköl» formation met with in the Storfors working and in the Uddeholm drive and Bly drive at the 109 *m* level, as well as in the Japan working in the so-called Källargruve shoot, is still doubtful. In the Storfors working, where this »sköl» formation appears in a width of about one metre, it is bounded on the N. side by rich hematite, on the south side by leaner hematite. On the N. side of the »sköl» there is a »sköl»-fissure filled with calcite and other new mineral formations, indicating a possible fault. In a cross-cutting to the Uddeholm drive, which followed the same »sköl», the »sköl» thinned out, and the hematite which before had lain on its S. side began now to disperse in the dolomite. In the Japan working there has been, on the whole, a very scattered deposit arranged around the same »sköl»; here there is magnetite mixed with green »skarn» on the south, and poor hematite and hausmannite mixed with lime on the north side of the »sköl». This is thus a phenomenon similar to the one just quoted from the Myhrman working, where manganese ore lay on the north and iron ore on the south side of the »sköl». The same »sköl» formation as in the Storfors and the Japan workings appears also in the Lundström working, partly forked in two parts and with a strike from E. to W.; this »sköl» is now known for a length of over 200 *m*.

Another »sköl», which can be suspected to derive from a trap dike like those in the Gustaf mine, is the one found in Bjelke's shaft or the Konst shaft between the depths of 175 and 187 *m*. In width it there only reaches 0.4 *m*; in part it is so decomposed that only a little mountain-leather and a dark ooze remained; such large cavities had formed, that a man could enter them, and these cavities were partly filled with beautiful calcite crystals.

Most recent fissures.

After the ore and gangue formation stopped in the deep zone, the rocks and ores have been exposed to crushing and cementation in the zones that are higher and nearer the surface. The fissures that ensued have been filled with various secondary minerals, and a very large number of rare minerals that characterize Långban occur in such fissures. Calcite, as one of the most easily soluble of all the minerals occurring here, has generally been the last mineral deposited, and consequently fills the middle of the fissures. Many of the fissures contain only calcite. This calcite, which is of another structure and appearance than the great primary dolomite masses, is here called »secondary calcite».

Examples occur of such fissures still being open to circulating water, so that a formation of minerals is still going on. At many places in Långban there issues from the crevices of the dolomite wall spring-water as clear as crystal, which in contact with the oxygen of the air deposits precipitates rich in manganese oxide as for instance in the Botten level on 150 *m*. In other places occur spring-waters containing iron, e. g. in the Stalaktit drive at the 85 *m* level and in the Botten level. In the former place there are deposited from the clear water, which tastes strongly of iron, large rusty-brown stalactites. TIBERG has had an analysis made, which is given below under A. In the Botten drive a similar spring-water has deposited a dark, fine silt of the composition shown by the analysis B.

	A.	*B.*
Mechanically combined water	11.60	3.46
Chemically combined water and organic substances (including nitrogen)	22.30	20.36
Carbonic acid	6.00	—
Phosphoric acid	2.60	0.48
Silica	0.20	1.00
Iron oxide	28.28	1.96
Manganese oxide	13.84	35.52
Lime	7.33	7.75
Magnesia	2.50	15.10
Alumina	0.64	0.082
Insoluble in concentrated hydrochloric acid	4.66	12.24
Total	99.95	99.952

As appears from these analyses, the main constituents in these spring deposits are in the one case hydrated iron and manganese oxides, in the other hydrates of manganese oxide and magnesia. That the organic substances contain nitrogen, prove that these waters derive originally from the surface.

The Hyttsjö fissure. With these most recent fissures must also be reckoned the large fissure which runs along the west outskirt of the field and really limits the works on that side.[1] It is a mainly straight, vertical fissure of unknown length, visible for at least a part at the surface, where it is marked by a very narrow glen of 3—5 *m* in width and 3—4 *m* in depth. To the N. it soon disappears in the Lake Hyttsjö, from which it derives its name; to the S. it presumably runs into the Långban Lake. In the underground mining they have several times run against this fissure or its branch fissures between 90 and 150 *m* levels, fortunately — since it is always filled with water under high pressure — only with drill-holes.

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[1] Tiberg in G. F. F. **31.** (1909), 105. Also several mining reports for different years.

The Persberg mines.

By

HJ. SJÖGREN.

(With Pls 52—53.)

Introduction.

Persberg is the most important and next to Nordmarken the oldest of the mining fields in Värmland's Bergslag. Mining there dates back to the 13th century, and the first privileges for this district were granted by King Eric the Pomeranian in 1413. The earliest Bergmaster's report is of 1637, in which it is said of Persberg that »the whole mountain is nothing but ore, and of mighty richness, and can be smelted without flux and is so yielding that pure ore is to be found wherever the soil is removed». In the report of 1656 the mines are described at some length, and the Storgrufvan is said to be full of water, in consequence of which it has not been worked since 1600. The Skärstöt mines are reported at that time, »to have lain waste for more than a hundred years, but they were reopened 12 years ago, though they could not be worked because of the influx of water». It is also stated that all the mines were troubled by water.

In all, nearly 3,000,000 tons of ore have been extracted from the Odal-field, according to an approximate calculation, and about 600,000 tons from the Högberg-field. The greatest production was reached at the close of the sixties and the beginning of seventies of last century, when it went up to 55,000 tons per year. At present the yearly output is about 30,000 tons.

The area of ore within the Odal-field is calculated at 5,000 square metres and the whole field at 10,000 square metres. The ore is of an excellent quality and its good qualities have greatly contributed to the reputation of Swedish iron in the world's market. First quality contains 55 % Fe, 0·001—0·004 % P, and second quality 45 % Fe and 0·005—0·01 % P; the S-percentage varies from 0·012 to 0·025 %. The method of mining was formerly only underhand stoping. From 1879 the overhand and cross-working and filling methods have been resorted to in the Alabama mine and since 1881 in the Gustaf Adolf mine. In the present day the ore is broken in the Skärstöt mines by the magazine-method. In the Odal-field there are three perpendicular shafts, of which the Gustaf Adolf shaft is more than 300 metres deep.

Persberg was the first ore-field in Sweden where attempts were made at machine drilling. On the initiative of the Bergmaster A. Sjögren in 1864—66 Oscar Fredrik's adit was worked by machine-drilling. Now all drilling is done by machinery.

The hoisting power and supply of water has from time immemorial been taken from Stora Horrsjön, from whence the water has been conducted across the field in a well constructed system of canals and has turned 13 water-wheels and 4 turbines. This power having proved insufficient, owing to the increasing depth of the mines, 200 horsepower has been conducted by electric transmission from Älfvestorp and now drives the new dressing plant.

The oldest geological description of the Persberg ore-fields dates back to Linnæus and will be found in his »Västgötaresa». He states that »the richest iron ore was mined at Persberg, its quality being comparable to the ore of Dannemora, Bitsberg and Norberg». He further gives an account of the method of mining, »which was mostly blasting and seldom firing» [1] and in a Table embracing the years 1740—

[1] The use of blasting-powder was introduced at Persberg about 1720.

1745 he states »how much ore, rock, and water had been drawn from it». The ore is then described in the following manner: »The ore was generally somewhat greenish and the green admixture was supposed to be of a good quality and to consist of lime. White streaks, which were pure white lime, might be seen here and there in the ore. There was 'klingmalm' (?) and potstone in great abundance. Coarse red garnets were not rare.» Thus LINNÆUS mentions the gangues characteristic of Persberg, pyroxene and amphibole (the greenish kind), garnet and limestone and potstone (the »sköls»).

Concerning the lime he particularly remarks: »This white lime was clear and granulated like salt and acted as a good flux for the iron ore.»

A more detailed geological description of the Persberg ore-fields is given by TILAS in his history of the system of the Värmland ore-fields.[1] As an introduction he points out that the Värmland mines are concentrated within certain ore-regions, each of which has one or several ore-fields. The common rock of the ore-regions is »a pale reddish hälleflinta». TILAS's very correct observation that these ore-regions always are surrounded by granite »a coarse reddish or reddish brown granite from which wedge-like parts run into the rock of the ore-region» is of great interest. The ore-regions encircled by this granite, are of various sizes: »Some are so small that they are equal to 2 or 3 legal claims, and others again can be measured by the mile.»

The ore-field of Persberg is situated in the ore-region of Yngshyttan, which also includes the mining fields of Jordåsen, Högberget and Nygrufvan. The gangue rock of Persberg, that is the ore-bearing rock or »matrix of the veins», is described by TILAS as »a dark and blackish green »hornbinda», which, however, varies greatly, showing all the changes appertaining to the corneous genus». TILAS clearly understands that the ores accompany the gangue, »as long as hälleflinta is

[1] Manuscript of 1760.

prevailing, no ore deposits can be expected, and the 'hornbinda' should be looked for». TILAS first describes the limestone, finding it remarkable that it does not occur as vein but shows a stratification which corresponds to the strike of the other rocks in the ore-field. The »hornbinda» and its variations not only constitute the ore-bearing gangue, but also band the different ore-bodies. This is caused by their running lengthways and crossways and encasing the ore-bodies.

It is of interest to know that TILAS distinguished the diorite dikes from the gangue or »skarn»,[1] though they are petrographically so much alike, that even a hundred years later the one was mistaken for the other, and the microscope has had to be used in doubtful cases. He calls the diorite dikes »cross-walls» in contradiction to the skarn which is found in »length-walls or middle-walls». According to TILAS the diorite dikes are of greater or lesser thickness, consisting of fine-grained »hornbinda» and »schörlberg» finely mingled with iron ore; they are crossing the fields in different directions. TILAS emphasizes that the diorite dikes improve the ore-deposit, experience having shown that when a lode is cut by a »cross-wall» the ore is richer there than elsewhere. This is remarkable, as it is also the experience of the present day, apart from TILAS'S opinion. Thus H. V. TIBERG has pointed out that the part of the Krangrufvan, situated inside the great diorite dike has never yielded any large amount of ore; and hardly any at a depth greater than 200 metres, where the ore of the Krangrufvan is cut off by several dikes of diorite. The horizontal section of ore in the Storgrufvan at a depth of 115 metres is bounded on the North by a vertical dike of diorite, on the other side of which the skarn[1] is not ore-bearing.

The oldest geological map of the Persberg ore-field was made in 1837 by C. O. TROILIUS, at that time Bergmaster

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[1] Swedish expression to indicate the mineral constituents mixed with the ore; it also envelops the ore and separates it from the surrounding rock.

of the district. This map illustrated the distribution of the different rocks in the ore-field, as well as the intimate connection between the different skarn-zones and ore-deposits. In the main this map is still reliable.[1]

In 1871 and 1872 A. E. Törnebohm examined the geology of the Persberg ore-field in detail.[2] In spite of the theoretical view of the geology of iron ores having changed greatly since then, Törnebohm's investigation is in the main the basis for the following description. I have also been favoured with much valuable information from Mr H. V. Tiberg, who for a number of years was mining engineer at Persberg.

Surveys of smaller areas have since then been made by J. G. Jungner, who drew up a geological map of the Odal-field, on the scale of 1 : 800, and by V. Petterson, who examined the Högberget.[3] They have both revised Törnebohm's account in particulars.

»Skarn»-ores.[4]

One of the most prominent types of iron ores in Central Sweden are the skarn-ores. They are characterized by the predominance of more or less ferriferous, pale or dark coloured augite or amphibole minerals. Garnet, epidote, talc, serpentine, and chloritic minerals of primary or secondary origin often appear in the skarn, giving rise to formations of garnetiferous, epidotic, serpentinic, and chloritic skarn. However, many ore deposits in the skarn-ore districts don't carry any skarn worth mentioning.

On account of the chemico-mineralogical composition of the skarn, different types of skarn-ore have been distinguished. Thus H. Johansson has classified the groups of skarn-ores under the following chemico-mineralogical types:[5] quartz-

[1] This interesting map is kept in the Archives of the Bergmaster of the Western District at Filipstad.

[2] Geognostisk beskrifning af Persbergs grufvefält: Swed. Geol. Surv. 1875.

[3] W. Petersson, Beskrifning öfver Högbergets grufvefält. 1899.

[4] For this term, as used in the present work, see back (note 1, p. 3).

[5] G. F. F. **29** (1907), p. 286.

amphibole-ores, amphibole-ores, pyroxene-ores, magnesia-ores, and manganiferous ores. These types mainly correspond to those which B. SANTESSON, as early as 1889, pointed out among the skarn-ores of Nora »Bergslag». All these types cannot, however, be given the same degree of independence; magnesia-ores, for instance, are as appears in several places, among them at Persberg, only alteration products of the augite- and amphibole-skarn-ores, due to decomposing agencies in the katamorphic zone.

The ores which are most commonly found within Filipstad's »Bergslag» are chiefly characterized by a pyroxene skarn, mostly consisting of a variety of malacolite. Amphibole is, however, also an almost constant constituent. In certain skarn-zones garnets form a great or even prevailing ingredient. Epidotic and chloritic minerals are common accessorial constituents. This so-called Persberg type is most typically developed within the Persberg-field, but is also found in, for instance, the Nordmark mines and a number of smaller mines in Filipstad's »Bergslag».

The skarn-ores of this »Bergslag» are in many cases intimately connected with the limestone which occurs occasionally in the granulite (leptite) formation. On account of the great plasticity of the limestone in comparison with the surrounding silicate-rock it has often taken secondary boss-like shapes. This is the case in the Odal-field of Persberg itself, in Getön, at Gåstjärn and Assartjärn, SW. of Lake Ygnen, in the Nordmark mining-field, etc. But limestone also appears in winding zones, e. g., W. of Nordmarken. The skarn-ores may generally be divided into two great groups: ores connected with limestone and ores lying in the granulite without limestone. In the following we shall see that both groups are represented at Persberg.

The connection between the limestone and the skarn-masses is noticeable by the limestone stocks being in their contact against the granulite surrounded by zones of skarn. This fact, which is plainly visible for instance in the Persberg Odalfield, where the mighty development of the skarn-masses renders it easily observable, is of a general nature and is repeated in Getön, in the limestone-stocks of the Gåsgrufvan, and at Assartjärn. The limestone-stock at Assartjärn has a length of about a kilometre and a half and is enclosed on either side by skarn-zones of more or less thickness. The same may be said, though in a less degree, of the limestoné-stock of the same size at Assartjärn, which in the North and South is enclosed by a skarn-bed on the contact against the granulite.

These facts clearly prove, that the skarn-zones in these places owe their origin to the metamorphic influence of contact on limestones. The principal constituents of the skarn-zones are pyroxene, amphibole, and garnet minerals, viz. just the mineral association which characterizes the contact-metamorphosis of limestones. Yet extensive zones of skarn, also such as enclose considerable ore-deposits, occur in the same district without any connection with limestone; the skarn may, therefore, also owe its origin to the influence of magmatic solutions on silicate-rocks.

The formation of the skarn-ores.

It is obvious, on account of the mineralogical nature of the skarn, that skarn-ores are contact-metamorphic productions, the term contact-metamorphic taken in its broadest sense. This contact-metamorphosis may, of coarse, have made itself felt with different degrees of intensity and must, besides this, show its effects in different ways according to the depth under the surface at which the process has taken place. The nature of the diamagmatic solutions, their temperature, and the material which has been metamorphically affected by them, have evidently also been influential. The great variety of skarn-ore types may partly be explained in this manner, The eruptive rocks, occasioning these metamorphic effects are probably the granites. These are the only eruptives appearing in such quantities that iron ore-deposits can be attributed to them. Scarcely any part of the ore-district of Central Sweden is devoid of granites of intrusive character. This district contains the granites of Filipstad, Örebro, Sala, and Uppsala, which are among the most characteristic types.[1] This view explains the fact that the granites in themselves usually are not ore-bearing. The diamagmatic solutions which have segregated from the granitic magma have found their way into the surrounding rocks outside the circumference of the mass of granite after the consolidation of the granitic intrusions.

As contact-metamorphic ore-deposits the skarn-ores resemble some of the contact-formations, e. g. the Christiania type. This is to be expected, as both originate from acid eruptives or eruptives of medium acidity. It has also been pointed out that the contact-metamorphic deposits mostly belong to eruptives of greater acidity, whereas the magmatic ones belong to the basic, possibly owing to the greater richness in mineralizers of the former.

Rocks.

Granulite (*Leptite*). The prevailing rock in the district is a typically developed granulite (leptite) the pale tints of which indicate an albite-oligoclase rock. This coincides with the experience that skarn-ores usually are connected with plagioclase-granulites, rich in Na. The rock has a pale reddish or pale gray colour. The weathered crust is quite white.

The microscopic slices show a ground-mass with quartz-felspar mosaic. The phenocrysts of quartz and albite present

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[1] Högbom has compared the process of granulitization with a contact-action by the granites, and it is then only natural to put the iron ores which are connected with the granulites in a causal connection with the granites. Besides this, Trüstedt in his Monograph has put the skarn-ore deposits in intimate connection with the post-Ladogan granite of this district.

rounded, idiomorphic contours. In the fine-grained groundmass there are parallel zones of a coarser granular material which are, most likely, the crushed phenocrysts of quartz and felspar.

The rocks show but few traces of chemical alteration, the felspar is fresh and without any sericitization, and the scarce femic constituents are but slightly decomposed.

The felspar grains show the irregular lamellæ of the albite. On account of the mineral grains being bounded by comparatively plane surfaces the rock is not very hard and easily crumbles to a powder. As femic constituents occur both biotite in irregular scales, and also some amphibole. The following analyses show the chemical composition of the Persberg granulite.

A. Reddish granulite from the Alabama northern shaft.

B. White granulite from the railway cutting close to the Manager's building.

	A.	B.
SiO_2	78,25	80,28
Al_2O_3	12,27	11,35
Fe_2O_3	0,05	0,07
FeO	0,57	0,28
MgO	1,22	1,18
CaO	0,35	0,35
Na_2O	6,33	5,94
K_2O	0,33	0,26
H_2O	0,60	0,42
TiO_2	0,14	0,15
P_2O_5	trace	trace
S	0,02	0,02
MnO	0,01	0,01
Totals	100,14	100,31
H_2O lost at 105°	0,08	0,03
Spec. gravity	2,64	2,64

On the whole, the granulite (leptite) of Persberg is a very homogeneous rock without any remarkable variations.

Segregations of plagioclase-amphibolites, so common in other granulite areas, are not to be found in the Persberg district. Northwards between Persberg and Långbanshyttan there are, however, in several places segregations of amphibolite in the granulite (leptite) often mixed with iron ores. The ores of the Långskog mines belong to this type, characterized by amphibolitic and quartzy gangues. TÖRNEBOHM has discriminated a coarser, granular variety resembling granite or gneiss, from the common granulite; it is found within the eastern part of the peninsula between Sandviken and Lerviken. This rock, which is also met with in Älgön and Granön, and forms the greater part of Storön, seems to be a variety less granulitized than the original rock. It is not ore-bearing.

Granite. This is also the case with the granitic rock (gneiss-granite, primary granite) which is found west and north-west of the Persberg-field, chiefly spread about the area round Stora Horrsjön. The rock here is recognized as having been exposed to a high degree of mechanical metamorphosis. The mortar structure of the ground-mass consisting of quartz and felspar, interspersed with coarse grains of orthoclase, point to a far advanced deformation. As is usually the case with primitive granite, the granitic characters are better preserved in the interior of its area than on the periphery, where metamorphic structures are highly developed. The transitions of the structures to the structural conditions prevailing within the granulite point to a contemporaneous formation with the granulite, and that both have been partially subjected to the same regional metamorphosis. The granitic rock is entirely devoid of skarn-zones and ores.

TÖRNEBOHM first (»Persbergsfältet», 1875) considered this rock an intrusive granite, basing this view on certain intrusional contact phenomena noticed on the boundary against the granulite. Later (»Filipstads Bergslag», 1877, and »Mellersta Sveriges Bergslag», 1880) he considers this primitive granite as belonging to the gneiss series forming the bottom of the granulite series. According to this the granite is regarded as belonging to the older Archæan, while the granulite is referred to the younger Archæan. On the map, however, he makes plain the petrographical transitions between the two rocks.

The belief in a stratigraphical boundary existing between them can, hewever, no longer be maintained.

Limestone and dolomite. The existence of limestone and dolomite within the Persberg district has already been mentioned. The limestone stocks are extremely irregular in their boundaries, as will be seen on the map of the Persberg Odalfield, of Getön, etc.

Certain circumstances point to the possibility that the limestone has been the original material from which the dolomite has originated. At Assartjärn and in the Gåsgrufva-field there is chiefly limestone and the dolomitization has not acted very strongly; in correspondence herewith the skarn-zones are less developed and the ore-deposits smaller than at Persberg. This is also the case with the small occurrences of limestone in Limön. The limestone-stock in the Persberg peninsula is dolomitized to a high degree, and so is the limestone in Getön, where the limestone and the dolomite are separated in the manner that the dolomite occurs in the marginal parts of the stock next to the ore-bearing skarn-zone. The dolomitization may therefore be considered as a process connected with the formation of the skarn and ore.

The limestone usually shows a coarse-crystalline structure; it is sometimes banded, through admixture of silicate, as in Limön and in the quarries at Assartjärn. The dolomite is fine-grained and with sugar-like texture. In the hill of Persberg the two rocks are found mixed with one another and with well defined contacts between the two. In Getön they are separated by a narrow zone of skarn. In the northern part of Kutholmen (Högberget) there are nodules of unmetamorphosed limestone in the dolomite. There are, on the other hand, in the Persberg-field fragments of dolomite in the limestone, as if after the dolomitization dislocations had taken place, in which the brittle dolomitic parts of the rock have been broken up and worked into the more plastic limestone mass.

Nodules of limestone appear sporadically in all zones of the skarn and may be looked upon as a »limestone skarn» of the same origin as the other kinds of skarn.

Filipstad granite. Though this kind of rock does not occur in the Persberg-field proper, it is the predominant rock in the whole of Filipstad' »Bergslag». The Filipstad granite consists of a coarse amphibole-biotite-granite, characterized by its ellipsoidal microcline crystals, often surrounded by a crust of a yellowish white plagioclase, which gives it an »eye»-granitic structure.

The ground-mass consists of bluish grey quartz, often with idiomorphic boundaries against the felspar, biotite and hornblende. Though usually fully massive, it has often a secondary parallel structure, which sometimes becomes quite schistose. The Filipstad granite everywhere exhibits intrusive contacts against the granulite (leptite), and encloses large fragmentlike portions of this rock. These fragments are sometimes ore-bearing; the Äng mines and some other mines northeast of the lake Lersjön have been worked on iron ore enclosed in fragments of granulite. In these mines pieces of pure iron ore have even occurred in the granite.

It has already been intimated in the above that the formation of iron ores and skarn might in some measure, even if indirectly, be put in connection with the granite intrusions. The reasons are, partly the topographical association between the intrusive granites and the ore-bearing granulite formation and partly also the connection, shown in other places, between acid eruptives of granitic or syenetic type and contact-metamorphic formations of about the same mineralogical types as the skarns. For the present this must, however, be put down as a working hypothesis.

Diorite. The basic intrusive rocks occurring in this district are diorite and diabase, though only the former is found in the mining-field proper in the shape of numerous and, occasionally, mighty dikes, as for instance in the Krangrufvan, the Storgrufvan, and the Alabama mine.

As is shown by microscopic slices, the rock is often highly metamorphosed; the structures are mostly secondary; spots, bunches, and radiated masses of green amphibole are developed in a ground-mass of secondary feldspar mosaic. In the rock from other dikes, e. g. those of the Krangrufvan and the Storgrufvan, relics of ophitic structure are seen; laths of plagioclase, often closely twinned, penetrate great individuals of green amphibole. A brown pigment is often noticeable in the primary plagioclase. This rock does not either give the impression of being primary, and it may be just possible that it is nothing but highly transformed dikes of diabase, most likely of the bronzite-diabase (hyperitite), which occurs as great dikes in the vicinity (the Gåsgrufva-field, Lervik), and which is characterized by a sometimes brown-coloured plagioclase. It contains no olivine and alters easily into dioritic derivates. The colourless rhombic pyroxene mineral then alters into an aggregate of amphibole stalks at the same time as a formation of magnetite takes place.[1]

As may be seen on the map of the Odal-field the diorite dikes vary considerably in thickness; at some places they attain great thickness, only to shrink up again a little further off. They also cease quite suddenly, and no continuation can be seen.

The effect of the diorite dikes upon the ore-deposits in enriching the ore on one side of the dike, will be illustrated below in the descriptions of the Krangrufvan and the Storgrufvan. The same effect is noted in other Swedish mines, for

[1] In his description of Persberg and also in his explanation to the map of Filipstad's »Bergslag» and on his »Bergslag» map, A. E. Törnebohm has separated the diorite and the diabase as being different rocks.

instance Långban, as pointed out by H. V. Tiberg. As to the Timansberg mines C. A. Vrang stated as early as 1887, that the ore-deposits attain a much increased thickness in the vicinity of the traversing diorite dikes.[1]

Tectonic conditions.

The dip is, wherever direct observations have been made, a steep one, as is usually the case within katarchæan areas. With a few local exceptions the skarn-zones as well as the limestone stocks and ores stand almost vertically.

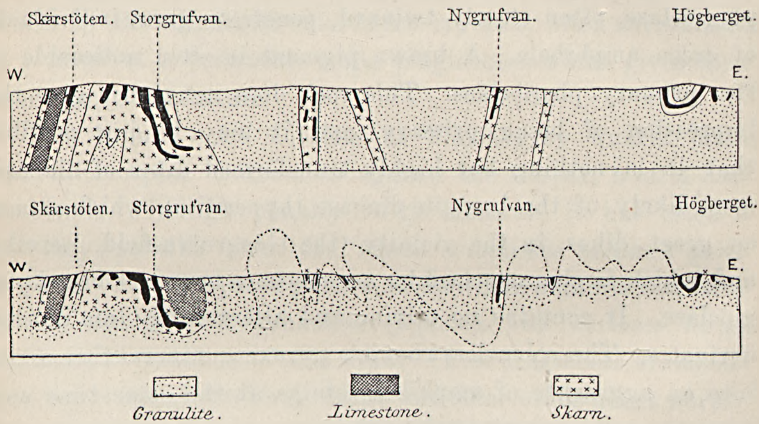

Fig. 1 (the upper). Profile across the Persberg peninsula from SW. to NE.
Fig. 2. The same profile according to Törnebohm.

Törnebohm, who embraced a sedimentary interpretation, considered the occurrences of limestone in the Persberg-Odal-field, Limön, Getön, etc. to be representatives of a stratigraphical horizon separating the lower skarn- and ore-bearing part of the granulitic formation from the upper one, which is not ore-bearing. He was of opinion that the limestone deposits fill comparatively shallow basins in the granulite and he also considered the skarn-zones trough-shaped.[2] This tecto-

[1] G. F. F. 9, p. 244.

[2] See e. g. Törnebohm's fig. 1, 13, in his work: Persbergs grufvefalt. 1875.

nic trough-shape has, however, never been proved, either by mining or in any other way, and direct observations rather point the other way. In the mines, the ores have not been found at any depth in a position to support this theory, though they have been followed to a depth of more than 300 meters.

The Skärstöt mine, which has been worked on an ore-stock in the skarn-zone surrounding the limestone, has followed this skarn-zone to a depth of more than 300 metres, and its original, almost vertical position has not been changed, nor has it shown the slightest tendency to assume a flat position. Törnebohm found a confirmation of his views in the fact that the ore in the Storgrufvan at 115 metres lies flat and has limestone in the hanging-wall. Mining has, however, since then proved that there is no limestone in the hanging-wall of the Storgrufvan, but that the skarn-zone borders on the granulite. The limestone stock of the Alabama mine continues northward east of the Storgrufvan but is separated by granulite from this mine. Consequently, this basin of limestone to which the Storgrufvan was thought to belong ceases to exist and the appearance of the profile is changed.

The limestone of the peninsula of Persberg, instead of being situated in a basin, seems, according to observations, to increase in thickness as the limestone-stock gets deeper. The mines situated in the skarn-zone bounding the limestone-stock to the west, viz. the Skärstöten, and the Gustaf Adolf, dip to the W.; the mines to the east, the Storgrufvan and the Alabama, dip to the east. So the limestone-stock between them has at least in this place greater thickness than at the surface.

Owing to the aforesaid observations it is most likely that the limestone-stocks continue against the depth with a steep dip, or that they are replaced by equivalent skarn-masses.

The skarn-zones.

The granulite (leptite) area, as well as the limestone stocks, are traversed by zones of skarn, running irregularly. They are also constant at the boundary between the granulite and the carbonate rocks.

The skarn-zones run extremely irregularly. In places they develop to great thickness, and at a short distance they thin out in the direction of the strike. In the Persberg hill the masses of skarn that surround the Storgrufvan and the mines W. of it have attained their greatest thickness and form irregular stocks enclosing the ore-deposits which have outcropped and been worked in these mines. In some places they project into the granulite or limestone as lodes, resembling apophyses.

Törnebohm, who worked under the assumption that the skarn-rocks were sedimentary formations representing certain levels of stratification in the granulite formation, made an attempt to combine the skarn-zones to a limited number of horizons. Thus he says[1] that several skarn-layers occur in the lower fine-grained part of the granulite and that, besides two or three small ones of short extension, four or five large ones may be distinguished, viz. at the very bottom one or two amphibolic zones represented by the Karl Sigfrid, Finnfall, and Dunderbacken skarns, and higher up three garnet-pyroxene-zones, the Krangrufvan-Högberg skarn-zone, the Storgrufvan skarn-zone, and the Storö-Älgö skarn zone. Törnebohm's view was, that the skarn-zones, in spite of their discontinuance, were not irregularly spread about in the granulite, but belonged to certain definite levels in it.

It is evident that certain skarn-zones are of considerable continuance, either their outcropping can be followed, or their occurrence can be proved by magnetic investigations. The one

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[1] Persbergets grufvefält, p. 14.

most easily followed is a zone varying greatly in thickness, which surrounds the stock of carbonate rocks of Persberg like a contact-zone and divides it by irregular walls into greater and smaller portions. Here the magmatic solutions occasioning the formation of the skarn, have apparently followed the plane of contact between the granulite and the carbonate rocks. Another skarn-zone easily traced is the one on which all of the Högberg-field mines have been opened. It is uncertain if this zone can be combined with the one on which the Krangrufvan is situated. Its course may be followed northwards to the Pumphål and Flintkärr mines by means of a number of small mines and exploratory workings, but there are at least two or three interruptions. Another well characterized zone is the one in which the Karl Sigfrid and Malmbergskärr mines are worked, which, in spite of its winding course may, because of the characteristic nature of the skarn, be followed for a considerable length.

According to Törnebohm, each of the skarn-zones represents a certain horizon or stratigraphical level. Thus the Krangrufva-zone represents a lower horizon compared with that of the Storgrufvan, which is supposed to be situated on the boundary between the granulite and limestone at the bottom of the latter. These two zones representing different levels according to the sedimentary view, cannot, consequently, run together. The fact of the Krangrufvan and Storgrufvan horizons being united by the dike of skarn in which the Harstigen mine is situated, rather upsets this theory. A connection also occurs between the skarn-zones of the Storgrufvan and Krangrufvan near the Badstu mines, though a mixture of skarn and granulite here forms the connection.

It has been usual to ascribe the winding irregular course of the skarn-zones to a process of folding. It may, however be of primary character. The gangue and masses of ore brought by magmatic solutions have presumably forced their way along the tectonic plane of the smallest power of resistance. These tectonic planes within the deep zone (the anamorphic zone or zone of flowage) where the injections of these solutions have occurred, can not be supposed to be of the same regularity as nearer to the surface within the zone of fracture. A tectonic plane of this kind has most likely been formed by the contact between the carbonate rocks and the granulite. Apparently this plane has been very irregular and the skarn-zone has taken a similar course. Presumably the other skarn-zones have in like manner had their strike directed by the irregular course of pre-existing tectonic planes.

The continuous skarn-zones which can be followed to any great length are, however, exceptions. As a rule, the skarn-rock, with or without ore-concentrations, occurs in the granulite in rather small, short bands without connection with others of the same kind near them. They are very common in the granulite of the Persberg-field and in the vicinity. The same may be said of them, as of the ore-deposits, that the small ones are the rule, the big ones rare exceptions. These small masses of skarn should not be passed over in interpreting the formation of the large ones, nor should the insignificant ore-deposits which are not worth utilizing be disregarded at the interpretation of the great deposits. Too little attention has hitherto been paid to them, because they are practically without value.

The mineralogical nature of the »skarn».

The typical Persberg skarn, as it occurs in the Krangrufvan and Storgrufvan, is characterized by an often compact malacolite. At times the malacolite skarn has a granular texture. It often has pale colours, pale green, or grayish green, thus originating from solutions containing little or no iron. It, however, sometimes contains more iron and takes a dark green colour.

Amphibole and garnet often occur in the pyroxene skarn, as accessory constituents. Amphibole, found in darker or lighter colours, usually belongs to the ferriferous and aluminous series of the amphibole-group. Masses of pale actinolite and grammatite are also found. The garnet is a lime-alumina-garnet af a brown colour (andradite). The amphiboles and garnets both appear to belong to a later period than the malacolite.

Törnebohm has classed the skarn rocks into garnet-pyroxene-skarn and non-garnetiferous skarn, the latter chiefly consisting of amphibole. The chief constituent in the skarn masses is pyroxene skarn, which alone constitutes some of the most important skarn-zones, among others, those surrounding the dolomite-limestone stocks in the hill of Persberg, and the great skarn-zones of the Krangrufvan and the Högberget. The amphibole-skarn is limited to some smaller zones (Karl Sigfrid's layer). The amphibole is often a dark actinolite. This skarn, which in Persberg has only a very local occurrence, is of a type which in other places, especially the government of Örebro and the province of Västmanland, is largely spread. The garnet only occurs in the malacolite skarn and is very unequally spread about the skarn-masses. In parts of considerable length it may not be found at all, but is abundant in others. Epidote occurs in »eyes» or nodules of radial structure surrounded by coarse-crystalline magnetite as a younger formation in the skarn. Besides this, partly crystallized epidote occurs filling fissures, which proves it to be of a later formation. In these cases calcite is the latest filling.

Most of the epidote occurring at Persberg is derived from the granulite. The epidotization of the granulite on a large scale is very easily observable in several mines, for instance, the Botten mine. — A mineral common in the skarn of some of the Persberg mines is fluorite; yet the fluorite is found only in the skarn and ore of the deposits lying in the granulite, never in the ores connected with limestone. Thus the deposits worked in the Malmbergskärret and the Långskog mines, which lie in granulite, contain much fluorite.

In the skarn-zones also limestone occurs as gangue and sometimes in such quantities that it is predominant, e. g. in the Gustaf Adolf mine and some parts of the Skärstöten. Limestone contained in the skarn is of a coarse-crystalline, granular structure. Dolomite is never found in the skarn; the dolomite appears exclusively outside the skarn and ore-deposits as a rock, not as gangue. The limestone in the skarn has been considered as relics from a pre-existing limestratum, partially metamorphosed to skarn-masses. There is, however, no reason for considering the lime-skarn a different formation from other skarn-minerals, viz. as deposited from magmatic solutions. Apparently these solutions, when coming in contact with the dolomite-stocks, have been saturated with lime and magnesia; the latter has combined with silica given rise to the formation of magnesia silicates, talc, serpentine, etc. which often occur in the lime-skarn (cfr the »black-skarn» in the Skärstöten). The occurrence of silica in excess may, to a certain extent, have had some influence. Also, it is apparent that the properties of the primary carbonate rock have influenced the quality of the skarn in the way that the pure limestone has given rise to salite- and garnet-skarn, the dolomite to magnesian pyroxenes and amphiboles, condrondite, etc., which have been metamorphosed into talc, chlorite, and serpentine (cfr the »black-skarn» in the Skärstöten.)

Metamorphosed skarn, partly in great masses, occurs besides the primary skarn. The talc-skarn characteristic of the Alabama mine, belongs to the derivated skarn-products. This skarn consists of a pale gray lamellated mass chiefly consisting of talc. The derivation of talc-skarn from malacolite-skarn is proved beyond doubt by its occurrence in a number of places in the Alabama mine. The typical talcose Alabama-skarn, and also malacolite-skarn sprinkled with garnet, as is the case in the Storgrufvan, may be observed there. The talc mostly occurs in »sköls» and fissures, also in those parts of the primary skarn that are traversed by crevices. The talcose skarn contains patches of the greenish primary skarn, plainly the relics of unmetamorphosed skarn. It looks as if the decomposition had begun with a crushing of the ore and the skarn-mass, leaving it open to chemical agencies.[1]

Metamorphosed skarn of another kind is the so-called black-skarn, which is especially developed in the northern part of the Skärstöten. It consists chiefly of chlorite or a compact mass of almost black serpentine. Besides this, radiating amphibole occurs. The entire mass is most likely a product derived from a skarn rich in magnesia-silicates, containing olivine, chondrodite or magnesian pyroxene and amphibole.[2]

The structure of the »skarn».

With regard to the structure of the skarn- and ore-masses it should firstly be stated that it entirely differs from the structure of any kind of rock hitherto known, both that of the eruptive rocks and that of the crystalline schists. As a matter of fact it may be said, that the skarn- and ore-masses are remarkable for their absence of regular forms of structure. Törnebohm has pointed out the likeness in mineralogical composition between garnet-pyroxene-skarn and eclogite,[3] but the difference is that the skarn is completely without any trace of rock structure. While rocks in general are characterized, not only by their mineral composition, but also by a certain structure, this is by no means the case with the masses of skarn-ore. This absence of a peculiar structure bears a close relation to the striking inhomogeneousness of the ore- and skarn-zones. In one place there is almost pure ore, in another skarn, and in a third a mixture of both, and the dif-

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[1] The metamorphosis of malacolite-skarn into talc-skarn was first pointed out by H. V. Tiberg (Värml. Bergsmannaför. Annal., 1904), who quoted the mine of Taberg and the Alabama mine at Persberg as illustrations.

[2] Some of the serpentine-skarn in the Kogrufvan of the Nordmark-field is proved to originate from metamorphosed chondrodite minerals. G. F. F. **17** (1895), p. 294.

[3] Persbergets grufvefält, p. 5.

ferent mineral components alternate in the skarn, so that malacolite predominates in one place and in another it is more or less intermingled with such skarn-minerals as garnet, epidote, and calcite. The absence of the usual rock-structure as well as the minerlogical inhomogenousness of the skarn-zones most plainly points to an origin different from that

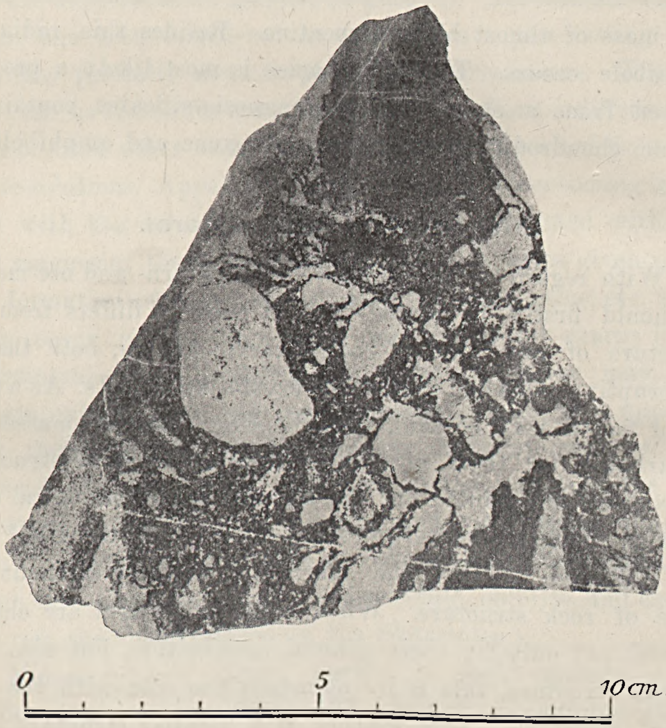

Fig. 3. Relics of malacolite in magnetite. The Storgrufvan (malacolite light, magnetite dark).

of rocks in general. In this respect the skarn-zones remind one of the pegmatites, which they most resemble with regard to the mode of formation, as both may be regarded as dia-magmatic formations.

Within the masses of skarn it is easy to distinguish the successive periods of mineral formation. When the garnet-pyroxene skarn is undecomposed, a pale greyish green malacolite is found to be the primary mineral, and magnetite comes next it in age. Sometimes relics of malacolite are contained in the magnetite in a manner which makes it obvious that the magnetite has pervaded and replaced the skarn. The garnet is younger than both the magnetite and malacolite and it sometimes, as for instance in samples from the Storgrufvan, cements together fragments of magnetite. Epidote is of a still

Fig. 4. Relics of malacolite in magnetite. The Storgrufvan (malacolite light, magnetite dark).

later period than the rest of the skarn-minerals and occurs as nodules with radiating structure or in crevices. The youngest fissure mineral is calcite.

The calcareous ore of the Skärstöten shows peculiar forms of structure. There are often great »eyes» or druses of coarse-crystalline magnetite in lime; against the lime the magnetite shows a particularly coarse-crystalline structure. In other

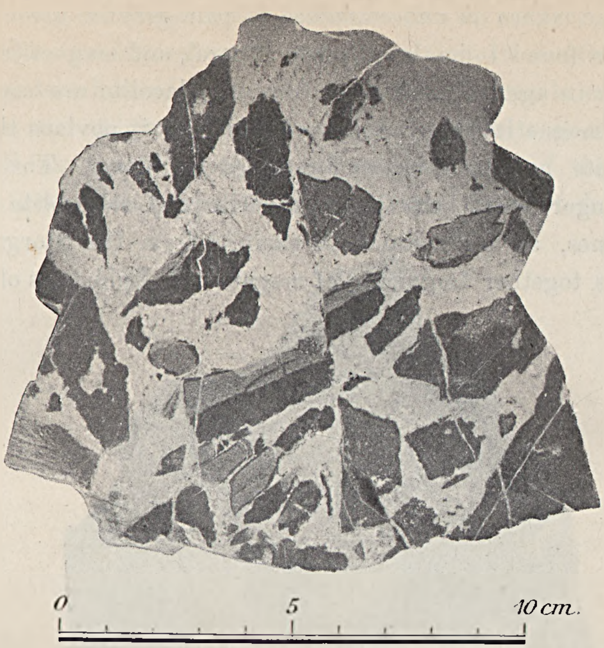

Fig. 5. Fragments of magnetite in a mass of garnet and malacolite. The Storgrufvan (magnetite dark, garnet and malacolite light).

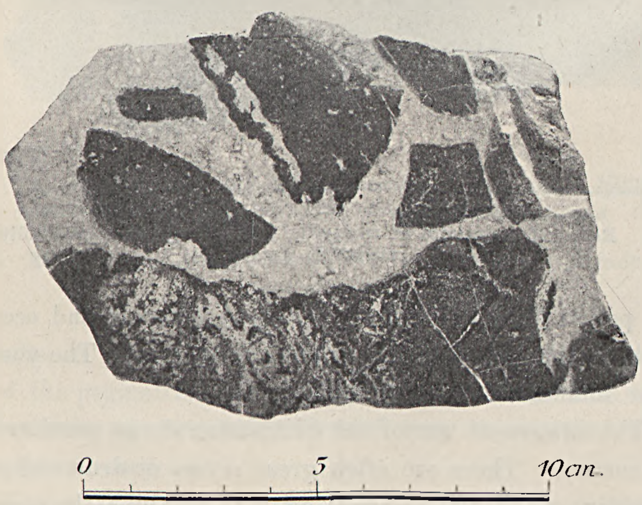

Fig. 6. Fragments of magnetite in a mass of garnet and some malacolite. The Storgrufvan (magnetite dark, garnet light).

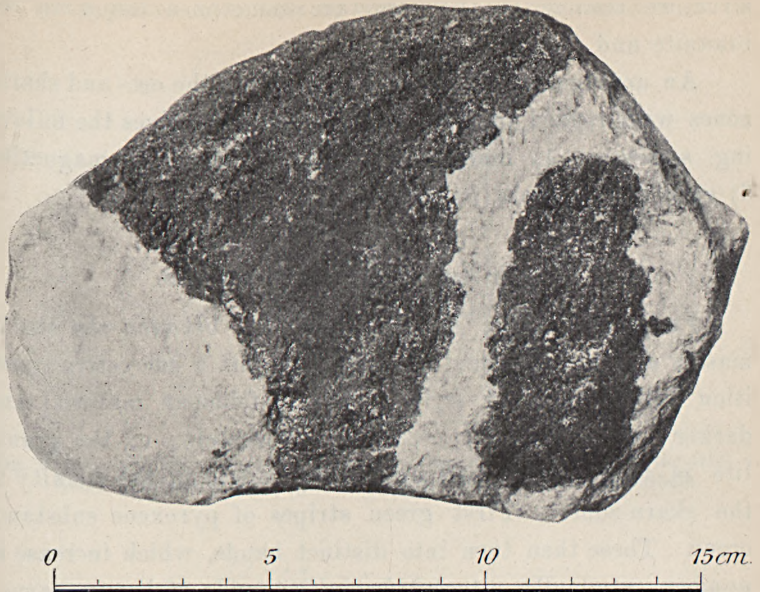

Fig. 7. Magnetite in limestone. The Skärstöt mine.

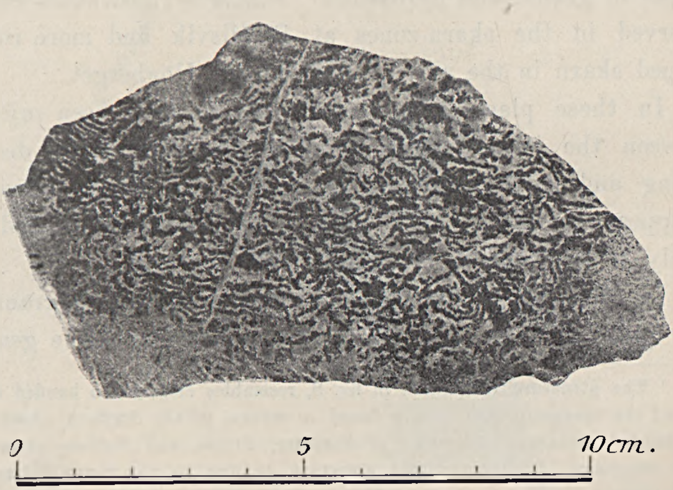

Fig. 8. Eutectic structure in a mass of magnetite and calcite. The Gustaf Adolf mine (magnetite dark, lime light).

places the mixture of lime and magnetite has a eutectic structure similar to the structure sometimes found in the braunite and calcite of Långban. [1]

An arrangement of the minerals within the ore- and skarn-zones with regard to their relative age thus gives the following sequence: 1) malacolite, granular lime, 2) magnetite, 3) garnet, 4) epidote, 5) calcite.

»Skarn» in relation to granulite.

Frequently there is no marked line between the skarn-masses and the surrounding granulite, but a successive transition takes place by stripes of pale feldspar material and darker skarn material occurring alternately; or the granulite is to a great extent altered to epidote in the vicinity of the skarn-zones. »First green stripes of pyroxene substance occur. These then turn into distinct bands, which increase in number, gradually alternating with bands of brown garnet. The granulitic material gets more scarce, and the rock is transformed into a banded skarnfels, consisting of alternating stripes of garnet and pyroxene.» [2] Finely striped skarn can be observed in the skarn-zones at Bertilsvik and more coarse striped skarn in the adit of Tilas at the Högberget.

In these places the skarn seems to have been injected between the joints of the schistose granulite, partly decomposing and partly replacing the rock. The stripes, however, disappear in the interior parts of the skarn-masses and are rarely to be found in connection with the ores.

In other places the contacts between skarn and granulite are quite distinct, and this may be considered the general

[1] The structure illustrated in fig. 8, resembles closely the banded structure of the magnetite and calcite found in several of the Striberg mines; and the banded ironstone (torrsten) of Striberg, Stripa and Norberg shows the same structure. I consider this structure as due to the consolidation and crystallization from a magma under special conditions. Compare H. Johansson, G. F. F. **29**, p. 186, and Hj. Sjögren, G. F. F. **30**, p. 385.

[2] A. E. Törnebohm, Persbergets grufvefält, p. 5.

rule. The contacts between the skarn and the granulite show in some places an intrusive character, as for instance in the

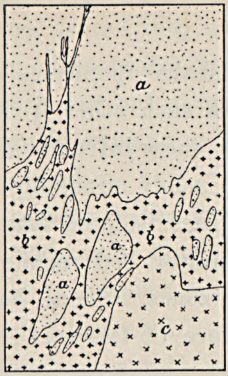

Fig. 9. Contact between granulite and skarn on the N. part of the islet of Getön (TÖRNEBOHM). *a* granulite, *b* actinolite, *c* dark amphibole.

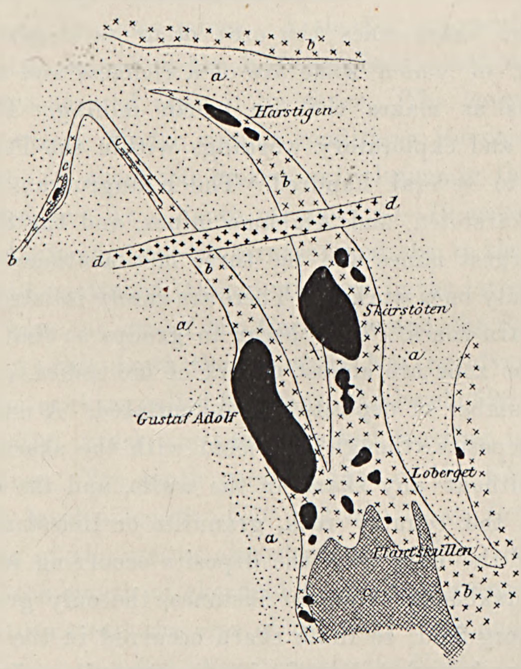

Fig. 10. Surroundings of the Skärstöt and Gustaf Adolf mines (TÖRNEBOHM). *a* granulite, *b* skarn, *c* dolomite, *d* diorite.

northern part of Getön. The skarn, consisting of actinolite and a dark amphibole, runs here in a sharp projecting point, enclosing fragments of granulite, giving rise to a peculiar brecciated formation.

The two mighty skarn apophyses which run in a NNW. direction parallel with each other from the great skarn-mass of the Storgrufvan, also show intrusive forms. The one contains the ore of the Gustaf Adolf mine, the other that of the Skärstöten. In some localities isolated masses of granulite, which may be regarded as unresorbed remains of the granulite, are contained in the skarn-zones. Small »horses» like these may be observed at the surface of the northern point of the skarn-mass of the Storgrufvan and larger ones have been found in the ore-bearing malacolite skarn of that mine at a depth of 140 m.

The ore-deposits.

In the skarn-zones the ores occur as larger or smaller ore-bodies, of which some are of a richness and attain such dimensions as makes the ore worth mining. The number of mines and exploratory workings within the Persberg-field amounts to several hundred. The Krangrufvan, the Gustaf Adolf, Skärstöten, and Alabama mines, and the Storgrufvan are the largest mines and the three last mentioned are at present the only ones worked. There are rarely isolated ore-bodies in the skarn-zones. They occur in groups so that long stretches of the zone are almost devoid of ore-bodies, and in other parts a number of deposits are accumulated. A number of the greater deposits, though connected with the skarn-zones, are almost without any skarn in the walls, and the ore lies directly in the country rock, granulite or limestone. This is especially the case with the deposits occurring in granulite. In the Torskbäckgrufvan for instance, the only great mine in the Högberg-field, so little skarn occurred in the walls, that the ore was bounded directly by the granulite. In places the bodies lie so close together that several of them may be worked in the same mine. Sometimes they occur in parallel bodies side by side, as in the upper part of the Krangrufvan, the deeper part of the Storgrufvan and in other places. Sometimes several bodies are united into one or they divide into branches. One of them often ceases at a certain depth, only to be replaced by one or several others. This fact is made plain in the following description of some of the deposits, which are worked at present.

We will take the eastern mines first.

The *Storgrufvan.* This mine is worked on an ore-complex, through which the above mentioned occurrence of parallel ore-bodies is singularly well illustrated.

On the highest levels a single ore-body seems to have been mined in the old mines called S. Kåfve-, Stor-, Carl-, Kammar- and Strete mines. The length of the ore was about 200 metres, only interrupted by a diorite dike between the Carl- and Kammar mines. A shorter ore-parallel was at the same time mined at the Kåfvegrufvan, south-west of the former and separated from it by skarn. The length of it was about 65 metres. Under similar conditions the ores continue to a depth of about 50 metres only losing in thickness as they got deeper. At a depth of about 60—70 metres the ores in the Carl mine and the Storgrufvan and also in the Kammargrufvan still continued, though the ore in the latter had been separated from the ore of the Carl mine and the Storgrufvan by skarn. At this depth the ore of the Kåfvegrufvan has been mined in the working called Kyrkan. At a level of 90 metres the North parallel mines are again worked together in a length of 150 metres. The south parallel, that of the Kåvegrufvan, has at this level a length of 70 metres. Down to this depth the position of the ores is almost perpendicular. At 100 metres' depth the length of the field begins to decrease, and soon (at 105—110 metres) the ores of the Carl mine and the Storgrufvan spread in a flat slope towards the North. At a depth of 105 metres the ore of the Storgrufvan has spread almost horizontally to a flat sheet of considerable thickness measuring 18 metres and bounded towards the North by the same diorite dike, running East and West which cropps out between the Carl and the Kammar mines. The ore is bounded on every side by skarn, which also is found on the other side of the diorite dike.

The Kåfve deposit, which in its continuation is worked in the so called Bergsrådsorten, begins at a depth of 135 metres to spread in a flat position below the ore of the Storgrufvan, showing a thickness of 20 metres. The same diorite dike also limits this ore and here it has a thickness of about 18 metres.

New ore-bodies, having a horizontal position have been opened inside this diorite dike. It is remarkable that granulite should be found everywhere in the hanging-wall, though Törnebohm has considered the hanging of the Storgrufvan deposit to consist of limestone.

The *Alabama mine.* The complex of ore-bodies, on which the Alabama mine has been mined, was worked at the surface in the so-called Sandelsgrufvan on a lenticular ore body in green skarn. At a level of about 40 metres the Alabama ore was found as a parallel to the former, both enclosed within the same skarn-zone. Somewhat deeper (about 60 metres) the ore-body of the Sandelsgrufvan thinned out or joined the Alabama ore, which with a steep dip to East runs under the Sandelsgrufvan, at the same time gaining in thickness and length (width 10 metres, length 60 metres). On the same level, within the same skarn-zone, a new parallel ore-body suddenly occurs, followed by the Galtorten to a length of 80 metres and a width of 2 metres. However, it soon disappears as it goes deeper.

Besides these three ore-bodies occurs on the same level the ore-body of the North Alabama shaft which has a greater width here.

It has been proved by cross-cuts that the skarn-zone containing these ore-bodies is enclosed in lime and dolomite.

The Galtorten ore-body having ceased, the others of the ore-bodies mined in the North and South Alabama unite in one stock which, at a level of 90—100 metres, has a length of about 150 metres and a maximum width of 25 metres. In proportion as the ore has gained in thickness, the skarn has diminished and in the foot-wall the ore is often in close proximity to the limestone.

This ore-stock continues with but slightly diminished dimensions as it gets deeper. The pitch towards the north is more and more noticeable, so that the ore runs closer to the ore-bodies of the Storgrufvan.

The diorite dike occurring in the Alabama mine and on the deeper levels accompangying the whole length of the ore-body is of particular interest. It was first observed in the foot-wall of the Sandelsgrufvan at about 60 metres, and run into the hanging-wall of the Alabama ore-body at a depth of 80 metres. At a level of 135 metres the diorite dike runs along the whole length of the ore-body in the hanging-wall. At this depth the ore appears also on the other side of the diorite dike, viz. the dike enters from the hanging-wall, traverses obliquely the entire length of the ore-body and at a level of 140 *m* stands nearly in the midst of it. The diorite dike having a more steep position than the ore deposit thus approaches the foot-wall and runs out there. It is worth noticing that the ore and the diorite in this mine have almost the same strike. This may be due to a cleavage occasioning a direction of minimum resistance of which both the ore-injections and the earlier diorite-injection availed themselves.

The *Krangrufvan* is one of the oldest and most prominent of the Persberg mines. It has been worked on several independant ore-bodies, some of which have outcropped, while others have been found at a greater depth, all being within the same skarn-zone. This skarn-zone, which at the surface has a most irregular course, has a thickness of 40—60 metres above the depth of 120 metres. From this level the thickness rapidly diminishes, beeing only 20 metres or a little more at a depth of 160—260 meters. As the skarn-zone diminishes in thickness the ore-bodies it contains also diminish in richness and thickness.

This skarn-zone contains a number of ore-bodies wholly or partially separated. The North and South Kran mines are worked on two ore-bodies, which close to the surface are separated by a body of not ore-bearing skarn. The ore-body of the North Krangrufvan had a thickness of 8—12 metres at higher levels, while the ore of the South Krangrufvan, which sometimes was as broad as 9 metres, narrowed as it went deeper to such a degree as not to be worth mining at a level of 100 metres. The so-called Gubbort ore-body is, however, situated below it and may be considered as its continuation. The above-mentioned body of skarn narrows in an easterly direction as well as downwards, so that the two ore-bodies are mined together in the so-called Kranhalsgrufvan in the South-East. These ores are thus mined together at a depth from 100 to 200 metres.

The ore of the Krangrufvehalsen, the easternmost part of the Krangrufvan, was up to 19 metres in thickness at places. Below a depth of 130 metres the different ore-bodies of the Krangrufvan were worked in one single mine, on an ore-body of about 15 metres in width and 70 metres in length, which, however, got more intermixed with skarn towards the depth. At a level of about 200 metres an almost horizontal diorite dike occurred, below which the ore was leaner and hardly worth mining.

A parallel to the Krangrufvan, within the same skarn zone, is formed by the ore mined in the workings of the Riksrätten and the Käringorten. This ore-body does not seem to have outcropped, but begins at 85 metres depth and has been followed down to 108 metres and is also known at 120 metres. It has had a maximum width of 5 metres, and its length has sometimes come up to about 70 metres. The extent downwards of this ore-body is not known, but it does not seem likely that it reaches any great depth, as the whole skarn-zone of the Krangrufvan narrows perceptibly beneath a level of about 130 metres.

There is further another ore-body separated at the surface from the other ore-bodies of the Krangrufvan, viz. the one mined in the Baggegrufvan. These ore-bodies are characterized by their precipitous pitch to the West corresponding to the linear parallel structure found in the surrounding granulite. This ore which was mined at the end of the 18th century and in the midst of the 19th century, was of extensive dimensions. It could be followed from the surface in three partly connected ore-bodies. The thickest of these, however, ceased to be worth mining at a level of about 100 metres. Below these a continuation of the ore-body of the Baggegrufvan occurs at a depth of about 180 metres, and such another is the ore-body mined between a depth of 170 to 275 metres through the Regulator and Svältort levels.

Consequently the ore of the Baggegrufvan has an extension downward exceeding that of the Krangruvan ore-bodies, although it is displaced by skarn masses at different levels.

The ore of the Krangrufvan is traversed by a number of diorite dikes, some of considerable dimensions; they do not seem to fault the ore-bodies though they are not without influence upon them. Below the above-mentioned diorite dike, occurring on a level of about 200 metres, in spite of extensive explorations no ore worth mining has been found. However, the skarn continues below the diorite. On about the same level the ore-bearing zone is cut by no less than four diorite dikes, viz., besides the one just mentioned, by one with a NE.—SW. direction and a 55° NW. dip, which is found also in the northern end of the Skärstöten and appears at different levels in the Krangrufvan; further by a diorite dike which has a N.—S. strike and a dip of 80° to the West and from a level of 187 metres—200 metres forms the east end-wall of the Krangrufvan; and lastly by a diorite dike which has also a N.—S. strike and an easterly dip of 65° and appears on a level of 165—200 metres. The three dikes first mentioned sometimes show a thickness of 10—15 metres, the last mentioned only of 2—4 metres.

The *Skörstöten* and the *Gustaf Adolf mines* situated close to each another, are illustrative of parallel ore-bodies which are at a comparative distance from each other at the surface, but approch each other with increasing depth, till at last they unite.

On the surface the ores of the Skärstöten have been rather unimportant and have been mined in three different pits surrounded by a mighty skarn zone. Only at a depth of 50 metres the minor ore-bodies unite into a continuous ore-body with a length of 140 metres and a width of 5—8 metres. The ore-body of the Gustaf Adolf mine is parallel to that of the Skärstöten, but has only half its extension in length. On a level of 100 metres the Skärstöten is worked on two separate ore-bodies, the North and South, surrounded by skarn. Granulite is found in the hanging-wall of the Gustaf Adolf mine and skarn in the greater part of the foot wall, and lime in the northern end.

Just below this depth the North and South Skärstöten mines are, however, worked together, forming a fold in the shape of a reversed S; at a depth of 140 metres the ore has been worked in a continuous length of 150 metres, only with some skarn banks between the different ore-bodies. Here the Gustaf Adolf mine has an extent of 60 metres and has still granulite in its hanging-wall and green skarn and lime in its foot-wall. The same lime that appears in the foot-wall of the Gustaf Adolf mine also occurs in the hanging-wall of the Skärstöten.

At 200 metres the ore of the Gustaf Adolf mine has been displaced towards the SW. through the pitch. Somewhat below this depth (at about 210—220 metres) the ore-bodies of the Skärstöten and the Gustaf Adolf mines approach each other and are only separated by a skarn-zone about 5 metres thick. At this depth the Skärstöten ores have divided into several interfering ore-lenses, viz. the N. Skärstöten, Mellangrufvan, Stanley and others. They are partly separated by skarn and partly by lime, at this depth found in a great part of the foot-wall, especially in the Stanley.

Another ore-body occurs at a depth of about 250 metres having a strike from NE. to SW., consequently at right angles to the rest of the ore-bodies. It has granulite and a mighty »sköl» in the hanging-wall, green skarn in the foot-wall, as is the case with the ore-bodies of the Gustaf Adolf mine of which they most likely are a continuation. It, however, winds as it gets deeper and assumes a strike corresponding more with the strike of the other ore-bodies. At a depth of 275 *m* the Skärstöten ores are worked in two mines; the N. Skärstöten and Mellangrufvan having united, and the Stanley mine having continued. The latter is almost entirely surrounded by limestone. At a level of 300 metres these ore-bodies have dilated considerably, so that the northern one has a thickness of 12—15 metres, the southern one of 25 metres. Green skarn occurs all over the hanging-wall, limestone in the foot-wall.

The ore of the Gustaf Adolf mine is an illustration of a continuous ore which it has been possible to follow from the surface down to a depth of 260 metres. It differs from most of the other Persberg ores by being situated on the contact between the skarn-zone and the granulite, whereas the Persberg ores usually are enclosed in the skarn. In this respect the Gustaf Adolf ore corresponds to the chief ore-bodies within the Nordmark mines, which are also situated on the contact between the skarn-zone and the granulite.

The Sala mine.

By

HJ. SJÖGREN.

(With Pl. 54.)

The history of the Sala Mine stretches over four centuries. In all probability the ore-deposits were discovered during the early years of the sixteenth century: the statements about earlier workings, accompanied by figures as to output etc., which assign the discovery of the mine to several centuries further back, have not stood the light of historical criticism. The first document in which Sala is mentioned is dated September 1st, 1510, and from the way in which the deposits are alluded to it is clear that they were newly discovered; from that date Sala is frequently mentioned in historical documents.

The oldest mine was presumably situated on what is now called Herr Sten's level, and subsequently the Sandrymningen was taken up. The rich outcropping ore-bodies were exploited without difficulty, and the first half of the sixteenth century saw the palmy days of the Sala mine, with an average production of about 4,000 kg pr annum. Under the regency of the three Stures, and during the reigns of Christian II and Gustaf Vasa the mine was an important source of public revenue.

But long before the century closed, these palmy days were over: large thrusts had made Herr Sten's level and the greater part of the Sandrymningen inaccessible about 1571, water gained the upper hand more and more. The Kungsrymningen was opened at the end of that century, and thanks to that mine the production reached 200 *kg*, but decreased in 1607 and 1609 to less than 10 *kg:* the mine was then nearly abandoned.

However, King Carl IX and King Gustaf Adolf, who took a lively interest in mining, adopted energetic measures for re-establishing the mine. New shafts, the Knekt, Makalös and Drottning, were sunk in order to exploit the deeper ore-bodies, independently of the old workings. With this advancement the name of the energetic Bergmaster Georg Griesbach is inseparably allied. Yet it took nearly fifty years before any visible results were achieved. The Makalös shaft had been sunk in 1658 to the rich ore-bodies, which were afterwards exploited in the Storgrufvan, further assisted by the completion of the Drottning shaft, in 1660. Now ensued the second period of prosperity of the mine, during which the rich ore-bodies on the first, second, third and fourth levels were worked. The annual production rose occasionally (1673) to 1,700 *kg* and averaged about 1,000 *kg* during the period 1650—1700.

At the beginning of the 18th century, however, these ore-bodies proved to be less productive, and a return had been made in part to older parts of the mines, at a higher level, which were made accessible by means of the Latort and Torg shafts, besides which also the Juthyll mine was worked. Nevertheless, from 1720 to 1750 the production of the mine was small, and the average output was little over 200 kg. Thanks to the skilful Bergmaster Bergenstjerna, the rich Halfvägs ores were discovered in 1760, and the mining was concentrated for a number of years in the higher part of the mine. The deeper levels were neglected: the Carl shaft was shut down in 1763.

These Halfväg ores were almost exhausted at the beginning of the 19th century, and the remunerative working was chiefly confined to the deposits that had been abandoned in days gone by. In order to continue the deep level working, the Carl shaft was re-opened and sunk to its present depth in the midst of the 19th century. But this great work has not led to the discovery of any deposits worth mentioning, as it was not carried to the necessary depth. The work of last century has been almost exclusively confined to exploiting the supplies of ore left behind, of which some were exceedingly productive, e. g. the Spiran deposits in the roof of the first level (1831—35), and in the sixties other rich deposits below the first level. In spite of that, it may be taken for granted that during the whole of the 19th century the mine was worked at a loss and was only kept going by the privileges enjoyed as long as it was leased out by the Crown to the »Sala Bergslag».

The fall in the price of silver that occurred during the eighties and nineties made it impossible to carry on the mine exclusively for the sake of that metal; in the following decade, therefore, attention was directed to the considerable supplies of zinc ore that remained in the mine. The interest in working the mine to-day is bound up in the first place with the experimental attempts to utilize these ores by means of a satisfactory method. The total production of silver during the four centuries the mine has been worked comes to about 400 tons, of which more than one half, 208 tons, falls in the 16th century (1510—1600), the three following ones showing 63, 37, and 87 tons respectively. The rise in production during the last period (1800—1908) is due less to the working of any particularly rich ores than to technical improvements.

An investigation into whether the value of the productions of the mine has equalled the direct costs expended in producing them together with the value of the extensive grants made by government, especially in earlier times, for the work in the form of ground-rents, services of tenants, woods, etc., would certainly show that there was a profit only during the first half-century of the existence of the mine, and that since the midst of the 16th century it has, on the whole, been worked at a loss and has been kept going by artificial means: the privileges already referred to. Some few periods, e. g. the latter half of the 17th century, have possibly yielded a profit, but that has been far from counterbalancing the losses during the other periods. From an economic point of view, therefore, this mine has been run at a loss for three and a half centuries.

To this result has contributed in no small degree the technically imperfect manner in which the ores were utilized until quite recent times. In the second decade of last century it was shown that from the wash-ores, which constituted the main part of the production of the mine, 64 % of the silver was lost in the washing, and furthermore 18 % of the metal in the smelting. The losses in metal (silver and lead) still amounted at the close of the seventies (19th cent.) to more than 60 % in the washing, besides which 19 % of silver and 35 % of lead was lost in the smelting. Of the silver in the washing-ores about a third was turned to account, and of the lead only a quarter[1]. The Sala ores, in order to be profitably smelted down, require, owing to the large percentage of silver, to be mixed with ores rich in lead. The strongly basic gangues rich in lime and magnesia also require a silicious charge or admixture of quartziferous lead ores, which were not always available. The chief cause of the great losses in smelting lies, however, in the fact that a predominant part of the charge consisted of slicks as fine as dust.

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[1] In olden times, when the mine yielded proportionally more of the richer ore, which could be smelted without concentration, the losses connected with the concentrating were not so great. The smelting losses were likewise less since proportionally less slick was smelted down.

Rocks.

The rocks that constitute the Sala district belong to the following groups: the basal complex consists of crystalline schists represented by »hälleflinta» and limestone, the latter extensively altered into dolomite: intruded in these appear Archæan igneous rocks represented by granite and porphyrite, and the whole is intersected by a post-Archæan dike rock, diabase.

The carbonate rocks here, as in other parts of the ore-province of Sweden, are the rocks which are most closely connected with the metalliferous deposits. In particular the deposits of galena show a marked tendency to collect in the limestone; the large and the majority of the small galena occurrences that appear in the neighbourhood of Sala are situated in the limestone, while only a few unimportant ones have been found in the adjoining hälleflinta.

The copper ores (the Lovisa mine, Per's copper mine) likewise show a predilection for limestone.

On the other hand, the iron ores in the district (the Snarpsätra and Springar mines, etc.) are connected with the hälleflinta.

In the continuation of the limestone territory to the N. there appear, along the granite boundary, several lesser bands of limestone of narrow width, while independent narrow strata occur within the hälleflinta, W. of the great limestone mass.

As a rule, the limestone shows granular structure without stratification: at times it presents a schist-like texture by alternation of lighter and darker stripes. Where it is intermingled with ingredients of the hälleflinta, as is the case nearer the border of that rock, a gnarled, crushed and exceedingly irregular parallel structure often arises.

The stratification only eventually appears in the limestone, it is for the greater part obliterated, either by crystallization or dolomitization, and the few scattered points at the surface or in the mine, where an evident parallel texture can be observed, show such different lines of strike and dip that a combination of these cannot be effected. Microscopic slices of the limestone show rectilinear, simple limitations and well developed twin-formation in the separate mineral grains.

Over extensive tracts the limestone is dolomitized, and this is especially the case in the district nearest the deposits. This dolomitization has worked very irregularly so that the dolomite and the dolomitic limestones containing more or less magnesia are irregularly intermixed, as has been found from numerous analyses of samples taken both at the surface and underground. In part, the composition approaches that of a normal dolomite, e. g. in Nyberg's quarry, where the white dolomite contains about 52—55 % $CaCO_3$, 40—42 % $MgCO_3$, and 4—6 % impurities.

Only at some distance from the deposits, e. g. at the N. end of Mellandammen, about 1,500 *m* from the main mine, a limestone free from magnesia occurs, which differs externally from the dolomitic limestone by its coarse crystalline texture.

In the neighbourhood of the hälleflinta, the limestone often includes felspatic substances to such an extent that real transition forms between the two rocks arise.

A transformation of the dolomitic limestone pointing to a silicifying process through siliciferous water has given rise to the formation of the series of lime-, magnesia-, and alumina-silicates, principally of the pyroxene, amphibole, mica, talc, chlorite, and serpentine groups, which constitute the gangues of the deposits. This silicified dolomitic limestone appears chiefly in connection with the ore-bodies, and in a manner that points to a genetic connection with them.

The *hälleflinta* is distributed W. of the limestone, where it forms a zone extending in a N.—S. direction, bounded on both sides by granitic and gneissic rocks. Both in appearance and composition the hälleflinta presents an exceedingly varied formation, whose common character is only the felsitic texture of the ground-mass.

In a structural respect, we can distinguish between the porphyric and the compact hälleflinta. Most widely distributed is a dark or light gray, often brownish rock, whose round grayish blue quartz grains and dark flakes of biotite indicate its porphyric development; phenocrysts of felspar are rare.

The felspar is a plagioclase of varying constitution.

No original surface-rock structures are preserved, but the rock has undergone a very radical dynamo-metamorphic transformation, of both chemical and mechanical nature, which appears in the sericitization of the plagioclase, the transformation of the biotite flakes, and the undulating extinction of the grains of quartz. The rock often presents a secondary parallel texture of dynamo-metamorphic origin, showing itself as scaly or flaky structure.

A parallel structure, reminding one of stratification, is the striping that sometimes occurs in the compact hälleflinta. The rock most resembles the ground-mass in the porphyric hälleflinta, but is occasionally still compacter, quite flint-like; the colour of the different stripes passes through a number of shades, from yellowish white to blackish gray.

The varied appearance of the hälleflinta corresponds to the variations in the constitution.[1] A few varieties have purely granitic or quartz-porphyric constitution; in general, however, the percentages of alkali are lower than in the quartz and felsitic porphyrites, and the constitution corresponds rather to that of the dacites and quartz-porphyries, with which rocks the hälleflinta also shows points of agreement in the quantity of Fe-Mg silicates. On the whole, the rock, in its composition, stands closest to the intermediate eruptive rocks. The percentage of lime, which preponderates over that of Mg, and the often considerable percentage of Na, which in some analyses outweighs the K, forbids the interpretation of it as a

[1] O. GUMÆLIUS, in the Explanation (pr. 1868) to sheet »Sala» of the Geological Survey map (Ser. Aa, No. 26), gives no less than fourteen analyses of hälleflinta from different localities round Sala.

metamorphosed sedimentary rock. The following analysis of the hälleflinta from Stampers has been executed for this paper:

SiO_2	71.53
Al_2O_3	13.51
Fe_2O_3	1.55
FeO	1.16
MgO	0.22
CaO	0.26
Na_2O	0.46
K_2O	10.50
H_2O	0.49
TiO_2	0.22
P_2O_5	0.05
S	0.06
MnO	0.01
Total	100.02
H_2O lost at 105°	0.05

In the boundary zone of the hälleflinta and the dolomitized limestone, there is a transition between hälleflinta and limestone of two kinds: either the hälleflinta takes up the limestone in its ground-mass and passes over in this way into calciferous hälleflinta, or the two rocks stratify alternatively in thin schists, often with a thickness of not more than a few *mm*, without further commixture. It is noteworthy that these mixed schists are always much contorted. The circumstance that no calcareous-magnesia-alumina silicates (garnet, epidote, micas, etc.) are formed within this boundary zone, though the material was present, indicates that neither during the metamorphosis nor after it were the rocks exposed to the degree of temperature requisite for the formation of these minerals.

The *porphyrite* appears in several irregularly bounded intrusive areas within the hälleflinta and the dolomitic limestone. It is characterized by a dark gray, compact ground-mass with phenocrysts of oligoclase and quartz, which often occur so amply that the ground-mass is highly reduced in quantity and the rock assumes a granitic appearance.[1] The structure of the rock refers it to the intrusive bodies. It has not undergone any metamorphosis worth mentioning, either chemically or mechanically. It seems to be sharply bounded against the surrounding rocks of the group of crystalline schists, and to be younger than these. The composition of the porphyrite is shown by the following analyses, executed for this paper.

A. Porphyrite, SW. from Långforsen.

B. Porphyrite, E. from Måns Ols.

	A.	*B,*
SiO_2	66.88	67.39
Al_2O_3	15.69	16.24
Fe_2O_3	0.80	1.14
FeO	2.94	2.29
MgO	1.17	1.05
CaO	3.80	4.33
Na_2O	3.79	4.50
K_2O	2.80	1.24
MnO	0.06	0.07
FeS_2	—	—
S	0.02	0.01
TiO_2	0.50	0.47
P_2O_5	0.15	0.14
CO_2	—	—
H_2O	1.47	0.77
Totals	100.07	99.64
H_2O lost at 105°	0.10	0.02
Spec. gravity	2.70	2.72

The *granite.* On the E. side of the boundary mentioned between the hälleflinta formation on the one side and the granite on the other, the Sala granite extends in a great connected mass. In its constitution the Sala granite is a quartzose, but yet intermediate or basic granite: a large percentage

[1] The rock, which was first marked out by A. E. TÖRNEBOHM in his »Bergslagskarta», Sheet 5, Explanation, p. 23 (1881), was indicated on the Geological Survey map-sheet Sala as granite.

of silica together with a considerable percentage of CaO and MgO. This corresponds to the mineralogical composition: rich in plagioclase, most often somewhat amphiboliferous and with the femic constituents generally abundant.

In structure it is quite massive in the central area, but towards the borders it shows dynamo-metamorphic structures, giving rise to schistose, gneiss-like varieties. The transformation there is both mechanical, revealing itself in parallel texture and mortar structure, and chemical, shown by an often far-extending saussuritization of plagioclase and cloritizing of biotite.

The contact between the granite and the limestone can be seen at the surface in several places and in the Trefot mine, where, thanks to the mining, we can follow the boundary into the depths: the contact there is nearly vertical, and the granite falls in slightly under the limestone.

As an exogenous contact-metamorphosis we may consider the formation of talc and potstone that occur just in the vicinity of the Trefot mine and which in the sixties of the 16th century was the object for a small industry of short duration.

That the Sala granite is younger than the limestone-hälleflinta was already stated by Törnebohm.[1] This is supported by the occurrence of the exogenous contact-metamorphosis at the Trefot mine.

Diabase. The youngest geological formation consists of diabase, as dikes intruding all the other rocks. It is met with as narrow, steeply inclined or vertically running dikes up to a metre thick, occurring both in the hälleflinta and in the limestone as well as in the granite. The rock is fine-grained or perfectly dense, dark gray or black and mostly greatly broken by both longitudinal and transversal cleavage. Microscopically the rock appears fresh and without any marked chemical or mechanical transformation; the ophitic structure

[1] Bergslagskarta, Explanation to sheet 5, p. 37.

is fully preserved. The diabase is closest to the Öje type of TÖRNEBOHM. The composition of the diabase is shown by the following analyses executed by G. NYBLOM for this paper:

A. Diabase, Rackelberget.

B. » , Nyberg's dolomite quarry.

	A.	*B.*
SiO_2	46.19	45.27
Al_2O_3	15.29	14.69
Fe_2O_3	1.27	2.31
FeO	10.90	11.02
MgO	6.76	8.18
CaO	8.53	9.47
Na_2O	2.45	2.19
K_2O	0.33	0.76
MnO	0.19	0.19
FeS_2	1.54	0.26
TiO_2	1.51	1.47
P_2O_5	0.13	0.13
CO_2	1.91	1.68
H_2O	3.70	3.18
Totals	100.70	100.80
H_2O lost at 105°	0.23	0.66
Spec. grav.	2.91	2.92

The diabase dikes occur at the surface, e. g. in Nyberg's dolomite quarry, at Krackelbacken and Solbohällarna, as also in the under-ground workings, e. g. in Grefve Bjelke's Stoll and in the Trundhem mine; in the Storgrufvan they are known at several levels, right down to the deepest parts of the mine, e. g. in the Schulzenheim working at 280 *m* level. The dikes have often a sinuous course, and at times ramify. The main direction of the long diabase dikes in the vicinity of the Sala mine is NE.—SW.

It is noteworthy that the diabase dikes, where they meet the »sköls» or crevices, often jump from one place to another in a way that forcibly reminds one of faults, and which have even been interpreted so. Such »jumps» can be studied in Nyberg's dolomite quarry, at Solbo and in the mine at 190 *m* level.

The fissures that have been filled through the injection of the diabase have evidently arisen through a pressure directed NE.—SW., i. e. parallel to the line of strike of the dikes. As this direction runs about vertical to the main direction of the large »sköls» and fissures, it is natural that at the rupture of the rock the course of the veins has been dependent

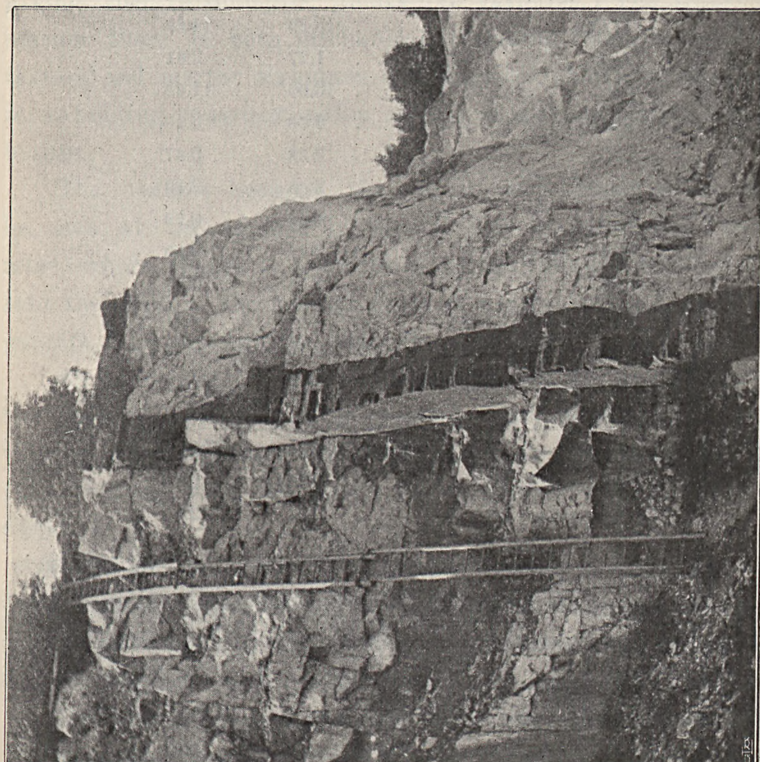

Fig. 1. Dike of diabase in Nyberg's dolomite quarry.

on the earlier existent cleavage, so that each block between two cleavages cracked indepedently, the result being that the loads in one block do not quite correspond to those in the other.

A correct conception of the age of the »sköls» in relation to the diabase dikes is of importance also for the interpretation of the age of the ore-formation. If we share the opinion of several writers who consider that the »sköls» which were simultaneous with the ore-formation really dislocated the diabase dikes and consequently are younger than these, we should be forced to the conclusion that the ore-formation — just as the diabase dikes — were post-Archæan which is by no means the case.

Form and constitution of the metalliferous deposits. The Sala mine is worked on a system of ore-bodies which with a strike of N. 20° W. stand almost vertical. The system has a pitch to the NW. of about 45°, through which the deposits with increasing depth shift towards NNW. The breadth of the metalliferous zone is about 80—100 m. The various ore-bodies are united among themselves in groups, but every attempt that has been made to divide them into a certain number of lodes, or upright and inclined strata, has been abortive. FORSELLES regarded the tectonic of the limestone as a compressed trough and attempted to attribute the most important ore-bodies to the various layers of this supposed trough. DAUBRÉE for his part sought to refer the ore-bodies to a limited number of parallel lodes with a vertical position. Such constructions are not justified and do not correspond to the reality, which exhibits, generally viewed, a tolerably irregular distribution of ore-bodies within the metalliferous zone.

Broadly we can observe a distribution of the ore-bodies into certain groups. Such a group is the one on whose outcropping the ore was discovered, and which has since been worked up through Herr Sten's level, the Sandrymningen and Kungsrymningen ores to a depth of about 140 m. Here occurred a less metalliferous zone with fairly horizontal extension, succeeded in its turn by the considerable group of ore-bodies on which the Storgrufvan, including the first to the fourth levels, is broken. A special group of ore-bodies is the so-called Halfväg ores, which are separated from the foregoing by a non-metalliferous belt, which reveals the same pitch as the ore-bodies themselves. Another group consists of the ore-bodies that are worked in the so-called Torg shaft section.

Broadly speaking, we may say that the first-named of the groups mentioned above was worked up in the 16th century and formed the source of the large productions during the first prosperous time of the mine, which have never since been surpassed or even attained to. The ore-bodies in the Storgrufvan gave rise to another rich period, which fell in the latter half of the 17th century. The Halfväg ores, which were worked up at the end of the 18th century, in their turn gave rise to a fresh increase in production, though of less duration than the foregoing. During various periods there has been a predilection for returning to the mining of the Torg shaft section as soon as the deeper deposits proved too poor.

Similar groups of ore-bodies are those that crop out a little to the N. of the main deposits and which were worked up in the Nygrufvan, the Trundhem and Biskop mines, and other smaller mines in the immediate neighbourhood.

The lack of reason for connecting the ore-formations with the bedding of the limestone is evident from the fact that the ores, as far as their main direction (NNW.—SSE.) runs, do not correspond with the bedding of the limestone at any place where the latter can be observed. The strike of the ore-system (NNW.—SSE.) cuts obliquely across the line of the main strike of the limestone-dolomite, which is NNE.—SSW. In the Hästhag quarry, only a few hundred metres from the Carl shaft, one can observe a strike in the dolomite limestone, here mixed with hälleflinta, which runs almost at right angles to the general strike of the ore. Here, as everywhere where a stratification of the limestone is observable, the latter is very much crumpled and folded, while the direction of the ore-system is straight-lined. In a word, there is no reason to connect in any way the ore-formation with the bedding of the limestone. Most of those who have studied the mine have also pronounced for an epigenetic formation of this metalliferous deposit.

Constitution of the ore-bodies.

The *gangue.* The metalliferous limestone always contains silicates, more or less; the most characteristic are a light green pyroxene (salite), amphiboles, such as tremolite, actinolite, biotite, gray epidote, chlorite, talc and serpentine. The richer the concentrations of ore, the more, too, the silicate formations seem to have developed. Where the dolomitic limestone contains only impregnations of sulphides, the gangue of serpentine and talc mineral is irregularly interspersed as scattered grains or divided into veins forming an ophicalcite. If the concentration of ore is richer, the anhydrous silicates of the pyroxene and amphibole groups and biotite, etc. occur in such a mass that the limestone is entirely extruded. In such places the silicate minerals are often idiomorphically developed against the sulphides. Fragments of shattered crystals of diopside are sometimes cemented together by galena. Under the microscope the ores often show large diopside individuals enclosed in a ground-mass of sulphides. These have invaded along the prismatic cleavages or along cross-fissures, so that only the central part of the crystals is tolerably free from sulphides, while the edges, especially the ends, are saturated with them.

Or, again, there are stalks of actinolite in the sulphide mass; the ends of the stalks divided into filaments that disappear in the sulphide mass, which has invaded it along the prismatic cleavage and also in all cross-fissures. Crystal fragments belonging to one and the same individual are enclosed in a ground-mass of sulphides.

Similarly, there are foliaceous and fibrous aggregates of chlorite, talc and serpentine in a compact compound with fine, dispersed sulphides.

Of special interest are the macroscopic diopside crystals, which in their inner part contain regularly arranged stalks or lamels of galena; in this case we have either enclosures of sulphides, of the same age as the diopside, or else later immigrations into it.

Very common in the richer parts of the ore are concentric arrangements of the gangue and sulphides forming kidney-shaped concretions. Radiate masses of tremolite, with talc, chlorite and serpentine, are surrounded by galena and blende; or radiate, coarsely foliated, gray biotite is arranged in rosette form round a core of galena and blende. Glands of compact serpentine with some chlorite and amphibole sometimes contain also a core of galena, zincblende or iron pyrites. Similar concentric structure forms are characteristic for metasomatic formations.[1]

The chief ore mined in Sala has of old consisted of argentiferous galena; at the end of the 19th century the large supplies of zincblende also began to be turned to account. The galena presents various textures from coarse-crystalline to almost compact and also laminated, but as the significance of these varieties from a paragenetic point of view is not cleared up, there is no reason to go deeper into the matter here. The zincblende is seldom wholly pure, but occurs mostly as impregnation, either by itself or together with galena.

The galena in Sala is one of the richest in silver that we know. Its percentage of silver, reckoned in pure galena, varies between 1,500 and 10,000 grams pr ton of ore. Wiborgh states (1879) that the ore contains 7,000 *gr* of silver pr ton as the average of mined ore and slick, i. e. such as it is sent to the smelting-house.[2] On the whole, however,

[1] As an example of the intimate metasomatic transformation that has taken place, we may mention the transformations of actinolite to stibnite and fibrous galena. These have already been observed by Durocher.

[2] From olden times we have statistics of still higher proportions of silver. Cronstedt states (Mineralogi, p. 199. 1781) that he found galenas with 3 % of silver (= 30,000 *gr* pr ton). Rinman (Lexikon I, p. 249. 1788) states that the galena of Sala generally contains 2,500 to 2,800 *gr* pr ton, and Forselles that it contains 5,000 *gr* pr ton.

the ores, as they have been mined of late, are much poorer in silver, and percentages of 1,000—2,000 *gr* Ag pr ton of ore. have in recent times been looked upon as rich.

Of old the ore has been sorted in three grades: first grade with about 50 % of lead and 4000 *gr* Ag, second grade with about 20 % of lead and 1700 *gr* Ag, and dressing ore with 2—3 % of lead and 2—300 *gr* Ag; the bulk of the mined ore has consisted of dressing ore. During the latter half of the 19th century the first and second grades together hardly exceeded much more than 1 % of the rock raised.

It has of old been taken for granted that the silver occurs as an isomorphous constituent in the galena, and that the insignificant quantities of other silver minerals, which have been observed as rarities, viz. silver amalgam, native silver, pyrargyrite and Weissgültigerz, etc., played no practical part. Not until the lixiviation processes (especially the Russell process) began to be employed on the tailings, and when it showed itself that one could leach out a comparatively large part of the silver while the lead remained unsolved, was the conclusion arrived at that the quantities of silver and lead could not occur as isomorphous constituents in the same mineral, but that the percentage of silver, at least in part, must occur independently of the galena.[1]

As a result of direct experiments it was shown after this[2] that the silver, which could be dissolved with potassium cyanide, is united with sulphur in the form of argentite and that, roughly speaking, a third to a half of the percentage of silver occurs as argentite and the residue as argentiferous galena.

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[1] This was first understood by the brothers A. and W. Heberle; as an expression of their opinion communicated to De Launay on his visit to Sala in 1890 must be considered the statement that occurs in Fuchs et De Launay, Traité des gites minéraux et métallifères, II, p. 611 (1893).

[2] Hj. Sjögren, Angående silfrets förekomstsätt i Sala-malmerna. G. F. F. 22 (1900), p. 178.

The occurrence of other argentiferous minerals in the mine, above all in the upper parts, is mentioned by older reports. In these a special ore, called Kofring, plays a certain part. In HANS RANIE's report of the year 1711 we read, that at the N. end of Herr Sten's Botten, near the place called Sundet, there has been found a kind of brownish and very rich ore, called Kofring. RANIE says that such ore has been mined before in that part of the mine rather extensively, but that now it has not been found within the memory of man. He assumes it to consist of »the German Glasertz or something of that kind».

BERGENSTJERNA also speaks (1754) of a brownish ore, called Kofring, »which the old miners dug close by Sten's Sköl on the side of Sundet at about 30 fathoms' depth» and presumes that it constituted »the rare horn-silver or rather the red silver-ore».

In reports from the 18th century there is also mention in several places of the occurrence of Weissgültigerz and pyrargyrite, which is also testified to by RINMAN.[1]

Essentially similar to that of galena is the occurrence of the zincblende; yet the zincblende does not seem to occur in such rich concentrations as the galena did in the richer parts of the mine. In conformity with this the zinc ores are less intermingled with the gangue, and occur more directly in the dolomitic limestone. Especially characteristic for a great part of the zinc ores are breccia structures, appearing as sharp-edged pieces of light dolomitic limestone being enclosed in an intermass of light brown, dolomite-mixed zincblende.

On the investigation of the zinc ores, which was undertaken during the early years of the present century and which included the resources of the older part of the mine above the

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[1] Bergverkslexikon (1788) I, p. 249. Curiously enough, the occurrence of these minerals is not mentioned either by CRONSTEDT, HISINGER, or other Swedish mineralogists.

DUROCHER, on the other hand, speaks of the occurrence of Jamesonite or Weissgültigerz with about 2,5 % Ag.

first level (187 *m*), the existence of several special ore-bodies was established, containing, together with some galena, mainly zincblende, and which for this reason have remained neglected.

The larger of these ore-bodies go under the names of Penninge, Rödstjärt, Sten's, Bjelke's, Winblad's, Bockort, and Lundström's ore-bodies. They are situated along a few lines, so that the Winblad lies somewhat in the strike of the Penninge ore and the Lundström in the continuation of the Rödstjärt; the Sten Bjelke forms a parallel about 30 *m* from the Penninge ore; this ore is characterized by its percentage of baryte, in which re-

Fig. 2. Brecciated structure of the zinc deposits in dolomite.

spect it is unique in the mine. The zincblende ores occur both E. and W. of the galena deposits mined for a long time.

It is scarcely possible to point out any real difference between the lead and zinc ore-bodies, and there is no indication that they belong to different periods of formation. Zinc occurs in the former just as lead in the latter and they pass over in each other. The zinc ores hitherto mined have contained about 12 % Zn and 1—2 % of lead; they are exclusively dressing ores.

The zinc ores are known also at the greatest depth of the mine (e. g. in the Åkerman at 275 m), though their occurrence below the first level has not been made a subject of inquiry

The zincblende (according to DUROCHER) contains 150 to 200 *gr* Ag pr ton.

Besides silver, lead and zinc ores there occur, as accessory ingredients, minerals containing *gold*, *quicksilver*, *antimony*, *arsenic*, *copper* and *iron*.

Gold. The first mention of the occurrence of gold in the Sala ores comes from the time immediately after the discovery of the mine.[1]) To what extent the silver ores may have been gold-bearing in those parts that were then worked, can now scarcely be established; yet it is by no means impossible that the quicksilver which occurred in certain parts of the older mine, brought about a local concentration of the gold.

In general, however, the Sala ores are remarkable for an unusual absence of gold, a fact already pointed out by ANTON SWAB.[2])

Attention was again directed to the gold, when at the close of the 19th century they set about the lixiviation of the old after, which comes in part from the upper levels of the mine. Some gold was extracted in this way, but we lack statements about the quantity. Amalgam collected in the gullies of the dressing plant showed a proportion of 40 *gr* of gold to the ton. 41 samples taken from different parts of the mine, which were examined for gold, all gave negative results with a single exception, showing a proportion of 3,2 *gr* of gold to the ton.

Quicksilver. The occurrence of quicksilver mineral in the Sala mine was known long ago. The Bergmaster ODELSTJERNA wrote to URBAN HJÄRNE about the find of amalgam in the Penning shaft in 1660, 1689, and 1696[3].

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[1] Thus, early in 1512, the Dean of Linköping, Johannes, sent the new regent, Sten Sture, a remarkable communication, in which he pointed out the depreciation in which the coin of the realm stood in relation to that of its neighbours, and which he considered the less justified because the Sala silver contained some gold.

[2] Vet. Akad. Handl. 6 (1745), p. 118.

[3] Act. Liter. Suec. 3 (1710), p. 59. Sala is consequently the earliest known locality of natural silver amalgam; the well known occurrence at Moschellandsberg is first mentioned 1783 in the literature.

The quicksilver minerals were found in the Sala mine exclusively at the higher levels, in the S. part of the mine, and when mining stopped here, the finds were forgotten for a time. When the upper levels began to be mined again, the amalgam reappeared, and in the working of zinc ores during the last decade the occurrence of quicksilver minerals has not at all been rare. They have appeared especially in the so-called Torg shaft section on the levels between 50 and 100 m depth, e. g. in the Juthyll mine at about 70 m level and in Fågelburen at 90 to 100 m level. Besides amalgam in a liquid and solid form cinnabar has also been met with.[1]

That nevertheless quicksilver minerals enter to a small extent as a constant constituent in the Sala ore is shown by the fact that in treating the tailings by the RUSSEL's process, as much as 600 kg of quicksilver were found on one occasion.

Nore experience concerning the proportion of quicksilver was gained in 1908 while carrying out the attempts to turn to account the zinc ores by DE LAVAL's cyclone process. They show that the zinc ore from the Penninge mine contains at least 0,01 % Hg.

Antimony minerals. Native antimony occurred at the close of the 17th century in the Carl shaft[2] and at the close of the 18th century in the Torg shaft section and the Marknad mine.

Stibnite and the sulphantimonites geocronite and boulangerite, have occurred sporadically together with galena.

Arsenic minerals. Arsenic pyrite is found in several parts of the mine.

Copper minerals. Copper pyrites occur among the other sulphur metals, though rather sparsely in the Sala mine. Copper pyrites are found in quantities in several of the smaller

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[1] It is noteworthy that the solid amalgam occurs in a state of labile aggregation, so that through mechanical action such as shaking or pressure it passes into a liquid form. The pretty well formed crystals occasionally found pass into liquid drops soon after they are fetched up from the mine.

[2] The native antimony was first defined in its proper nature and described by ANT. SWAB: (K. Vet. Handl. 1748, p. 99). D. TILAS had found such from the Gubb shaft, which is sunk in the Storgrufvan »sköl» from the 1st level.

deposits that occur in the neighbourhood of the mine, e. g. Per's copper mine, which lies in dolomite in the strike direction of the main deposit, where it has constituted the chief ore.

Iron minerals. These occur both in the form of iron pyrite and magnetic pyrite as well as magnetite, though not especially abundant in the mines themselves, but abundant in the smaller deposits in the dolomite and hälleflinta of the neighbourhood.

Decrease of the percentage of metal in the lower levels.

Already very early the experience was gained that the ores declined in richness towards the depth. This has been practically shown by the circumstance that at several periods of mining a return was made to higher levels instead of opening up new ores at greater depths. Thus at the end of the 17th century the work was taken up in the Trapprymningen, which was the beginning of the afterwards so productive Torg shaft section. In the middle of the 18th century mining was abandoned at the fourth level in order to render the mining of the Halfväg ores possible. Bergenstjerna, in his report of 1761, says that the upper workings, the Fjärdedel, Halfväg and Ulrika localities, yield an ore in general double as rich in silver as that from the deeper workings, and that these upper workings contain very littles phalerite, especially when compared with the fourth level.

At the end of the 18th century a return was made once more to the Torg shaft section, to which in recent times, as well as to the Juthyll mine, one had profitable recourse, as the deeper parts of the mine did not yield sufficient ore.

It is not easy now to determine with any certainty under what conditions the metal percentage decreased with depth. But it seems obvious that the first grade ores occurred in much larger proportion at the higher levels than at the lower. It is almost impossible to assume that the considerable production during the time directly after the opening up of the mine could have taken place, if the deposit that was mined had contained only about 1 % of first grade ores, as is the case at a greater depth.

But also the occurrence of the rich silver minerals, »kofring», red and white silver ore, native silver, silver amalgam, etc., is confined to the upper half of the mine. An explanation of such a phenomenon would be a difficult matter to-day. Nothing points to a secondary enrichment from the surface, which even theoretically would be difficult in this case to adduce. It should rather be interpreted as a primary property of the deposits, which stands in some connection with the conditions of pressure and temperature at different depths at the time of the formation of the metalliferous deposits.

However, this does not mean that the deposits were confined to the supplies now known to us; such an assumption would be improbable from every point of view. It has already been pointed out that the ores that have been worked hitherto belong to certain large groups, which are separated from one another by less metalliferous zones. This fact has been reflected in the history of the mine, which presents an alternation between periods of prosperity and periods of poverty, according as the richer ore-bodies were worked or one had to be satisfied with the poorer ones until newer and better discoveries were made. By reason of the experience gained from the condition of the ores at the higher levels, there is considerable plausibility in the opinion that the comparatively poor horizon at about 300 *m* which was worked in the deepest workings, will be succeeded farther down, by richer ore-bodies of the same quality as those which have been worked at the first four levels. The general position of the deposits in relation to one another being exceedingly regular — more so than is the case with most mines — and dependent entirely on the regular pitch, it is at once clear in what direction development works hould be undertaken.

Genetical history. An attempt to make out the geology of the Sala mine is at once a hazardous undertaking, since the deposits are enclosed in, generally speaking, a homogeneous rock, the dolomitic limestone, which offers practically no basis for a division. To this may be added that large parts of the mine are now inaccessible, owing to thrusts and that other parts are under water. For such parts we are, therefore, entirely dependent on the statements of older reports.

In order rightly to understand the genetical history of the Sala deposits, it is necessary to make clear the relative age of the various geological constituents within the area of the mine. This means that we must take into consideration the limestone, the dolomite, the silicate gangues, the metal sulphides, the »sköls» and the diabase dikes.

Relations of the dolomite to the limestone. As has been mentioned already, the commixture of dolomite and limestone is quite irregular. On the whole, the limestone seems to have been more strongly dolomitized in the direct vicinity of the mine than at some little distance from it. The quarries near the mine (Nyberg's, the Hästhag, etc.) show a pure and homogeneous dolomite, in its constitution approaching normal dolomite, and pure limestone occurs only in the quarries further distant from the mine; the nearest quarries containing limestone are those situated at the so-called Rödfärg mine, about 1,5 km N. of the Carl shaft. In the mine itself, according to some 80 analyses, there is an absolutely irregular alternation of more or less dolomitic limestones. Some approach normal dolomite in constitution; only in a few cases does carbonate of magnesia enter in any quantity greater than corresponds to normal dolomite; in most cases the carbonate of lime is predominant. No regular distribution of the carbonate of magnesia in the rock was revealed anywhere. Some twenty samples taken at the Halfväg levels, for instance, at about 86 m depth, show a variation in the number of molecules from carbonate of lime to carbonate of magnesia, of 10 : 1 to 1 : 1, and that in an area of about 100 m in length.

From this we may conclude that the amount of magnesia was introduced later into the limestone in an irregular manner, and cannot be considered as an original constituent of it.

Gangues and metal sulphides in relation to the dolomite. The metal sulphides are younger formations than the dolomitic limestone in which they occur; in many cases this can be directly proved, and is perhaps most evident from the breccia-like structure of the dolomite, the space between the fragments of the original rock being replaced by metal sulphides. These breccias should not be looked upon as fracture breccias, but as metasomatic formations, a kind of relic breccia, the metalliferous solutions having been introduced through crevices, from which gradually the metalliferous material invaded and partly replaced the limestone. The later formation of the sulphides is also proved by the concentric structure, in which the gangue and sulphides sometimes appear. Often enough, however, one cannot observe either breccia formation or concentric structure in the metal sulphides, these being interspersed in or impregnating the dolomitic limestone. It is this circumstance that has given rise to the conception that the ores, in bulk at least, were formed at the same time as the rock (HAUSMANN, GUMÆLIUS, TÖRNEBOHM). But it is evident, in our present knowledge of the metasomatic processes, that the circumstance referred to in no wise excludes the possibility of a later immigration.

The gangue, chiefly consisting of silicates of the pyroxene, amphibole, chlorite, serpentine and talc groups, accompanies the ores in a manner that evidently points to a genetic affinity. The gangue-forming minerals are in the main the same as those that appear in the case of contact metamorphoses of the limestones, but still we cannot venture to doubt that they are a secondary formation due to fresh material. Along with the deposition of the metal surphides, a silicification has also taken place. The formation of silicates has largely come to pass through the influence of silicic solutions on the dolomitic limestone. We can scarcely call in question that it is not the same solutions that supplied the metal sulphides which also brought the silicates constituting the gangue. Nevertheless, as has already been stated, we can often observe that the diopside crystals, for instance, are idiomorphically bounded by the galena mass, or that fragments of shattered diopside crystals have been cemented together with galena mass; in that case the galena generation is therefore somewhat younger than the silicate formation.

The ore-formation and the »sköls». Of especial interest is the connection between the ores and the »sköls»: this has, in fact, been the object of the attention of all earlier observers, and any theory dealing with the history of the formation of the Sala deposits must depend to a large extent on the solution of this problem.

The sköls in Sala are fundamentally of the same nature as those amid other Swedish ore deposits; but attempts have been made to interpret them quite differently, viz. as channels for the mineralizing solutions (FORSELLES and others). The sköls appear as a kind of divisional planes which traverse the dolomitized limestone; they are of all thicknesses, from that of a leaf to several metres. The body of the sköl consists of the same mineral that enters as the gangue into the dolomitic limestone; yet the main body is made up of hydrated magnesia silicates of the talc, serpentine and chlorite groups. In the constitution of the sköls there are occasionally amorphous or massive varieties of silica, which have been confounded with hälleflinta. The sköls are only exceptionally metalliferous.

The sköls have often a sinuous course and thus irregularly confine ellipsoidal parts of the rock mass.

The Storgrufva »sköl». This sköl intersects practically the whole metalliferous deposit throughout its length, from the

Juthyll workings right up to the Carl shaft. It has a somewhat bent course, and its strike, which winds somewhat, is N. 10° W. to N. 30° W.

According to statements in the older reports, it had, in the older workings in the uppermost part of the mine, a thickness of up to 20 *m*, but thins out towards the depth, where it has only 1—2 *m*. The sköl has the character of a friction breccia, consisting for the most part of lenticular fragments of a dolomite mixed with magnesia silicates, divided up by gliding-planes, filled with secondarily formed hydrous magnesia silicate of the serpentine and talc groups. In the S. part of the field the »sköl» of the Storgrufvan has a dip of 25° to the W.; further N. it runs almost vertical.

It is clear from the sections that at the higher levels the deposits occur chiefly on the W. side of the great sköl or above it. Owing to the dip of the sköl to the W., however, it soon reaches the deposits, which it cuts obliquely, and at a depth of 160—200 *m* leaves the deposits to its right. The chief sköl is consequently, in its position and course, to some extent independent of the deposits: broadly speaking, it determines the position and extent of the deposits, but the ore-bodies are not bound to it in detail, being situated now on the one, now on the other side of it.

Other large »sköls». The S. part of the field is cut in two by a sköl system, the Juthyll and Skänkeborn sköls, which may be observed in the S. wall of Herr Sten's level and in a number of work-rooms in the neighbourbood. These sköls have a declivity of about 40—50° to the N., consequently about the same dip as the deposits in their entirety; the strike is S. 10° W. (?) On the S. side of these dividing sköls, however, deposits occur, e. g. the whole Torg shaft section, so that the sköls do not constitute any dislocating termination of the field in this direction.

A considerable sköl formation, the Sandrymning sköl, which runs fairly parallel with the sköls named, also borders the Sandrymning to the S. The sköl appearing in the more northerly and consequently deeper parts of the mine, have been divided into two systems; those lying to the E. of the Storgrufva sköl, and those to the W. At the higher levels near the surface these sköl systems are almost at right angles to each other. Remarkably enough, they are parallel to the sköl systems, which can be observed in Nyberg's and the Hästhag quarries. The sköls in the former quarry, which lies E. of the Storgrufva sköl, have an almost regular N.—S. strike and thus correspond in the main with the direction of the Flintort, Landrymning, Ribbing and Drottning sköls at higher levels. The sköls in the Hästhag quarry, situated to the W. of the Carl shaft, have a main strike of N. 70° W. with about 45° dip to the N. This is in the main the strike and dip that the Tand, Fågelort, Kungsrymning, Fjärdedelsort and Torkel sköls have at the higher levels.

At a greater depth the sköls belonging to both the E. and W. systems change the direction of their strike, so that they become almost parallel with the Storgrufva sköl, with which too, one after another, they unite.

In the Storgrufvan embracing the 1st to the 4th levels from a depth of 187 to 267 *m*, the development of the sköls has been very rich, corresponding to the well developed ore-deposits here. Besides the Storgrufva »sköl», which crosses this part of the mine, there were to the E. of it two particularly large sköl formations accompanied by very rich ore-deposits, the Ribbing sköl and the Drottning sköl. These sköls here run parallel to the Storgrufva sköl and approach it towards the depths. The Ribbing sköl which had already made its appearance at a higher level, where it enclosed the ore-bodies that were mined through the Bergenstjerna shaft (150 *m*), also contained the considerable ore-bodies that were mined through the Ribbing drive (160—175 *m*), the Riksdag, the Collegie (178—187 m), and the Bergman drives (187—196 *m*). At a depth of 200—220 *m* this sköl shrinks up and becomes so disturbed that it cannot be followed further; at the same time the metalliferous deposits cease.

The Drottning sköl lies between the Ribbing sköl and that of the Storgrufvan, parallel to both. At the first level we have the considerable ore-bodies that have been exploited in the Fall and Väderort pits; they lie between the Drottning and Storgrufva sköls.

However, large and rich ore-bodies may also occur which do not seem to stand in any connection with sköls, but are independent of them; as an example we may mention the ore that was mined in the Wrangel pit level (220—230 *m*) at the end of the 17th and the beginning of the 18th centuries, and which at that time was one of the best profitable parts of the mine. A similar example is the case of the ore-bodies that were mined through the Vattenpelare drive at about 240—250 *m* depth, apparently the largest deposit met with so deep down; it had a maximum breadth of 7 *m*, and, to judge from the extent of the workings, a length of *50—60* m.

Minor »sköls» and leaders. These traverse the deposits and the ore-bearing rock irregularly in every direction, and can scarcely, as far as their direction goes, be referred to any certain system.

The transition between the richer and poorer parts, and between ore-bearing and barren rock, is often quite gradual; sometimes they are divided by sköls. Often there are fine ore-breccias (galena or zincblende) which on both sides or on one of them are bounded by thin sköls (the Tegelmurstappen): on the other side of the sköl the rock is either barren or contains only sporadic patches of ore or lean impregnations. Here and there one can observe how the deposits in the direction of the pitch grow leaner and cease at the same time as the sköl (the Heberle, 89 *m*).

At some places there are fine ore-breccias enclosing pieces of dolomite of the size of a human head; the breccias may either be bounded by thin parallel sköls which separate them from poorer breccias (cross the Hetort shaft, 90 *m*); or else the sköls are lacking, no sharp boundary can be drawn, and a regular thinning of deposits takes place towards the surrounding rock (the Rödstjärt).

A summary of the preceding shows:

1. That the ore-bodies on the whole are arranged on either side of the Storgrufva sköl, which crosses the ore-field from N. to S. along the whole of the greatest depth that has been reached;

2. That the ore-bodies only exceptionally lie directly close to this sköl, being often at some inconsiderable distance from it, and that it is not ore-bearing along its whole extent. *This excludes the probability of the mineralization having proceeded from the Storgrufva sköl;*

3. That many of the largest and richest ore-bodies were confined to other large sköls, such as those of the Juthyll and Skänkeborn, the Flintort, Ribbing and Drottning; the ore-bodies occur most often in such a way that the sköls form the boundary between the more or less metalliferous and the absolutely barren rock. *This also speaks against the ore having been supplied through cracks in the sköls, since in that case we should have expected both sides of the sköl to have been mineralized.*

4. That the ore-bodies, even if they appear in connection with a large sköl, do not lie close up to it but at some distance off, and that considerable and rich ore-bodies occurred quite independent of any sköl.

5. That we can often observe that when the ore thins out and ceases, the accompanying sköl likewise disappears.

6. That the parts of the mine where the large sköls occur abundantly and have approached one another, e. g. in the Storgrufvan between the Storgrufva, Drottning and Ribbing sköls, were remarkable for exceedingly rich ore, or in other

words, *that the development of the sköl phenomenon and ore formation have gone hand in hand.*

7. That this also shows itself in the manner in which the richest ores have, generally speaking, occurred at the higher levels, where the Storgrufva sköl had a greater thickness, while the ores declined, on the whole, towards the depths in the same degree as this sköl was less developed.

It seems to result from the foregoing that we cannot place the »sköls» and ore-bodies in such a connection with each other that the former were pre-existing channels for the mineral-bearing solutions, or that, on the whole, they occurred earlier than the mineralization and exercised any influence on them. Nor, in general, are the sköls essentially younger than the ore-formations; a number of calcite sköls, however, with a tendency to cause faults, are presumably younger.

It seems, on the whole, as if *the sköl formation and the mineralization were two sides of the same phenomenon, which have gone hand in hand and are of about the same age.* Possibly we may connect the sköl phenomenon with the decrease in volume that accompanied the metasomatic substitution of metal sulphides for dolomite.

That the mineral constituents of the sköls, hydrated magnesia silicate of the serpentine and talc groups, are secondary formations deriving from the influence of solutions on the dolomitic limestone, is obvious. It is true that their constitution seems to point to an origin within the surface zone, within reach of descending, atmospheric surface water. Though our knowledge of the conditions of the formation of these minerals and their area of stability is still incomplete, yet geologic experience from other places (e. g. the serpentine formation in connection with the olivine stones) shows that a part at least of these minerals may be a result of a subterranean influence from solutions. By reason of their physical constitution, however, the sköls have since becoem water-ways from the surface, which has contributed, in some measure, towards the formation of secondary mineral products in them (jasper, etc.).

Relation of the diabase to ores and »sköls». As has already been pointed out, the youngest geological formation consists of diabase dikes. Already in 1816, BILLOW lays emphasis upon the fact that the diabase dikes are younger than the ore and are intruded in it without exercising any influence upon it.

Occasionally, however, impregnations and crevice fillings of sulphides occur in the diabase in such a way that several observers have been induced to regard the ore formation as younger than the diabase; this is the case with both DAUBRÉE and DUROCHER. Yet this view is based only on the insignificant secondary infiltrations of sulphides, chiefly galena, which are met with in the crevices of the diabase, and which are to be attributed to the easy solubility of the galena, which gives it a tendency to dislodge and be deposited in secondary spots.

The relation between the diabases and the sköls has already been touched on. GUMÆLIUS, who has reproduced and described the appearance of the diabase dikes, both on the surface and in the mine[1], gave a correct interpretation of the apparent faults. He showed that the irregularities which the dike exhibits by jumping off at the meeting with a crack, etc., depend on original irregularities in the formation of the dikes and the filling of the crevice in the rock, and are not true faults. In the same way are to be explained also the sudden changes in thickness, the dike in passing a crack often becoming multifold, or that in ramifying now the one, now the other fork appears as the chief dike. The Storgrufva sköl alone, in the opinion of GUMÆLIUS, has caused a true fault in the diabase dike, and he therefore considers this sköl to be younger than the diabase.

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[1] Geological Survey map-sheet Sala, Explanation, p. 91 seq. On trap »sköls» in the Sala mine, G. F. F. 1 (1872), p. 162.

But in reality there is no reason to consider the Storgrufva sköl as of a different kind from the other sköls or of a different age. It is the largest and the most regularly formed, but for the rest similar to them. It is therefore probable that also the fault is only an apparent one, despite the seemingly greater throw.[1]

Historical Synopsis of the Opinions about the Formation of the Sala ores. Already in the middle of the 18th century, there was a correct general conception of the genesis of the Sala ores. BERGENSTJERNA, a contemporary of the eminent mining geologists TILAS, SWAB and CRONSTEDT, in an interesting report of 1754 has left not only the first geologic description of the deposits, but has also advanced a theory to explain them. He attributed the ore-deposition to metal-bearing solutions rising from the depth and following the sköls and their ramifications, depositing their contents in the porous limestone. Both he and his successors, STAFF and PIHL, consequently maintained a purely epigenetic interpretation, which is also in complete concord with the views held by the Swedish geologists of his days. The same view is expressed by BILLOW (1816) and FORSELLES (1818), though the latter considered that a trough-shaped tectonical structure of the limestone determined the mineralization. The same oponion was also advanced by HISINGER. The Wernerian HAUSMANN (1816) represented a purely Neptunian view, while the two excellent french geologists DAUBRÉE (1843) and DUROCHER (1848) returned to an epigenetic theory.

GUMÆLIUS (1868) and TÖRNEBOHM (1880) tried to unite these different opinions by considering the greater part of the deposits as a stratified formation of contemporary origin with the limestone, the richer ore-bodies appearing in connection with the sköls being held to represent younger concentrations.

[1] Unfortunately, during the time when this examination was made, the deeper levels were not accessible, owing to the presence of water, so that the relation between the Storgrufvan and the trap sköls could not be investigated in this particular.

According to the account given above, the epigenetic origin is certainly much more obvious in some of the ores than in the others, but there seems no reason why we should attribute to them a twofold formation. To connect the ore with any of the intrusive rocks of the district, granite or porphyrite, would be entirely hypothetic, and could not be supported by any fact at present known to us.

The perfectly similar mode of occurrence of galenas, pyrites and iron ores in and around the Sala mine forms a support, moreover, for the many other proofs that can be gathered from various parts of the ore district of Central Sweden, that no genetic difference between sulphide and oxide ores, i. e. betwen lead, zinc, silver, copper and iron ores, within this metalliferous district can be established.

On the Sequence of Strata within Southern Gotland.

By

HENR. MUNTHE.

(With Pl. 55.)

Since the days of LINNÆUS the rocks of the island of Gotland have been an object of special attention for naturalist because of the abundance of their well preserved fossils.

For the earliest scientific information about the rocks and fossils of the island we are indebted to LINNÉ (1745 [1] and later). Afterwards (in 1818) WAHLENBERG referred the strata of Gotland to the so-called »Übergangsgebirge» (WERNER), while HISINGER, who (in 1827) gave a somewhat fuller description of the different strata and their extent, was of opinion that the Crinoid and Coral limestones of Gotland were younger than the »Übergangsgebirge» in other parts of Sweden and that the sandstone and oolite of the southern part of the island were the youngest of all, probably belonging to the Jurassic system.

Sir RODERICK MURCHISON stated (1847), that the strata of Gotland, which he termed *e* to *k*, are *Upper Silurian* in age and belong to the *Wenlock*, *Aymestry*, and *Ludlow* strata of Britain; the *Wenlock* including the strata *e* and *f* of Northern Gotland (e = shales with nodules of limestone,

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[1] See the Bibliography at the end of the paper.

f = reddish encrinite limestone, and f′ = hard limestone with concretions); the *Aymestry* including the strata *g* and *h* of Central Gotland (g = shales, and h = limestone); and, finally, the *Ludlow* the strata *i* to *k* of Southern Gotland (i = sandstone, f = oolite, k = coralline limestone, and k* = encrinite limestone). MURCHISON was led to this division of the strata partly from their contents of fossils, and partly also from their dipping gently towards SSE., *e* being thus the oldest and k* the youngest of them.

FRIEDR. SCHMIDT, who travelled in Gotland 1857, and in 1859 published a valuable stratigraphical paper, agreed in the main with the views of MURCHISON, but was of opinion, that the dip of the strata was rather from NW. to SE., and, thus, his order of succession was (1) the NW. or Wisby-zone, (2) the Centralzone, which was, again, divided in *two sub-zones*, that of *Pentamerus estonus* and that of *P. conchidium*, and, (3) the SE.-zone or Southern Gotland, being the youngest of all.

In contrast with the views of MURCHISON and SCHMIDT, HISINGER (in his later papers), HELMERSEN, F. RÖMER, ANGELIN, LINDSTRÖM, DAMES, and others were of opinion, that the strata of Gotland are nearly horizontal, having only a very gradual dip towards the East and that, therefore, synchronous strata are to be found in all parts of the island.

As early as 1857 LINDSTRÖM stated, that the sandstone of Southern Gotland passes gradually into shales towards the North (in the parish of Burs), and this opinion seems to have been with him later on, when speaking on the sequence of the strata of Gotland.

As is well known, LINDSTRÖM published a large number of valuable papers on the Lethæa of Gotland, and in some of these he also deals with the stratigraphy, especially in 1860, 1884, and 1888. Thus, in the paper of 1860 he gave a detailed description of the different strata and their fossil faunas, dealing in the first place, with the Brachiopoda. As to the sequence of the strata he still agreed fairly well with that given by SCHMIDT in 1859. Thus his division was: (1) the Wisby group, (2) the Middle Gotland group, and (3) the South-Gotland group.

In his papers of 1884 etc., and especially that of 1888, on the contrary, he fully developes the view, that, on the whole, different strata occur within different areas of the island. His results were tabulated as follows, and were somewhat added to in 1890:

Gotland.	Britain.	Approximat. thickness in metres (accord. to BATHER 1893.)
h) *Cephalopod beds*	Ludlow beds	9
g) *Megalomus banks* with *Trimerella* . .		3.5
f) *Crinoid beds and Coral conglomerate*		15
e) *Pterygotus* and *Palæophonus beds*, chiefly near Wisby.		0.3—1.5
d) 1. The beds of Northern and Central Gotland: *bands of shale and limestone*, the latter being more abundant upwards; 2. The beds of Southern Gotland: *oolitic beds alternating with other sorts of limestone*	Wenlock limestone	6—15
c) *Shale beds* in different parts of the island, except in the southernmost area, where they are gradually replaced by *sandstone*	Whenlock shale	7—22
b) *Stricklandinia marl*, near Wisby . . .	Upper Llandovery	15
a) *Arachnophyllum shale*, near Wisby, but only below sea-level.		

As this paper of LINDSTRÖM is of a great importance in considering the questions here under discussion, we may review it here.

While the strata *a* and *b* are only found near Wisby and are, therefore, of no special interest for the present account of Southern Gotland, the strata *c* to *g* are said to be represented in different districts of the island, though some of them occur with different lithological and faunistic developments.

Thus ***the bed c*** is divided into the following synchronous »faunal-districts», running about SW. and NE. across the island:

c_1) The Wisby fauna, which is characterized by *Palæocyclus porpita*, *Cyathophyllum angustum*, *Strophomena Walmstedtii*, etc. At Gnisvärd (SSW. of Wisby) *Holophragma calceoloides* etc. occur.

c_2) The Westergarn fauna (also including the marl of Stora Carlsö) with *Leperditia Schmidtii* Kolm. (= *L. Hisingerii* Schm.) and *Spirifera exporrecta* (both also found in c_1), *Orthis osiliensis*, and a variety of *Whitfieldia tumida* etc.

c_3) The fauna of the Central area [Fröjel to Eksta and towards NE. to Slite etc. (on the map-sheet of »Wisby»)] with *Whitfieldia tumida*, *Strophomena funiculata*, *Orthis elegantula*, *O. biloba*, *Orthoceras annulatum*, etc. Locally, in Fröjel, a flagstone with *Atrypa cordata* etc. belongs to this facies.

c_4) The Petesvik (Hablingbo) fauna (towards NE. to Hemse, Burs, etc.), with *Calymmene intermedia*, *Orthis canaliculata*, *Dayia navicula*, etc. Probably the lowest shale beds at Östergarn are also an equivalent. They contain, *inter alia*, *Chonetes striatella* and *Atrypa didyma*.

c_5) The Sandstone fauna of Southern Gotland, with *Homalonotus Knightii*, *Chonetes striatella*, *Pterinea retroflexa*, etc.

The bed d contains, in the North of Southern Gotland, as characteristic forms *Orthis basalis*, *Eichwaldia Capewelli*, *Atrypa Angelini*, etc.; in places *Pentamerus oblongus* is common. — As a curious facies is mentioned a dense limestone with *Ilionia* (*Lucina*) *prisca* and several species of *Orthoceras* (*O. angulatum* etc.). These are met with at Östergarn and in Southern

Gotland. The oolite there is rich in *Lamellibranchiata* etc.

The bed e has a rather local development and may here be omitted.

The bed f in the parish of Lau contains *Leperditia phaseolus*, *Spirifera Schmidtii*, *Rhizophyllum*, etc.; in the hill of Klinte *Pentamerus conchidium*, and in N. Gotland *Pleurotomaria limata* etc. occur.

The bed g extents from N. Gotland to Hejde and Ardre. It contains, *i. a.*, *Megalomus gotlandicus*, *Trimerella*, *Dinobolus*, while in Southern Gotland, of the fossils above mentioned, only *Trimerella* is met with.

The bed h is found in different districts all over the island. It consists principally of masses of *Stromatopora*, *Crinoids* and *Cephalopoda* (species of *Ascoceras*, *Phragmoceras*, *Ophidioceras*, etc.).

As to the *tectonics* of the strata of Gotland, LINDSTRÖM pointed out, that in several places there are marked dislocations (both anticlinal folds and normal faults). Thus, for instance, the bed *c* in Eastern Gotland is mostly below the sea-level, while at Högklint near Wisby it reaches about 50 ft, in Follingbo (SE. of Wisby) 100 ft, and in Fardhem 90 feet above sea-level. In the SE.-most district of the island the bed *h* is in part below sea-level.

In 1890 FRIEDRICH SCHMIDT published a paper, in which he on the whole adheres to his opinions as expressed in 1859. His division into zones is now somewhat altered. The NW. or Wisby zone is said to contain LINDSTRÖMS beds *a* to *d* (possibly *e* also), the Central- or North-Gotland zone to be equal to LINDSTRÖM's bed *f*; the South-Gotland zone is characterized by the *Pentamerus conchidium* bed and some younger strata (the sub-zone of *P. estonus* being annulled).

In agreement with his view as to the regular dip of the strata towards SE., SCHMIDT expresses the opinion that

LINDSTRÖM's »faunistic bed» c_1 to $c_{4(5)}$, striking from SW. to NE., is not always one and the same bed, but is *a series of strata, c_1 being the oldest and c_4 the youngest of them.* He thought that c_3 is probably either equivalent to the bed *f* of the Wisby district, or that there it thins out between the beds *f* and *g* to *h*.

Special attention is drawn to *Leperditia Schmidtii* (= *Hisingerii*, see above) and. *L. baltica* (*pectinata*), of which the former occurs only in c_1, the latter in c_2 and in somewhat younger strata.

As to LINDSTRÖM's beds c_5 and *d* (the sandstone and oolite respectively) SCHMIDT (in 1891) agrees with LINDSTRÖM, and says that the sandstone is an equivalent of the Petesvik marl-shale (c_4) and the oolite to the Östergarn limestone (*d*) which contains *Ilionia prisca*, etc.

As regards this latter bed SCHMIDT points out, that it is nearly related to a lower zone of a *Megalomus*-bearing limestone, which is found at Ardre and at Östergarn where the *Megalomus* bed is thought by LINDSTRÖM and DAMES to be faulted down.

Since *Pentamerus conchidium* is said to have been found in the marl-shale of Petesvik and is found both in the Östergarn bed just mentioned and in the middle part of Klinteberget, etc., all these beds are considered by SCHMIDT to be synchronous. Still younger are the Stromatopora beds etc. which rest upon these.

SCHMIDT gives also much valuable information as to other points under discussion, and his paper includes an interesting comparison between the fossil faunas of the strata of Gotland and of Esthonia.

Prof. DAMES in his paper of 1890 agreed in the main with LINDSTRÖM but was of opinion that the uppermost part of the table of strata may be rewritten as follows (cfr. LINDSTRÖM's table, cited above):

g = *Upper Cephalopod limestone;*
f = *Crinoid and Coral limestone with reefs of Stromatora; Gastropoda and Ascoceras limestone, as well as the banks of Megalomus.*

Dr. F. A. BATHER in 1893 proposed to rename the bed *g* of DAMES as *h* of LINDSTRÖM = *the uppermost Cephalopod bed* and, with LINDSTRÖM, agress to retain the bed *g* as the *Uppermost Megalomus* and *Trimerella beds.* In other respects, he agrees »that Prof. LINDSTRÖM's correlation of the rocks in the different parts of the island is in all essentials perfectly correct» (l. c. p. 16).

In 1896 E. STOLLEY pointed out the important rôle which *Girvanella* has played in the formation of some strata of Southern Gotland and in the Wisby district. He agrees with LINDSTRÖM as to the division of the strata, as also does C. WIMAN who (in 1897) points out a further synchrony between LINDSTRÖM's bed *d* and the reef-limestone, which LINDSTRÖM had previously referred to his bed *f*. In the same year (1897) K. A. GRÖNWALL stated that the younger Upper Silurian strata of Skåne are to be correlated with the lower strata of Southern Gotland which, therefore, might be younger than was thought by LINDSTRÖM, and the same conclusion has been reached by him and J. C. MOBERG in 1909.

In 1892 the mapping of the rocks, along with that of the Quaternary deposits of Gotland, was begun by the Sveriges Geologiska Undersökning. This mapping was at first confined to the topographic map-sheet of »Hamra», and was undertaken by Prof. J. C. MOBERG, who was at times assisted by Dr. K. A. GRÖNWALL. Later on, it was commenced also on the »Roma» map by myself, and still later, on the »Wisby» sheet, by Dr. H. HEDSTRÖM. When Prof. MOBERG had nearly finished his minute and valuable mapping of »Hamra», the revision and publication of his map was left to me. These map-sheets, on the scale of 1 : 50 000, are still under preparation, but are not yet ready for publication, since the changing of the scale from 1 : 100 000 to 1 : 50 000 has made a more special revision necessary. The map-sheet of »Hamra», on the scale of 1:100000, was printed in 1897 but has since been recalled.

For some summers Prof. G. Holm travelled for Sveriges Geologiska Undersökning in Gotland in order to study the stratigraphy. As yet, however, only the following communication from his hand has appeared:[1]

»Within the Upper Silurian of Gotland two great divisions are to be discerned, viz. *a lower division* consisting of *marlshales with nodules and beds of limestone* and *with sandstone* (the sandstone of Bursvik) *and oolite at the top.* Since the strata of this lower division dip slowly towards SE., the sandstone and the oolite are to be found only in the southern part of the island.

An upper division consists nearly exclusively of *limestone, principally old coral reefs:* accumulated masses of Corals, Bryozoa, Spongia(?), Echinodermata, etc. Its strata are, on the whole, horizontal and rest, therefore, with slight unconformity on the strata of the lower division. At the boundary between the two divisions conglomerates are not infrequent. The discordance as well as the occurrence at this horizon of a land animal, a scorpion, makes it probable that land existed in Gotland during the middle part of the Upper Silurian period.»

In a paper (1902) and a lecture (1907) I have tried to present the sequence of strata within the south-eastern and southern parts of Gotland (see below), and in connection with the lecture mentioned, some remarks on the question were made by C. Wiman, H. Hedström, K. Grönwall, and myself. (Cfr. Geol. För. Förh. Bd 29, pp. 138 to 140.)

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[1] In the explanation to »Geologisk öfversigtskarta öfver Sveriges berggrund, upprättad och utgifven af Sveriges Geologiska Undersökning 1901». (Ser. Ba, N:o 6.)

In 1905 Dr. H. G. JONKER puts forward the opinion that LINDSTRÖM'S division is not right and that that of SCHMIDT is, on the whole, more satisfactory.

Lastly (in 1908) Dr. JOHAN KIÆR, Kristiania, in his important work on the Upper Silurian of the Kristiania district discusses also the question of the sequence of strata in Gotland and draws parallels between the Silurian strata in Northern Europe. (See under.) *Inter alia*, he is of opinion that SCHMIDT'S subdivision of LINDSTRÖM'S bed c is, on the whole, correct.

During the last few summers I have had opportunity to add to the older researches. As will be evident from the following description, several lacunæ still remain to be filled up before all doubtful questions of the stratigraphy of the interresting but heterogeneous area of Gotland are competely cleared up.

When I try, notwithstanding, to give to the Congress a general survey of the stratigraphy of Southern Gotland (the topographic map-sheets of »Hamra» and »Roma»), I beg to remark that though this may be considered rather a risky undertaking, it is a new attempt, following upon the several former ones, and is made with a further knowledge of the facts. Finally, I would express my sure hope that some of the obscure questions will be cleared up when we discuss them during the excursion in the field.

As to ***the topography*** of the areas in question a few words here will be sufficient, since it is very easily picked up from the topographic maps.

Southern Gotland may be characterized as a rather low plain the higher parts of which do not often reach more than 30 to 50 *m* above sea-level. From this plain there rise in places, some few tens of metres above the surrounding district, hills, isolated by erosion, and having limestone at their top. Commonly those hills consist of reef-limestone, which has resisted the work of the land-ice more successfully than have the shales and the bedded limestones. A belt running NE. to SW. through the parishes of Etelhem, Stånga, Löjsta, and Fardhem is especially noticable. Sometimes steep cliffs (»klintar» in Swedish) rise almost directly from the sea, as at Hoburgen (in the extreme S.), Karlsöar, Tofta (NW.), and Östergarn. As instances of steep cliffs inland may be mentioned Klinteberget, Fröjelberget, and Gannberget (in the parish of Östergarn. (For fuller information see MUNTHE 1910.)

Since the south and south-eastern districts of the island are relatively well known, it may be convenient first to review these areas, and then, for comparison, to glance at some other districts.

1. The sequence of strata within the map-sheet of Hamra and adjacent districts.

As I tried to show in 1902 the sequence of strata within the parish of Lau and in adjoining districts of the parish of När is somewhat as follows. (The letters *f* to *c* are used approximately in the sense of LINDSTRÖM, in 1888 and afterwards):

f. *Rhizophyllum*-bearing marly reef-limestone, sometimes replaced by calcareous marl-shale.

e. *Pterygotus*-bearing sandy and in some places micaceous marl-shale.

d_3. Crystalline limestone, locally replaced by marly limestone, conglomerate, or reef-limestone.

d_{2+1}. Hard, marly, dolomitic flags, rich in *Dayia navicula* and (or) *Strophomena impressa.*

c. Clay- or marl-shales with thin bands or lenses of marly limestone.

Of the more southern parts of the island (the area included within the topographic map-sheet of »Hamra») I gave in 1907, in a lecture to the Geologiska Föreningen in Stockholm, a review of the sequence of strata, as determined by the researches of G. LINDSTRÖM, J. C. MOBERG, K. A. GRÖNWALL, and myself.[1] The results (compared with the above mentioned stratigraphy in När and Lau), may be tubulated as follows (cfr. MUNTHE 1907):

	Map-sheet of *Hamra.*	*Burgen* in *När* and its environs.	*The canal of Lau* (MUNTHE 1902).
The youngest limestones	+	+	—
»*Ostracodan limestone*» (MOBERG in Journals)	+	?	+ ?
Girvanella limestone	+	*Reef-limestone a conglomerate* (with *Girvanella*)	*Rhizophyllum reef-limestone and marl* (with some *Girvanella*)
Oolite	+	+	*Pterygotus-bearing marl*
Sandstone	+	*Crystalline limestone*	*Crystalline limestone* with *reef-limestone*
Girvanella marl	+	?	
Dayia flags	+	+	+
Marl-shales with bands of limestone	+	+	+

Since later researches have not caused any essential alteration of my views as to the division of the strata just-mentioned this classification will be used in the description of the strata SW. of När.

[1] As mentioned above the map-sheet of »Hamra» has been worked out geologically principally by MOBERG and GRÖNWALL. My map of this district Pl. 55, is, therefore, mostly based upon their work and on the abundant collections of rocks and fossils made by them.

90—100170. G. F. F. 1910.

Description of the beds.

Oldest marl-shale with bands and lenses of marly limestone. This stratum is developed as a bluish grey, soft, marly shale which contains more or less abundant, thin bands and lenses of marly limestone. It is probably some ten metres in thickness.

As seen from the map this bed forms wide plains within the NW. part of »Hamra» and the SW. part of »Roma» etc. It is limited towards the SE. by a sweeping line running from Näsudden in the SW. towards the NE. at Alfva and, then, towards the ENE. to the shore of Bandlundaviken in the parish of Burs. The line is especially distinguished by the outcrop of the next younger bed, the hard *Dayia flags* (see below).

As the most abundant species of this lowest bed we may mention: *Atrypa reticularis* (a large variety), *Dayia navicula*, *Orthis canaliculata*, *Pholidops implicata*, *Calymmene intermedia*, *Phacops obtusa*, and *Monograptus priodon.*[1]

More rarely fragments of *Eurypterus* sp., *Ceratiocaris* sp., *Emmelozoë* sp., *Conularia* spp., etc., are found. Besides these, the upper part of this division contains such other forms as *Ctenodonta pinguis*, *Phacops Downingiæ*, fragments of *Crinoidea* (rare) etc. Moreover, the bed contains numerous minute Ostracoda, which have not yet been determined.

The tectonics of this as of other beds will be treated farther on, and it is sufficent here to state, that a gentle dip of the strata approximately towards the SE. is predominant. The older strata, especially the thinner ones, are,

[1] As to the names and authors of the fossils I follow LINDSTRÖM's List of fossil Faunas (see the Bibliography).

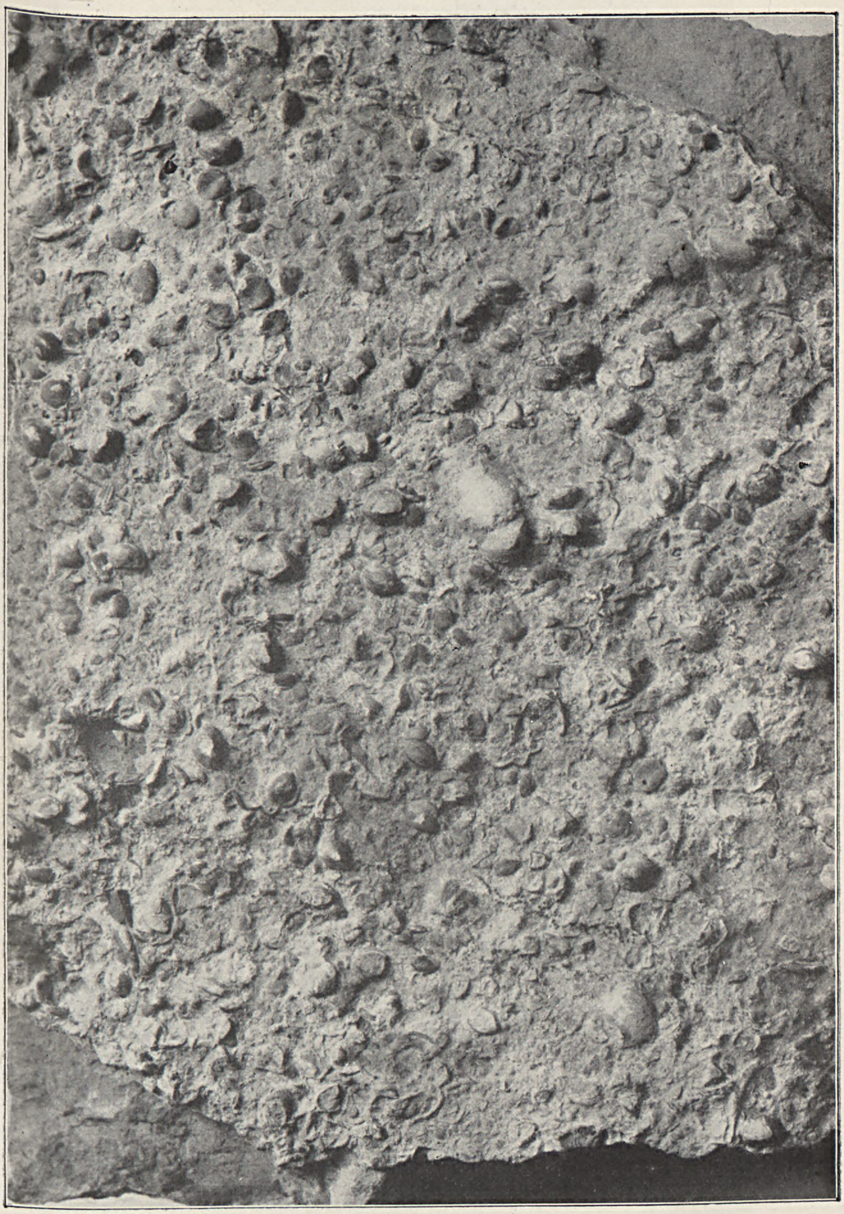

Fig. 1. *A Slab of flagstone* full of *Dayia navicula.* Hafdhem, Gotland. — 1/1.
Photo by A. Hj. Olsson.

Fig. 2. *Sphærocodium marl* with *S. gotlandicum, inter alia* incrusting *Ptilodictya*.
From the bed overlain by Sandstone. Ronehamn $^1/_1$.
Photo by HJ. OLSSON.

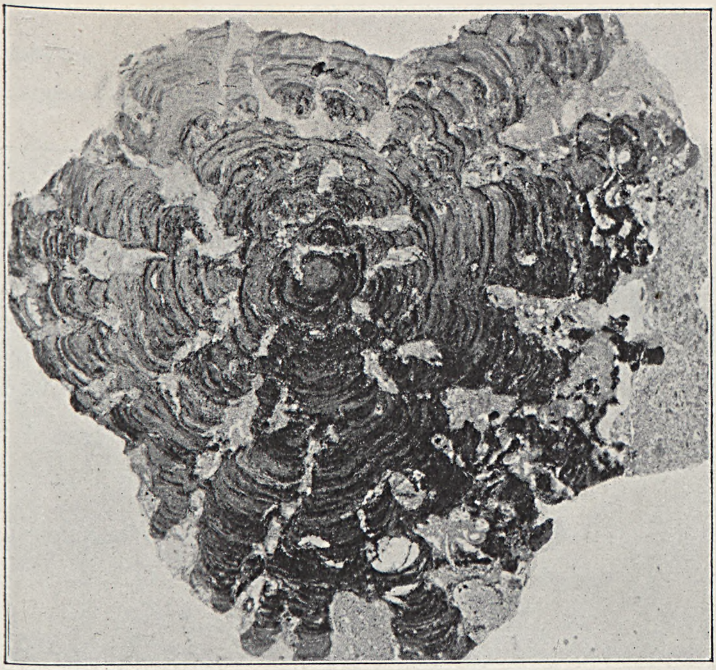

Fig. 3. Section of *Sphærocodium gotlandicum* showing its concentric structure. From the Spærocodium marl. Ronehamn. × 2.

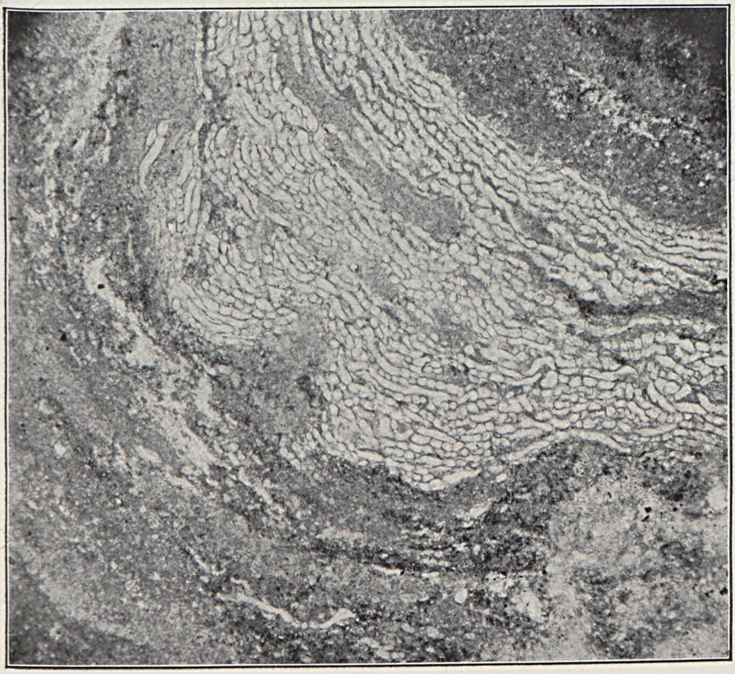

Fig. 4. Section of *Sphærocodium gotlandicum* showing its characteristic microscopical texture. × 40. Ronehamn.

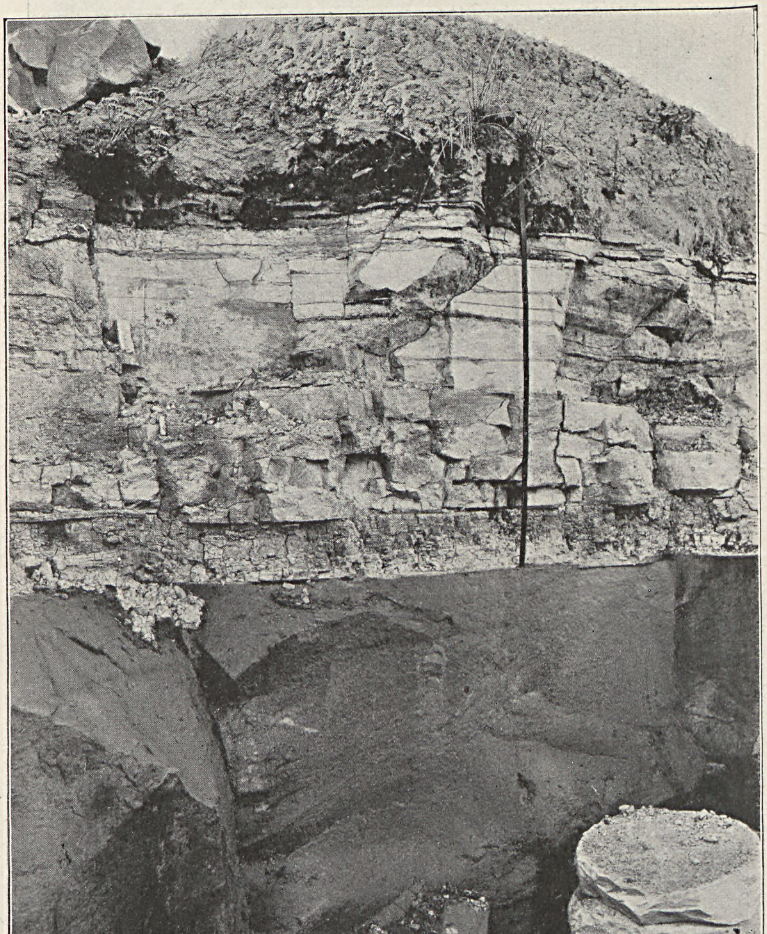

Fig. 6. Section showing *Sandstone* (S) *overlain by clay* (C), and *Oolite* (O).
W. of Gansviken, Grötlingbo parish. — Photo by G. Holm.

therefore, commonly to a great extent burried beneath the younger (see the map).

The so-called ***Dayia flags*** form a thin (less than one decimetre thick) bed of a hard, dolomitic and calcareous flags, which might possibly also be considered as the uppermost part of the marl-shale beds. In Gotland, however, this bed is an uncommonly good type-bed and it may therefore be treated as a distinct stratum. Its distribution is mentioned above. In places it is very rich in *Dayia navicula.* (Fig. 1.) It contains several other of the fossils found in the marl-shale, but with them also some »new» forms, such as *Strophomena impressa* (cfr. fig. 3 in MUNTHE 1902) and *Chonetes* cfr. *minima.*

The next younger bed, the *Girvanella* marl, which we may now name ***the Sphærocodium marl,*** since ROTHPLETZ has recently (1908) determined the fossil in question as *Sphærocodium gotlandicum* ROTHPL.[1] (Cfr. figs. 2—3—4 of *Sphærocodium*, showing its rough, granulated surface, its internal concentric structure and fibrous texture. See also ROTHPLETZ, l. c.)

This bed is a bluish-grey, somewhat hard, marl, the upper part of which is replaced by a marly limestone. (See above).

It contains masses of *Sphærocodium* at several levels, and with these are found some of the species, already mentioned from the marl-shale, such as *Orthis canaliculata*, *Pholidops implicata*, fragments of *Crinoidea*, etc. Moreover, the following species, *inter alia*, are probably not yet found below this horizon: *Spærocodium*, *Spirifera sulcata*, *Orthis hybrida*, *Atrypa*(?) *pusilla*, *Strophomena euglypha*, *Chonetes striatella* (typica), *Proetus signatus*, *Platyceras enorme*, etc.

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[1] During the summer of 1908 a collection of specimens and slides of calcareous algæ etc. from Gotland was send to Prof. ROTHPLETZ of München for determination. Prof. ROTHPLETZ has been kind enough to give in letters some preliminary informations, and on these, the data bearing on the algæ and a Hydrozan mentioned in this paper, are chiefly based.

The uppermost part of the bed is a marly limestone and contains almost the same fauna as the lower, but it is characterized also by *Spirifera striolata*, *Sp. sulcata* var. *elongata* (nov. var., see fig. 5), *S. elevata*, *Rhynchonella deflexa*, *R. nucula*, *R. diodonta* (var.), *Retzia* sp., etc., and, occasional *Bryozoa*, *Corals*, etc.

For the extent of the bed one may be referred to the map. In the parish of Rone its lower parts have a more calcareous character.

a *b*

Fig. 5. *Spirifera sulcata* var. *elongata*. *a* = from the dorsal, *b* = from the ventral side. — Sphærocodium marl. Näs. 1/1. Photo by A. Hj. Olsson.

Sandstone with clay. During the making of the map of SE. and S. Gotland in 1896, I as well as Dr. Grönwall was able to prove that the sandstone of these districts does not, as Lindström thought, gradually pass into the marl-shale nor does it rest directly upon the shale, as was stated by Schmidt, but that instead it rests upon the bed which I now name *Sphærocodium marl* which separates the marl-shale from the sandstone beds. This observation was of a great importance in the determination of the stratigraphy of the Gotlandian rocks.

The sandstone of S. and SE. Gotland is usually a bluish-grey, unstratified, or indistinctly stratified, somewhat clayey and loose quartzose rock, containing beds of a somewhat fine sandy clay or clayey marl. (Figs. 6 and 7.) The sandstone which is commonly very homogeneous and sometimes forms thick banks, has long been quarried, and many of the old churches of S. Gotland are built of it.

The true thickness of the beds is not yet known, but borings have shown that they are at least 15.5 metres thick.

Fig. 7. Section showing *Sandstone* (S), *Sandstone and Oolite* (S + O), *Oolite* (O), *Sphærocodium limestone* (S. l.) and *Reef-limestone* (R. l.). Kettelviken, Vamlingbo parish. — Phot. by G. Holm.

Fig. 8. *A Slab of Sandstone* containing *Orthis rustica* (1), *Chonetes striatella* (2), *Atrypa* (?) *pusilla* (3), *Ctenodonta pinguis* (4), etc. $^{1}/_{1}$. Burgsvik. — Photo by A. Hj. Olsson.

The lowest and uppermost parts of the sandstone contain numerous fossils, while the interjacent portions seem almost to be devoid of such remains. In addition to several species which occur in the underlying bed, such as *Phacops Downingiæ*, *Proteus signatus*, *Platyceras enorme*, *Atrypa*(?) *pusilla*, *Rhynchonella nucula*, *Chonetes striatella*, *Ctenodonta pinguis*, etc., the following may be mentioned as not having yet been found in older beds or, as regards some of the species, as occurring but sparsely there: *Holmalonotus Knightii*, *Cornulites serpularius*, *Autodetus calyptratus*, *Bellerophon* sp., *Cyrtolites* sp., *Tremanotus dilatatus*, *Murchisonia* sp., *Tentaculites annulatus* etc., *Aviculopecten reticulatus*, *Pterinea retroflexa*, *Grammysia exarata* etc., *Strophomena* cfr. *imbrex*, *Orthis rustica* etc. (See fig. 8.)

The totally absence of the *Sphærocodium*, so common in the bed below, was certainly due to altered physical conditions of the sea-bottom, a fact which is also evident from the change in the composition of the sediment.

As shown upon the map, Pl. 55, the distribution of the bare sandstone bed is somewhat irregular. On the whole, it follows the shore, partly as a steep cliff a few metres in height, which, from the southernmost part of the island (Hoburgen), crosses to the NE. to the neigbourhood of Vale (W. of Burgsvik), and to the western part of the isthmus S. of Grötlingbo. Farther to the N. it occupies the broad valley to the NE. of Burgsviken and to the SW. of Hafdhem church. Towards the E. it runs through Grötlingbo and towards the NE. along the shore of Rone parish. Beyond this area I have found it only as pebbles on the shores of Närsholm, and it may, therefore, there be represented by submarine rocks. Possibly, however, it is not exactly of the same age in the two districts. Farther N. and NW. the bed is not met with, and it is evident that the sandstone with clay either thins out in these directions, or is replaced by other strata.

Between the sandstone and the next younger bed, the *oolite*, there is sometimes *a passage bed*, having characters in common with both beds. This stratum is sub-oolitic in structure and its fossils are commonly so overgrown with a crust of precipitated calcite, that it has a conglomeratic appearance (fig. 9). In some places an intimate interstratification of sandstone and oolite is common and then sometimes a diagonal bedding is observed. More rarely *pebbles of oolite* are found in the passage bed (fig. 10). The existence of a crust of *Sphærocodium* on such pebbles has also been observed, and indicates the re-appearance of this organism at this horizon. Sometimes the fossil remains are sorted according to their size and show that they have been rolled and worn by the Silurian waves. From several features, therefore, it is evident that these passage bed was formed partly as a shore-deposit within the shallow-water region.

The faunas of the bed is, on the whole, the same as in the uppermost parts of the sandstone proper. Some species, however, are rare or absent in the sandstone, but common in the oolite, such are *Lucina Hisingerii*, *Orthis punctata*, *Pentamerus galeatus*, *Leperditia* sp., etc. *Strophomena euglypha*, which was mentioned as occurring in the *Sphærocodium* marl, but is not found in the sandstone, is again common in the passage bed.

The bed in question has a small thickness (generally it is but a few centimetres) and of such a local development, that it cannot be indicated on the map.

Oolite. (Cfr. figs. 11, 6, 7 and 10.) This bed follows as a more or less narrow belt along the SE. limit of the sandstone from Hoburgen to Grötlingbo. Commonly it has a thickness of a couple of metres, but it thins out to a few decimetres, and in places may disappear entirely.

The rock has the typical oolitic structure (see fig. 11), with spherules having, generally, a diametre of from one to three millimetres.

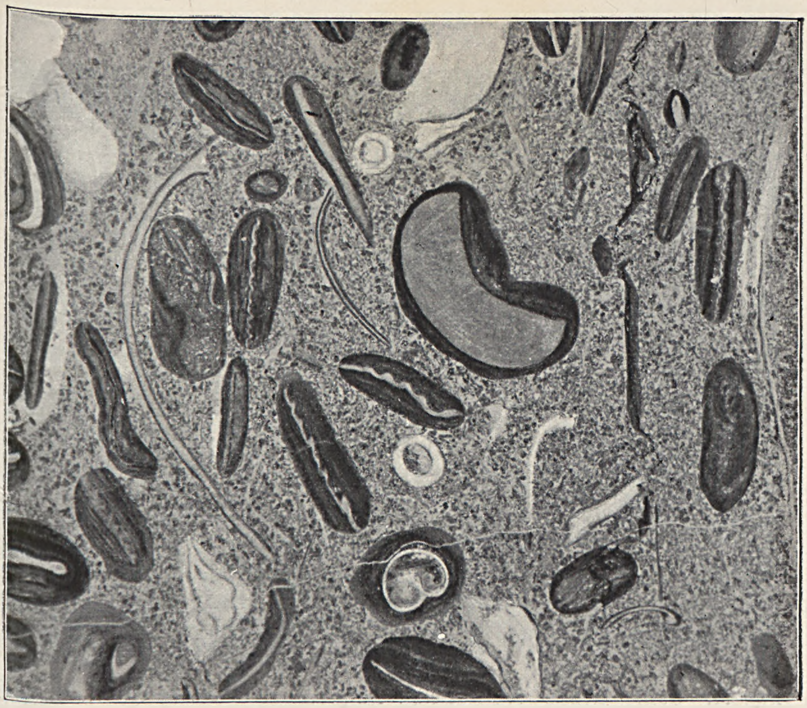

Fig. 9. *The passage bed* showing the fossils overgrown by precipitated Calcite. $^{2}/_{1}$. — Phot. by A. Hj. Olsson.

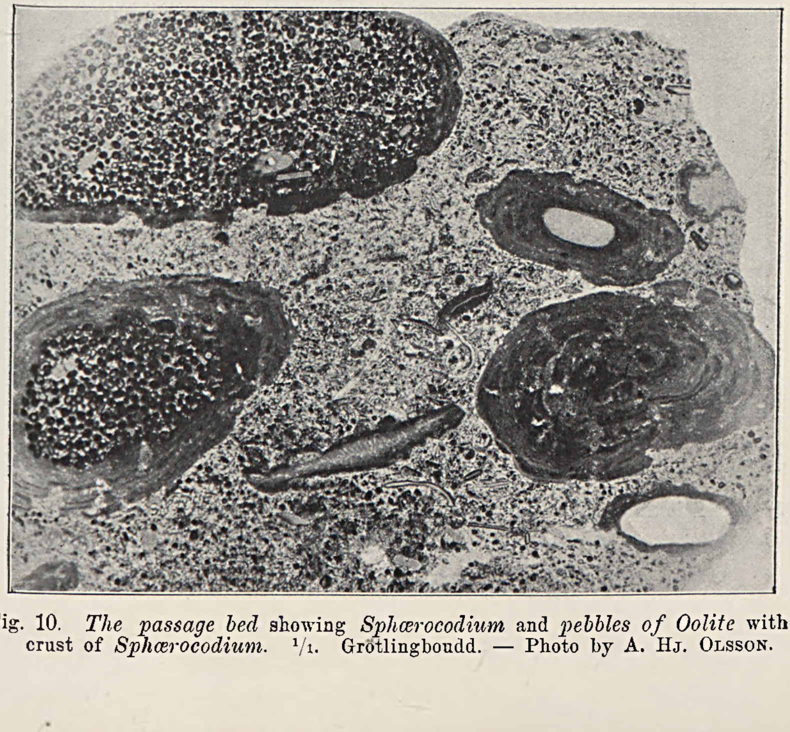

Fig. 10. *The passage bed* showing *Sphærocodium* and *pebbles of Oolite* with crust of *Sphærocodium*. $^{1}/_{1}$. Grötlingboudd. — Photo by A. Hj. Olsson.

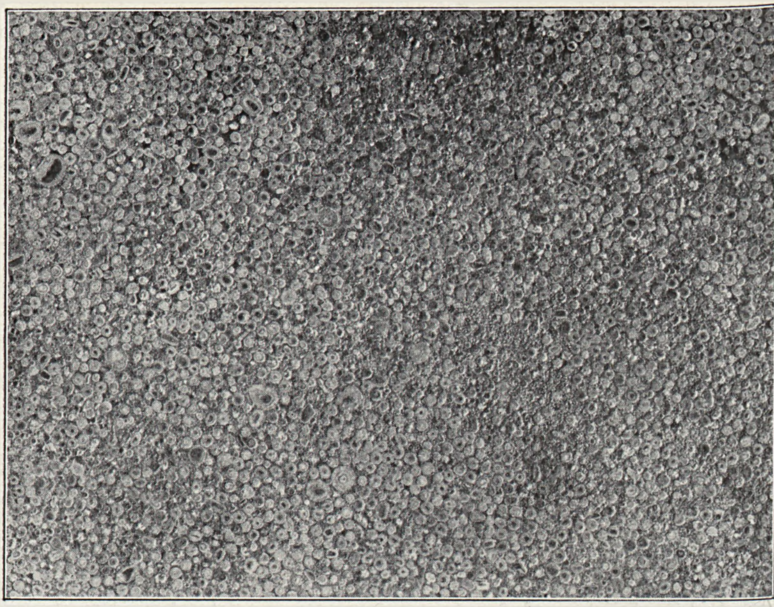

Fig. 11. *Oolite*, etched. Natural size. Burgsvik. — Photo by A. Hj. Olsson.

Fig. 13. *Ilionia limestone* containing *Spongiostroma Holmii* Rothpl. × 2. Hamra. Phot. by A. Hj. Olsson.

Sometimes the fossil remains are so abundant as to form an organic conglomerate, the fossils having a crust of oolitic limestone or of *Sphærocodium*. In places they are worn in a manner which indicates their deposition as shore-pebbles. Occasionally also round pebbles of oolite are found in oolite (as shown from fig. 10), thus proving that during the formation of this bed also, and the Silurian sea-bottom must, at times, have been uplifted above sea-level.

The oolite in places is very rich in fossils. Its fauna is very like that of the passage bed, but some species seem to be new or here first to become abundant e. g., *Conocardium* sp., *Retzia Salterii* and *R. Salterii* var. *Baylei*, *Rhynchonella diodonta*, *Atrypa Barrandei*, *Holopella* sp., *Chelodes gotlandicus*, *Bellerophon* cfr. *sphæra*, etc.

The oolite contains also a great number of such bivalves as *Lucina Hisingerii* and species of *Pterinea*, *Aviculopecten*, etc.; *Homalonotus Knightii*, *Proetus signatus*, *Chonetes striatella*, *Atrypa*(?) *pusilla*, and species of *Strophomena*, etc. are known chiefly from the sandstone.

The Sphærocodium limestone. The oolite is overlain by a more or less oolitic or somewhat clayey limestone, rich in knobs of *Sphærocodium gotlandicum* (figs. 2 to 4). Sometimes this *Sphærocodium* limestone gradually passes into the next younger bed, the *Ilionia limestone*. The bed is best seen in the bare rocks of Grötlingbo, where it is in close association with the oolite, from which it has not been separated on the map. Its thickness is only a few decimetres.

Among the fossils of the *Sphærocodium* limestone, *Sphærocodium itself* plays the most important rôle. It is associated with several other fossils with which it sometimes gives rise to a biogene conglomerate. Among these other forms we shall mention only a few of those which are found also in the next older beds: *Retzia Salterii* var. *Baylei*, *Rhynchonella diodonta*, *R. nucula*, *Spirifera elevata*, *Conocardium* sp., *Autodetus calyptratus*, some *Corals*, fragments of *Crinoids*, etc. As forms not yet found in older beds *Meristina didyma*, *Rhynchonella Wilsonii* (typica), *Eichwaldia Capewellii*, *Spongiostroma Holmii* ROTHPL. (rare), and large *Stromatopora* may be mentioned.

It is worth noting that such forms as *Chonetes striatella*, *Atrypa* (?) *pusilla*, *Homalonotus*, several *Pelecypoda*, etc., which are common in the sandstone and the oolite, are rare or absent from the *Sphærocodium* limestone. To some extent this was probably due to altered physical conditions, and in any case the faunas of the *Sphærocodium* marl and the *Spærocodium* limestone have so many forms in common, that there must have been approximately similar physical conditions during the formation of these beds.

In several places *marly reef-limestone* is found to *replace the Sphaerocodium limestone*. (Fig. 7).

This reef-limestone is rich in fossils. Among the species found *Stromatopora discoidea*, *Labechia conferta*, some species of *Favosites*, *Retzia Salterii* var. *Bayleii*, *Spirifera striolata*, *S. Schmidtii* and var. *elongata*, *Rhynchonella nucula*, and *R. deflexa* may be mentioned; more sparsely *Orthis hybrida*, *O. punctata*, *Atrypa* (?) *Barrandei*, *Rhynchonella diodonta*, *Autodetus calyptratus*, *Calymmene spectabilis*, *Ptychophyllum truncatum*, *Sphærocodium gotlandicum*, etc. are found. Palæontologically, this rock is, therefore, closely related both to the *Sphærocodium* limestone and to the next older beds. As important differences we may mention that the reef-limestone is relatively rich in *Corals* and *Stromatopora*, but is nearly destitute of *Sphærocodium*.

In places also *a greyish Crinoid limestone* and *a finegrained Crystalline limestone*, etc., *replace the Sphærocodium limestone*, and the same is also the case with *the marly shale with calcareous bands* which occurs N. of Hoburgen. This last rock contains the above mentioned *Retzia Salterii* var. *Baylei* and *Rhynchonella deflexa* together with such »new» forms as *Crania Grayii*, *Spirifera striolata* (var.), *Atrypa* *marginalis* (var.), *Orthis* cfr. *Bouchardii*, *Orthis rustica*, and, with them *Bryozoa*, *Corals*, etc.

As is evident from the foregoing account the four last mentioned beds (1) *the Lower Sphærocodium bed*, (2) *the Sandstone with clay*, (3) *the Oolite*, and (4) *the Upper Sphærocodium bed* are a closely related series, both palæontologically and also in part lithologically. They are all shallow-water deposits and were in part formed upon a shore.

The Ilionia bed. By this name FR. SCHMIDT has called the marly and somewhat soft, often brownish limestone contai-

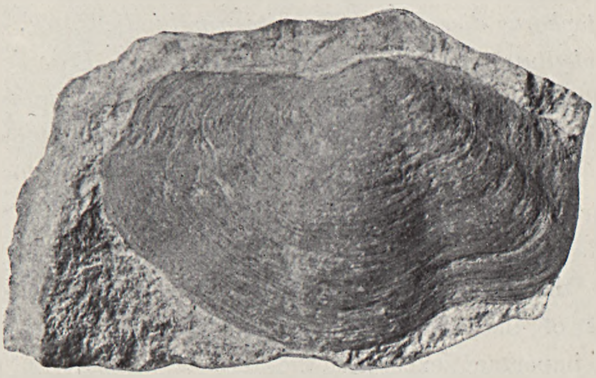

Fig. 12. *Ilionia* (*Lucina*) *prisca* HISINGER. NE. of Histilles, Kråklingbo parish. — Photo by A. HJ. OLSSON.

ning, *inter alia*, *Ilionia* (*Lucina*) *prisca*, which occurs at Östergarn in E. Gotland and in Osel (cfr. fig. 12). Later (in 1888) LINDSTRÖM parallelized the bed at Östergarn with that of Hamra, since here also he had found *Ilionia prisca* and several species of *Orthoceras* etc. common to the Östergarn bed. While mapping S. Gotland J. C. MOBERG in his journals termed this bed »the Ostracodean limestone», since it is commonly rich in Ostracoda.

In its more brownish varieties the rock is somewhat *bituminous*, and seems originally have contained masses of organic matters, *inter alia* those of plants, which have, however, not yet been determined. Like other bituminous rocks, as, for instance, the alum shale, it sometimes contains also lenses of harder limestone.

In places a sub-crystalline and less marly limestone replaces the typical Ilionia limestone. This latter seems to be richer in Ostracoda than the normal variety, which again, is locally relatively rich in Hydrozoa (*Spongiostroma* etc.) and, generally, richer in other fossils. Between the two facies transition forms are common.

Among fossils found in the harder rock we may mention: *Spongiostroma Holmii* (fig. 13)[1] (sometimes in masses), *Stromatophora discoidea*, *Favosites gotlandicus*, *F. clausus*, *Cyathophyllum articulatum*, *Syringopora* sp., *Ptilodictya* and other Bryozoa, fragments of *Crinoids*, *Proetus signatus*, *Leperdisia phaseolus* (and several minute Ostracoda), some *Cephalopoda*, *Platyceras cornutum*, *Conocardium* sp., *Spirifera striolata*, *Retzia Salterii* var. *Baylei*, *Rhynchonella diodonta*, *R. nucula*, *R. deflexa*, some species of *Strophomena*, etc.

As this list shews, the fauna bears a close relationship to that of the *Sphærocodium* limestone and its equivalents. As an important exception the absense or rarity of *Sphærocodium* in the Ilionia bed may be especially emphasized. The Ilionia bed in places contains, on the contrary, abundant *Spongiostroma*. Sometimes small fossils (*Ostracoda*, *Corals*, *Bryozoa*, etc.) are found in the cavities of the larger *Stromatopora*, a fact which may probably indicate a symbiosis. Masses of *Grammysia* cfr. *exarata* are also locally met with in the Ilionia bed, but *Ilionia prisca* itself is very rare in these southernmost parts of the island.

The typical Ilionia limestone, which is relatively poor in species but rich in individuals, is characterized by *Leperditia*

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[1] Both macroscopically and microscopically *Spongiostroma*, with its smooth surface and nearly dence, but concentric structure, is easy to distinguish from *Sphærocodium*. (Cfr. ROTHPLETZ, l. c.)

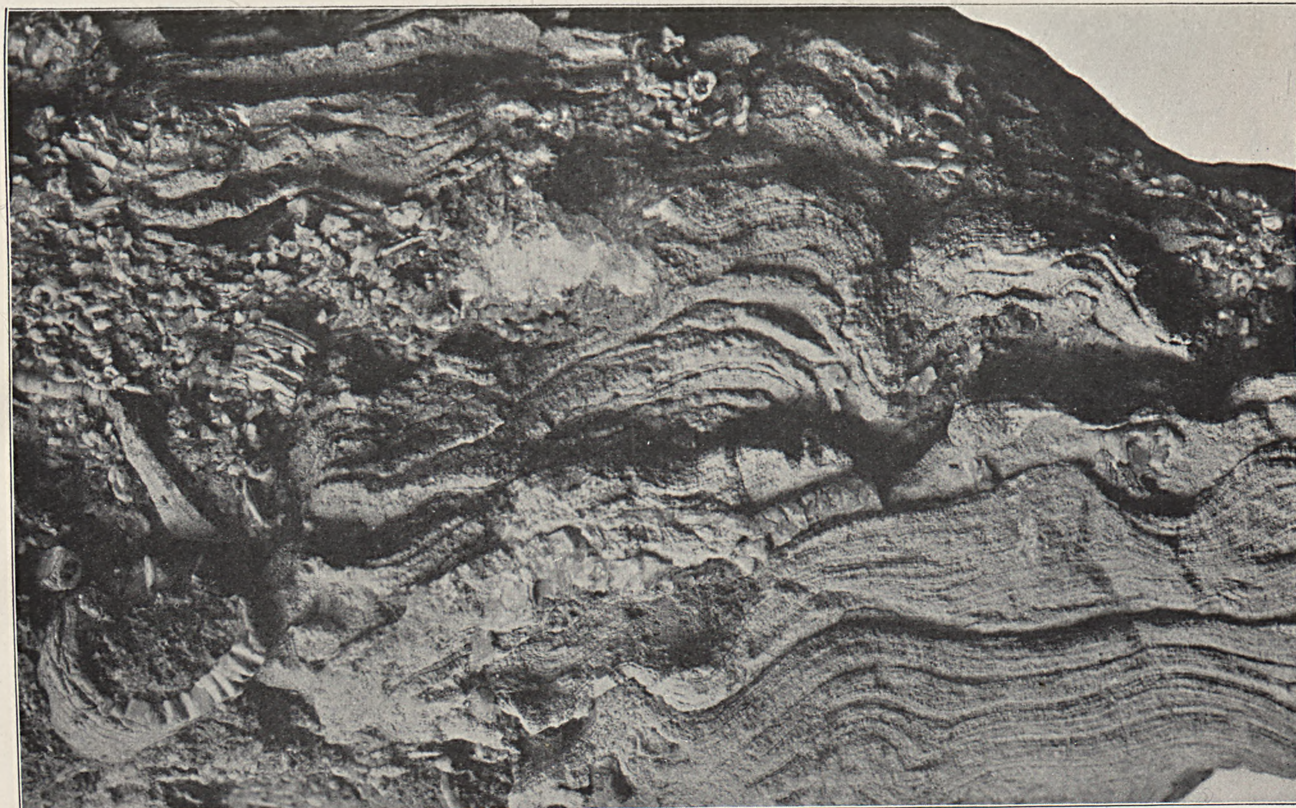

Fig. 14. *Crinoid limestone* highly replaced by *colonies of Stromatopora*. Nat. size. Wamlingbo parish.
Phot. by A. Hj. Olsson.

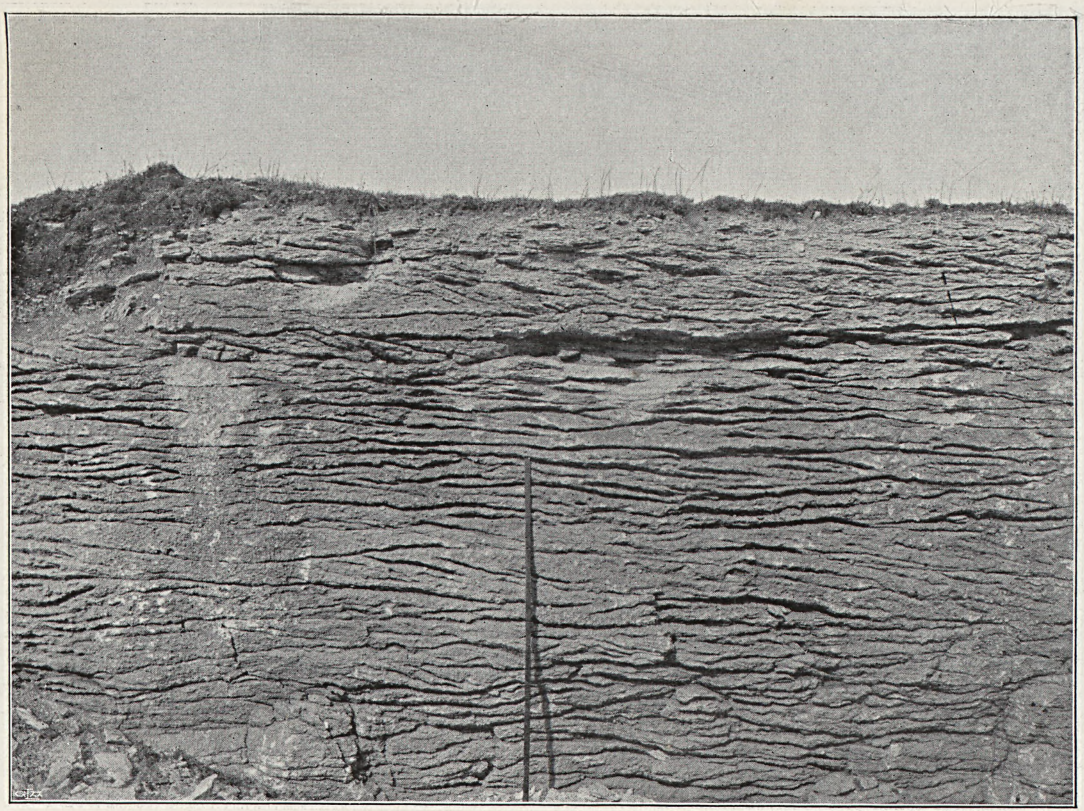

Fig. 15. *Grey Crinoid limestone showing diagonal bedding.* Sundre parish. — Photo by G. Holm.

phaseolus and masses of minute Ostracoda. Besides, there occur *Proetus signatus*, *Conocardium* sp., *Retzia Salterii* var. *Baylei*, *Orthis hybrida*, *Strophomena* sp., *Orthoceras imbricatum*, *O. angulatum* and other species of *Orthoceras*, *Ilionia prisca*, etc., all forms already known from older beds. Lastly may be mentioned the occurrence of some *Cephalopoda*, viz. the big *Nautilus Hisingeri*, the rare, *Trochoceras costatum*, *Ascoceras manubrium*, and *Ophidioceras reticulatum*.

As is seen on the map, the *Ilionia* limestone shews comparatively wide extent of bare rocks within the southernmost parts of Gotland, and lies to the E. of the outcrop of the sandstone and the oolite. The northernmost occurrence in the district is on the islets E. and NE. of Grötlingboudd.

Besides the two more normal facies of this bed just discussed there are in places other rocks which may be considered as the equivalents of these. These will be mentioned again further on.

Younger Crinoid limestone. As has previously been alluded to the *Ilionia* beds and their equivalents are generally overlain by *Crystalline limestone.* Commonly this bed is a stratified, somewhat coarse grained limestone, consisting chiefly of fragments of crinoids and of re-crystallized calcite generally of a light greyish or even a white, and, more seldom, as in Hoburgen, a reddish colour (»Hoburgen marble»). Sometimes it is more or less rich in colonies of *Stromatopora*, which can in places almost or entirely replace the crystalline rock (see fig. 14).

The Crinoid limestone sometimes shows a diagonal bedding on a small scale (fig. 15), and this may be interpreted as a shallow-water (but not as a true shore) phenomenon; more rarely pebbles are observed, and these may possibly indicate a temporary rise of the sea-floor, during the formation of the bed, to or above sea-level.

Besides the above mentioned masses of *Crinoids* and *Stromatopora* the bed contains but a few other fossils, such are *Labechia conferta*, *Atrypa reticularis*, *Pentamerus linguiferus*, *Strophomena filosa*, *Withfieldia tumida* (var.), *Orthis rustica*, and last but not least, a variety of *Atrypa marginalis* which may be named *5-costata.*[1] (See fig. 16.) More rarely *Omphyma turbinata*, and locally (N. of Wamlingbo church) *Plemotomaria limbata*, *Tremanotus longitudinalis* as well as *Bellerophon* spp., and *Trimerella* sp. are found.

The Crinoid limestone is confined to the southernmost and SE. parts of the areas in question. In places it is quarried. Its thickness seems to vary from a few to about ten metres.

a *b*

Fig. 16. *Atrypa marginalis* var. *5-costata.* a = from the ventral, b = from the dorsal side. $^1/_1$. Hoburgen. Phot. by A. Hj. Olsson.

Ascoceras limestone. The youngest bed of the district may be called *Ascoceras limestone*, since species of this genus are almost wholly confined to this bed. It is an unstratified, compact and hard, somewhat clayey marble, reddish-brown or greenish-grey in colour. Unlike the crystalline Crinoid limestone it contains relatively large, coherent portions of *Crinoida* (fig. 17), which may well be preserved by reason of the great quantity of its marly material. The rock also contains greater or less colonies of *Stromatopora.* This youngest limestone, therefore, may be considered as a *Reef-limestone* formed chiefly of *Stromatopora* and of large fragments of *Crinoids*

[1] This form was mentioned by Lindström long ago (1860 p. 363) as occurring into the upper strata of Hoburgen. The dorsal shell has only 5 ribs, which are sometimes bifurcated, but the ventral one has 6 ribs. Otherwise, the shells are smooth and without ornament.

Fig. 17. *Ascoceras limestone* showing *colonies of Stromatopora* (to the left) and numerous *fragments of Crinoidea.* — Hammarshagehällar, Hamra parish. — Photo by G. Holm.

(principally roots and adjacent portions of the stems) with marly sediments to fill the interspaces. The thickness may be estimated at about ten metres. While totally unstratified und built up of somewhat heterogenous material the limestone bed has been especially suitable for the sculpturing of such irregular erosion forms, as stone pillars (»raukar» in Gotland), caves, etc. (See MUNTHE 1910.)

This rock contains, *inter alia*, the following fossils: Brachiopoda (commonly not yet determined) with a smooth surface (such as *Atrypa phoca* etc.), Cephalopoda: as *Ascoceras cochleatum* (var)., *A. decipiens*, and *A. gradatum* (LINDSTRÖM 1890); a few *Gastropoda* and *Bryozoa* (chiefly *Coenites repens*), etc.

As is seen on the map, *the Ascoceras limestone* is chiefly confined to the south-easternmost part of the area.

In places it appears as if this rock were synchronous with the youngest parts of the Crinoid limestone, which in such cases, may be considered as »woods» of Crinoids living outside the Stromatopora and Crinoid societies of the neighbourhood and grown in situ in places where a sedimentation of marly material also took place. Probably, the Crinoid limestone was formed by masses of Crinoidal stems and arms which were accumulated outside the »wood» whose roots in the marly sea-bottom gave rise to the *Ascoceras* limestone which is formed chiefly of the roots of the Crinoids.

In the following table some of the most important of the fossils found in the different strata are enumerated and a notice given as to their approximate distribution in time. The distances between the lines of the table approximately mark the relative thicknesses of the strata.[1] From this we may

[1] For typographical reasons the thickness of the thinnest strata, as e. g. *the Dayia flags*, must, however, be too great.

obtain an idea of the greater or less relation between the different beds. Thus, for example, is it evident, that, palæontologically, there is a relatively close relationship between the Oolite and the *Sphærocodium* limestone and between these beds and the Sandstone and the *Sphærocodium* marl. Some species, however, are confined to a particular bed, partly owing to their earlier or later immigration and partly also to the lithological differences between the beds.

	Marl-shale with lenses and bands of marly limestone.	Dayia flag.	Sphærocodium marl.	Sandstone and Clay-marl.	Oolite.	Sphærocodium limestone.[1]	Ilionia limestone.[1]	Crinoide limestone.	Ascoceras limestone.
Atrypa reticularis LINNÉ (and varieties)	—	—	—	—	—	—	—	—	—
Strophomena rhomboidalis WAHLENB. (and varieties)	—	—	—	—	—	—	—	—	—
Crinoidea (fragments)	—	—	—	—	—	—	—	—	—
Corals	—	.	—	—	—	—	—	—	—
Bryozoa	—	.	—	—	—	—	—	—	—
Stromatopora	—	.	—	—	—	—	—	—	—
———									
Dayia navicula (Sow.)	—	—	—	.	.	.	.	.	.
Calymmene intermedia LM	—	—	—	.	.	.	.	.	.
Strophomena impressa LM	—	—	.	.	.	.	.	.	.
Chonetes cfr. *minima* (Sow.)	.	—	—	.	.	.	.	.	.
Spirifera sulcata nov. var. *elongata*	.	.	—	.	.	.	.	.	.
Sphærocodium gotlandicum ROTHPL.	.	.	—	.	—	—	.	.	.
Atrypa(?) *pusilla* HIS.	.	.	—	—	—	—	.	.	.

[1] and equivalent rocks.

	Marl-shale with lenses and bands of marly limestone.	Dayia flag.	Sphærocodium marl.	Sandstone and Clay-marl.	Oolite.	Sphærocodium limestone.[1]	Ilionia limestone.[1]	Crinoide limestone.[1]	Ascoceras limestone.
Retzia Salterii var. *Baylei* DAV.	.	.	—	—	—	—	—	.	.
Chonetes striatella DALM.	.	.	—	—	—	—	.	.	.
Strophomena euglypha DALM.	.	.	—	—	—	—	—	.	.
Proetus signatus LM	.	.	—	—	—	—	.	.	.
Aviculopecten Danbyi MAC COY	.	.	—	—	—	—	—	.	.
Spirifera striolata LM	.	.	—	—	—	—	—	.	.
Rhynchonella nucula SOW.	.	.	—	—	—	—	—	.	.
» *diodonta* DALM.	.	.	—	—	—	—	—	.	.
Rhynchonella deflexa SOW.	.	.	—	—		—	—	.	.
Homalonotus Knightii KÖNIG	.	.	.	—	—		.	.	.
Autodetus calyptratus SCHRENK	.	.	.	—	—	—	—	.	.
Pterinea retroflexa WAHL.	.	.	.	—	—	—	.	.	.
Conocardium sp.	.	.	.	—	—	—	—	.	.
Orthis rustica SOW.	.	.	.	—	—		—	—	.
Lucina Hisingeri MURCH. & VERNEUIL	.	.	.	.	—	.	.	.	.
Orthis punctata VERN.	.	.	.	.	—	—	—	.	.
Chelodes gotlandicus LM	.	.	.	.	—	.	.	.	.
Leperditia sp.	.	.	.	.	—	.	.	.	.
Meristina didyma DALM.	.	.	.	.	.	—	.	.	.
Rhynchonella Wilsonii SOW.	.	.	.	.	.	—	.	.	.
Calymmene spectabilis ANG.	.	.	.	.	.	—	—	.	.
Eichwaldia Capewellii DAV.	.	.	.	.	.	—	.	.	.

[1] and equivalent rocks.

	Marl-shale with lenses and bands of marly limestone.	Dayia flag.	Sphærocodium marl.	Sandstone and Clay-marl.	Oolite.	Sphærocodium limestone.[1]	Ilionia limestone.[1]	Crinoidal limestone.[1]	Ascoceras limestone.
Labechia conferta Edw. Haime	.	.	.	.	.	—	— — —	— —	—
Ptychophyllum truncatum L.	.	.	.	.	.	.	— — —	.	.
Spongiostroma Holmii Rothpl.	.	.	.	.	.	.	— — —	.	.
Leperditia phaseolus His.	.	.	.	.	.	.		.	.
Ilionia prisca His.	.	.	.	.	.	.	— — —	.	.
Nautilus Hisingerii D'Orb.	.	.	.	.	.	.	— — —	.	.
Orthoceras spp.	.	.	.	.	.	.	— — —	.	.
Atrypa marginalis nov. var. *5-costata*	.	.	.	.	.	.	.	.	.
Pleurotomaria limata Lm	.	.	.	.	.	.	.	—	.
Trimerella sp.	.	.	.	.	.	.	.	—	.
Ascoceras cochleatum Lm	.	.	.	.	.	.	.	.	— —
» *decipiens* Lm	.	.	.	.	.	.	.	.	— —
» *gradatum* Lm	.	.	.	.	.	.	.	.	— —

Some remarks as to the tectonics.

As shown in the above description, the different strata within the area in question follow the one after the other, in order from about NW. to SE. Hence it is evident that the strata dip approximately towards the SE. The amount of this dip, however, is commonly not definitely known, since the beds are usually lacking in a clear stratification. Even when the stratification is seen, local disturbances of the strata have taken place and have given rise to dips and strikes also, in directions other than the normal ones. Such, for

[1] and equivalent rocks.

example, is the case within the peninsulas of Faludden and Grötlingboudd, and again near Burgsvik, where the strike of the strata (as well as of the coast-line) is about from W. to E. and the dip of strata towards the S. Near Burgsvik the folding of the solid rock seems to be somewhat as is shown from fig. 18.

In other districts the relatively high position of some of the older beds as, e. g. *the Ilionia limestone* SE. of the church of Sundre, indicates other local disturbances.

As to the distribution of the beds of Sandstone with clay, which are relatively thick and suddenly thin out towards the North, it is probable that they were formed during a period of the sinking of the sea-bottom, and that the considerable sedimentation approximately kept pace with the sinking. Certainly the relatively great dip of the Lower *Sphærocodium* bed, where it is overlain by Sandstone with clay, which is observed SW. of Hafdhem railway Station, indicates a dislocation at a later time.

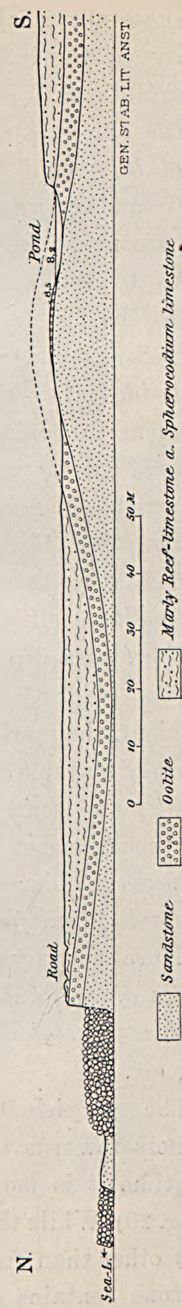

Fig. 18. Schematic section illustrating *the normal fold of the strata* W. of Bobbenarfve, Burgsvik. Figures in metres above sea-level.

Description of some abnormal rocks.

A review having been given of the various, *more normal strata* within Southern Gotland, we may now glance more closely at some ***abnormal rocks*** which are thought to be the equivalents of some of the beds, already mentioned.

These abnormal rocks are met with chiefly at and in the vicinity of the isolated hill named Hoburgen, at the SW. end of Gotland.

The bare western steeps of this hill consist for the most part of *Reef and Crinoid limestones*, resting upon beds of *Oolite* and *Sandstone*, and it is probable that the hidden parts are principally built up of marly limestone (see below).

As to the details of the lower parts of the hill I may refer to the fig. 19, which shows from below:

1) *Sandstone* (S); 2) *Oolite interstratified with Sandstone, cross-bedded* (O + S); 3) *Greyish Crinoid limestone* (Cr. l.) equivalent to *marly Reef-limestone* (R. l.) and containing *Sphærocodium*, *Corals*, etc.; 4) *Conglomeratic* and *Crystalline limestone* with *Sphærocodium* (Sp. c.) and its equivalent: *marly Reef-limestone* (R. l.) seen to the right; 5) *Crystalline Crinoid limestone* (Cr. l.) of medium coarseness equivalent to *marly Reef-limestone* (R. l.) to the right.

The strata dip slowly towards the SE.

This older Crinoid limestone is here, in contrast to its equivalent, the marly Reef-limestone, poor in fossils. This latter commonly contains *Stromatopora* cfr. *discoidea*, *Labechia conferta*, *Favosites* and some other *Corals*, *Bryozoa* etc., along with the forms usually met with in *the Sphærocodium limestone* (and nearest older and younger beds), such as *Retzia Salterii* var. *Baylei*, *Spirifera striolata*, *Rhynchonella nucula*, *R. deflexa*, etc. More sparesly are found, *inter alia*, *Orthis punctata*, *Rhynchonella diodonta*, *Autodetus calyptratus*, *Conocardium* sp., *Calymmene spectabilis*, *Ptychophyllum truncatum*, *Sphærocodium*, etc.

The greyish Crinoid limestone generally increases in thickness towards the North, as is seen from fig. 20, but at the same time it is more or less replaced by *marly Reef-limestone* (see fig. 20). While the former rock is nearly destitute in fossil remains other than fragments of *Crinoidea*, the synchronus reef-limestone contains a somewhat rich fauna, with such forms as

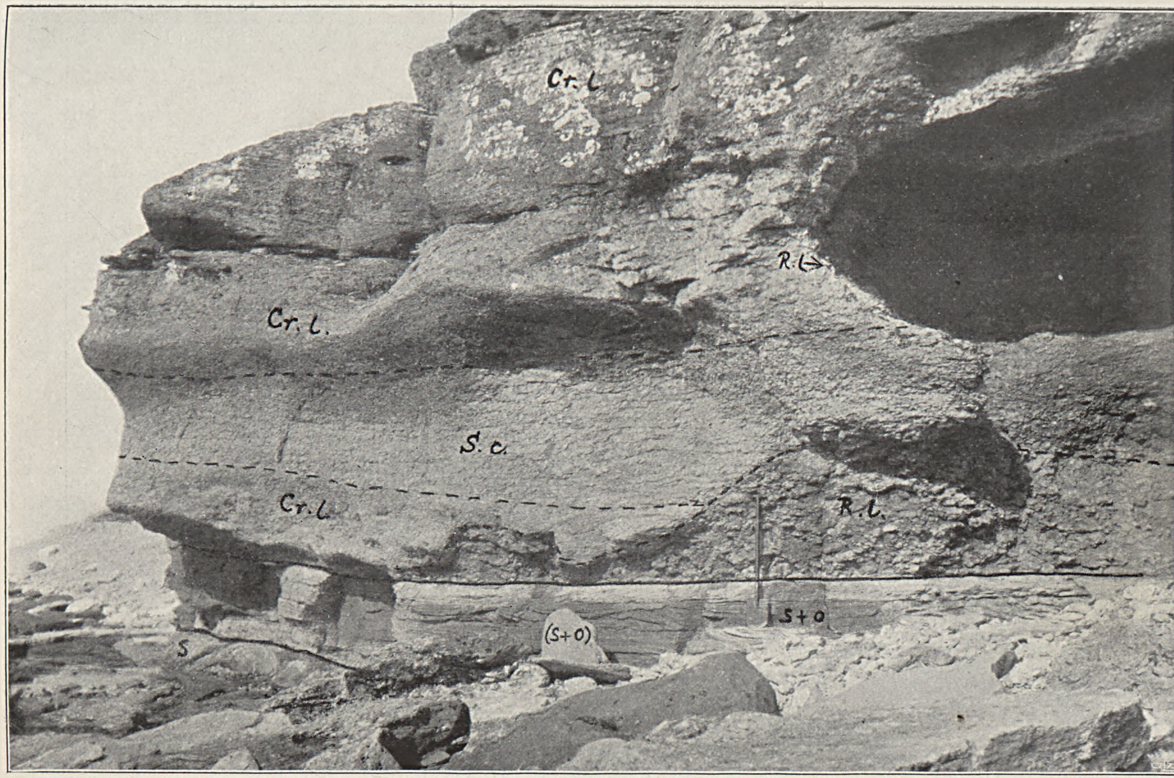

Fig. 19. *Section through the lower Gotlandian series at the SW. corner of Hoburgen.* S = *Sandstone:* S + O = *Sandstone and Oolite;* Cr. l. = *Grey Crinoid limestone;* S. c. = *Sphærocodium conglomerate;* R. l. = *Reef-limestone* (marly), equivalent to Cr. l. and S. c. — Photo by the autor in 1903.

Fig. 20, illustrating the correlation between *Crinoid limestone* (to the left) and *Reef-limestone* (to the right of the white line). At and outside the shore is *Sandstone* (S) dipping gently towards the SE., and at × *Oolite, marly Reef-limestone*, etc. Hoburgen. — Photo by the author 1908.

Fig. 21. *Reef-limestone with irregular portions of bedded Crinoid limestone and Marl-shale.* At the base (to the left) Sandstone, Ooolite, etc. The lower half part of Hoburgen SW. — Photo by G. HOLM.

Fig. 22. *Reef-limestone* partly equivalent to and overlain by *Crinoid limestone* (Hoburgen marble). Hoburgen NW. Photo by the author in 1903.

Orthis rustica, *Atrypa marginalis* var. *5-costata*, *Labechia conferta*, etc. Fragments of *Crinoidea*, *Bryozoa* and *Corals* are also common.

The last-mentioned rock locally continues upwards, as in the southern part of Hoburgen, and builds up nearly the whole steep cliff, about 40 *m* in height. (Fig. 21). Its higher parts is equivalent to the reddish Crinoid limestone, the »Hoburgen marble» (fig. 22), and in places the youngest parts of it rest upon this marble bed. Fossils are not often abundant. They are represented by *Coenostroma*, *Labechia conferta*, *Atrypa marginalis* var. *5-costata*, etc.

Since on the E. and SE. sides of the hill *a bluish-grey marly limestone* is found directly below the Hoburgen marble this main mass of Crystalline and Reef-limestone must be entirely replaced by it within the middle part of the hill. A similar blue grey rock also occurs at lower levels both on the SE. side of Hoburgen itself (fig. 23) and to the N. of it, forming the marked slopes which there occur (see fig. 24). I, therefore, am of opinion, that the south-eastern part of Hoburgen, beneath the marble bed at any rate, is built up chiefly of marly limestone.

The place of this marly limestone between the upper part of the Crinoidal limestone and the Oolite and Spaerocodium limestone indicates, therefore, that the beds in question may be taken as *an equivalent to the Ilionia limestone* farther to the NE. This marly limestone N. of Hoburgen contains, *inter alia*, the following species: *Proetus signatus*, *Spirifera striolata*, *Retzia* sp., *Chonetes* cfr. *striatella*, *Orthis canaliculata*, *Strophomena* cfr. *Fletcherii*, etc.

A similar limestone is found in the SW. part of the hill named Klef, ENE. of Hoburgen, as well as at lower levels to the S. of it. The eastern steep of Klef shows a section through a stratified, generally *fine-grained*, *Crystalline limestone* (see fig. 25), which is overlain by Reef-limestone. For stratigraphic reasons this fine-grained limestone might also be an equivalent of the *Ilionia* bed. Along with fragments of *Crinoidea*, *Corals*, and *Stromatopora*, it contains *Cyclonema carinatum* var. *glabrum*, *Proetus signatus*, *Strophomena filosa*, *S.* cfr. *Fletcherii*, *Chonetes* cfr. *striatella*, etc.

N. and NW. of Klef the strata equivalent to the *Ilionia* bed are developed partly like the last-mentioned limestone of Klef, partly, and more commonly, as a somewhat marly and hard limestone like that of the hard *Ilionia* bed described above. The fauna of these limestones is nearly related to that of the last mentioned limestone, *Strophomena* cfr. *Fletcherii*, however, being their most characteristic fossil.

As is evident from the above account, there is a vast difference between the fauna of the *Ilionia* limestones proper and that of their equivalents in the Hoburgen district. Most conspicuous is the absence of the locally common *Spongiostroma*, *Leperditia phaseolus*, etc., from the Hoburgen district. Among fossils which are common to all these rocks have may be mentioned *Proetus signatus*, *Retzia*, and *Chonetes* cfr. *striatella*.

This clear palæontological and lithological difference between synchronous strata of adjacent districts may, most probably, be due to the sedimentation-having taken place in belts at different distances from the series of Crinoid Coral, Stromatopora and Bryozoan reefs which were growing at Hoburgen etc. during these times. The Crinoid limestone and the more marly limestones appear to have been deposited relatively near to the reefs, the harder and somewhat marly limestones at a little distance, and the *Ilionia* limestones proper, farthest off.

Finally, the occurrence of *a marl-shale*, which is found within the coast-belt S. and SE. of Hoburgen may be mentioned. It is rich in such fossils as *Rhynchonella nucula*, *Retzia Salterii* var. *Baylei*, *Orthis* cfr. *rustica*. *Spirifera plicatella* and var. *globosa*, *Pentamerus galeatus*, *P. linguiferus*, *Strophomena euglypha*, *S.* cfr. *Fletcherii*, *S. filosa*, *Pterinea retroflexa*, *Aviculopecten Danbyi*, *Grammysia* cfr. *angulata*, *Monograptus colonus*, etc. With these, there is found a Gastropod which is

Fig. 23. *Hoburgen from the S.* showing *the covering of the Hoburgen marble* (with perpendicular steeps) *resting on Marly limestone* (in the slope). *These two beds are replaced by Marly reef limestone building up the steep farthest W.* In the foreground a quarry in *Sandstone.* — Photo by the author in 1903.

Fig. 24, showing *marked slopes chiefly built up by Marly limestone.* N. of Hoburgen, which hill is visible farthest off. In the foreground »quarries» in Sandstone. — Photo by the author in 1903.

Fig. 25. *Fine-grained, Crystalline limestone overlain by Reef-limestone* (to the right). The eastern steep of Klef. Sundre parish. — Photo by Alb. Nilsson in 1903.

probably *Pychnomphalus acutus* Lm [=? *Platyschisma helicites*, well known from the uppermost Gotlandian beds of Ösel, Kristiania, and Britain (see below)].

As I stated in 1903 this marl-shale rests upon *Spærocodium* limestone and this again upon Oolite. Both stratifically and palæontologically this bed (with *Strophomena* cfr. *Fletcheri*, *Orthis rustica*, etc.) may, therefore, probably be correlated with the lower part of the above mentioned marly limestone and is equivalent to the *Ilionia* limestone. Of special interest is the presence of several genera which occur also in the lowest marl-shale bed, as *Ceratiocaris* and *Emmelozoë*, a fact which may indicate the same physical conditions during the formation of the two strata.

From what has been said above it is, as I hold, clear that *the sequence of strata within the southern parts of Gotland* (SW. of the parish of När), *is as follows*:

1) ***Ascoceras limestone,*** locally replaced by *Crinoid limestone* and *marly Reef-limestone.*
2) ***Crinoid limestone.*** Sometimes replaced by *Stromatopora reefs* and by *marly Reef-limestone* containing *Atrypa marginalis* var. *5-costata.*
3) ***Ilionia limestones,*** with *Leperditia phaseolus*, *Spongiostroma Holmii*, etc., and their equivalents: *marly Limestone* and *fine-grained Crystalline limestone* with *Strophomena* cfr. *Fletcherii*, as well as *marly Reef-limestone*, whose upper parts contain the same *Atrypa.*
4) ***Upper Sphærocodium bed*** (*limestone*) and its equivalents: *marly Reef-limestone* with *Spirifera striolata*, etc., and *Crinoid limestone.*
5) ***Oolite.***
6) ***Sandstone with clay.***
7) ***Lower Sphærocodium bed*** (*marl* and *limestone*).
8) ***Dayia flags.***
9) ***Marl-shale,*** with *Calymmene intermedia*, etc.

Among these beds the following are mentioned by Prof. LINDSTRÖM (in 1888): 9 + 8 (= his c_4); 6 (= c_5), 7 + 5 + 4 + 3 (= his *d*), 2 (= f + g), and 1 (= his h, p. p.).

2. Districts N. of the map-sheet of »Hamra».

Having in the preceding chapter reviewed the sequence of strata of the more southern parts of Gotland, I ought, in order to discuss the correlation of the strata into these various areas, to glance at some localities of more northern areas.

När and Lau.

Burgen, in the parishes of *Burs* and *När*. By Burgen we mean a rocky ridge, extending W. to E. which rises 10 to 15 *m* above the surrounding district. Within this latter district the *Marl-shale* is predominant and has much the same character as farther to the SW., from which district it is directly continued. Above the marl-shale we find the thin zone of the *Dayia flags.* To the S. and SE. of Burgen *the Lower Sphærocodium bed*, which dips slowly towards the E. or ESE., and *a sandy limestone* which is probably equivalent to the sandstone with clay farther to the SW., have been observed. At a somewhat higher level typical *Oolite* is common in the quarries. It is partly interstratified with *a Conglomerate* (rich in *Sphærocodium* and *Spongiostroma*), *Crinoid limestone* and with *marly Reef-limestone.* Above these a still younger, *hard Reef-limestone* occurs, which to some extent resembles the greenish varieties of the *Ascoceras limestone* above described.

In the northern part of this narrow Burgen ridge, the rocks occurring between the uppermost limestone just mentioned and the *Dayia* flags (the slab with *Dayia*, *Strophomena impressa*, etc. figured in MUNTHE 1902, p. 234, is from this place) consist of nothing but *a marly Reef-limestone and Crinoid limestone* which, therefore, must be considered as equivalents of the oolite and interstratified beds seen in the southern part of the ridge. The reefy limestone in the N. contains, *inter alia*, the characteristic coral *Ptychophyllum truncatum.*[1]

A little E. of Burgen I have found *Ilionia* limestone with *Spongiostroma*, but no *Ilionia.* This rock has not yet been met with in Burgen itself.

E. and SE. of Burgen the lower part of the above mentioned series dips approximately towards the ESE. Thus, in the southern part of Närsholm the youngest limestone reaches the sea-level, while further to the North the Oolite etc. is somewhat above it. The sandstone also is found here, but chiefly as pebbles, and so may form a bed below sea-level (see above).

Lau. As may be seen from my map of 1902 (fig. 1, p. 228) the *marl-shale* in the parishes of När and Lau (N. and NE. of Burgen) has a wide extent. Both lithologically and palæontologically it has the same character as further SW. As in that district the next younger bed is the *Dayia flags* which are found at some places in När (cfr. the slab, rich in *Strophomena depressa* and figured by MUNTHE, l. c., p. 233). In my paper I described in some detail an interesting section from the canal of Lau, which shows about the following series of strata, generally dipping towards the NW. c) *Marl-shale*[2] (with *Dayia*, *Pholidops implicata*, *Chonetes striatella* (rare) etc.; d_{1+2}) *Dayia* and *impressa flags;* d_3) *Crystalline limestone* with *Reef limestone* (only a few *Dayia* are found here); e) *Marl-shale* (rich in *Conularia*, *Emmelozoë*, etc.); f) *Marl and marly Limestone as well as marly Reef-limestone* (with *inter alia Rhizophyllum*, *Spirifera Schmidtii*, *S. striolata*, *Retzia Salterii* var. *Baylei*, *Ptychophyllum trun-*

[1] As far as I understand Prof. LINDSTRÖM, he has named this species (in Mus. Holm.?) *Cyathophyllum bisectum*, which name was, therefore, quoted by me in 1902.

[2] From this bed c of LINDSTRÖM he (in 1895) described *Cyathaspis* (?) *Schmidtii.*

catum). With these »*Girvanella*» (which will now be named *Spongiostroma*) is met with. The youngest bed is *a yellow, fine-oolitic* (?) *Limestone* in which I have since found *Spongiostroma*. This rock is evidently an equivalent of the *Ilionia* bed.

In the same paper I shortly described the strata of Lau backar, the classic locality for *Rhizophyllum gotlandicum.*[1] Here we find upon *the Marl-shale* and *the Dayia flags* a *Conglomerate* with well rounded *pebbles of Dayia flags*, etc.; *Crystalline limestone* and *marly Reef-limestone* with *marl* follow and are rich in fossils, *inter alia Rhizophyllum* (two species), *Atrypa didyma, Spirifera Schmidtii, S. striolata, Retzia Salterii* var. *Baylei, Orthis Bouchardii, O. rustica, Ptychophyllum truncatum*, i. e. the same fauna as is mentioned as occurring in the bed *f* of the Lau canal. Similar fossils are also met with S. of Lau myr (in the parish of Burs), at Rikvide in När, etc, and as far as I can see, the horizon may form a good zone over the whole district of Lau and När.

This marly bed on the top of Lau backar contains such other fossils as *Conocardium* sp., *Leperditia phaseolus, Syringopora* sp. which are also met with in *a yellow, marly and dense limestone with Spongiostroma*, found on the NE. part of the same hill. Thus, both these rocks might be contemporaneous, or the yellow limestone might, with the similar limestone at the Lau canal, be somewhat younger than the Rhizophyllum marl and belong to *the Ilionia bed*. No doubt, the marly limestone with *Ptychophyllum truncatum* in the northern side of Burgen also belongs to *the Rhizophyllum bed*.

As we have seen, there is, lithologically, a striking difference between the complex of strata occurring between *the*

[1] This interesting fossil was first found by MARKLIN and later on (in 1845) is mentioned by HELMERSEN, who named it *Calceola sandalina*. In consequence, the bed thought was by MURCHISON (in 1847) to form a transition to the Devonian system. However, this opinion has been shown to be incorrect (cfr. LINDSTRÖM 1882, Palæozoiska operkelbärande koraller).

Dayia flags and the Ilionia bed in the southernmost part of Gotland (including the southern side of Burgen) *and in Lau; the Lower Sphærocodium bed, the Sandstone, the Oolite* and *the Upper Sphærocodium bed in their normal development being absent form the latter district where they are replaced by Crystalline, Marly and Reefy limestone.*[1] However, as shown above, *the same is approximately the case with the abnormal development of the Upper Spœrocodium bed and the Ilonia bed in the southernmost district. The fauna of the Reef-limestone belonging to these beds, is nearly related to that of Lau, such species as Spirifera striolata, Retzia Orthis rustica, Ptychophyllum truncatum,* etc. *being common, to both. I therefore think that the synchrony of the southern complex with the strata of Lau may be considered as a proven fact, and that the Dayia and Ilionia (Spongiostroma) beds of the two districts are fully synchronous.*

The areas N. of the line Lau to Näs.

As I pointed out in my paper of 1902 the strata NW. of Lau myr include *the youngest Gotlandian limestone,* which we now name Ascoceras limestone. From the occurrence of this limestone at so low a level there (only a few metres higher than the marl-shale) it must follow that the strata to the N. of Lau myr must have undergone a fold or a fault (see the map, l. c. p. 228). No traces of this limestone are seen in Lau backar, but it continues from Lye parish towards the NE. to Ljugarn etc. (See below). Farther N. older beds

[1] It might, however, be thought possible that during the denudation epoch indicated by the conglomerate just above the Dayia flags, some layers equivalent to the lower *Sphærocodium* bed, the sandstone, and the oolite have been to some extent destroyed. Possibly the curious absence of those beds in the N. side of Burgen and their presence in the S. side of the same ridge is to be explained by the denudation work having ended before it had fully destroyed these last mentioned beds.

are met with, and I may now deal with a few sections illustrating the sequence of strata there.

Etelhem. 2.5 kilometres ENE. of the church of Etelhem I found *a yellow to brownish-grey, marly Limestone*, with *Ilionia prisca*, *Syringopora*, etc. and which may, therefore, be considered as synchronous with the *Ilionia* bed of more southern districts. As shown in fig. 26 this bed is closely related to beds of Crystalline limestone and to a Reef-limestone rich in *Stromatopora*. Right E. of this section the *Ilionia* bed is more than two metres thick.

1.3 kilometres SE. of the same church another section shows a *Stromatopora* bank resting upon and gradually passing into the *Ilionia limestone* which is more than 2 metres in thickness. This section is mentioned at this place, though *Ilionia* itself has not been yet found there.

Near this place, but at a somewhat higher level *a white, fine-grained Limestone*, containing *Megalomus gotlandicus* (rare) is common. This bed which is closely related to the reddishbrown *Ascoceras limestone*, may be parallelized with the Crystalline limestone of »Hamra» which contains *Trimerella* etc., since both rest upon *Ilionia limestone* and are overlain by, or are partly equivalent to the *Ascoceras limestone*. As has been mentioned before, this latter rock, which is of identically the same character as at »Hamra», has a wide extent not only in Etelhem but also in the parishes of Lye, Garde, and Stånga. More locally it is found in Lojsta, Fardhem (*inter alia* in Linde klint and Sandarfve kulle, well known from Lindström's papers).

Ardre. In the parish of Ardre the following sequence of strata has been previously observed by Schmidt, in and near the Kopungsklint, S. of the church.

Stromatopora limestone.

Megalomus » , crypto-oolitic.

Stromatopora bank (locally).

Marly limestone with *Ilionia prisca.*

Megalomus limestone closely related to *a fine grained limestone with Leperditia grandis, Corals*, etc.

N. of the church, near Bringsarfve, the latter limestone also contains *Pentamerus* cfr. *conchidium.*

As will be shown below, this close relationship between beds with *Megalomus, Ilionia*, and *Pentamerus conchidium* is of a great importance in the determination of the stratigraphy of the Gotlandian rocks.

E. of Ardre church a limestone-shale resembling the so-called »Leperditia shale», which Dr. HEDSTRÖM found near Visby etc., is met with. It is overlain by *Megalomus* and *Stromatopora limestone* and contains, *inter alia*, *Leperditia* cfr. *grandis.*

Within a somewhat folded area at Sjausterhammar, in the parish of Gammelgarn, the same rock is found, and is probably overlain by *Grandis* limestone and by magnificent *Stromatopora banks.* It probably originally rested upon limestone rich in *Megalomus* (fig. 27).

Östergarn. In this parish several sections have been studied which seem to justify the following sequence of strata which, in the main, has been already cleared up by SCHMIDT and others.

Stromatopora and crystalline limestones, some ten metres in thickness. These beds build up the upper parts of the hills of Östergarn (Gannberget, Grogansberget). In the SE. parts of Östergarn etc. as well as in Gammelgarn (see above) these strata in part are below sea-level (cfr. fig. 28). They are poor in fossils other than *Stromatopora Bryozoa*, and *Crinoids.* Locally a marly limestone mentioned below forms banks in the lower parts of the complex and is replaced by a marly reef-limestone containing *Labechia conferta, Orthis Bouchardii* (var.), etc.

Marly limestone. This bed is bluish-grey and, when weathered, becomes brownish-grey in colour. It form, *inter* *alia*, the lower part of the hills mentioned and is some ten metres in thickness.

This marly limestone of Östergarn resembles the typical *Ilionia bed* of the southernmost area of Gotland as well as that of Etelhem and Ardre, but *Ilionia* is only found in its lower or lowest parts. At higher levels the bed is generally rather poor in fossils, only *Leperditia* cfr. *phaseolus* and some minute *Ostrocoda* (which are not yet determined) being common. In the slope proper the bed is rarely to be seen. Probably *Atrypa prunum* which is recorded only from Östergarn is at home here.

Over the neighbouring plains the same limestone has a wide extention. In places, as in ditches near Gutenviks and at Grogarnshufvud, it is rich in *Rhynchonella Wilsonii*, *Pleurotomaria planorbis*, *Calymmene spectabilis*, *Orthoceras angulatum*, etc. Near Grogarnshufvud some other species such as *Meristina didyma*, *Rhynchonella diodonta*, *Ilionia prisca*, are common. More sparsely *Orthis* cfr. *rustica*, *Pentamerus* cfr. *conchidium*, etc. are found.

In the parish of Kräklingbo (NW. of Östergarn) the shore rocks with *Ilionia* are also sometimes, as SE., E. and NE. of L. Hammars, rich in the same fossils, such as *Rhynchonella Wilsonii*, *R. diodonta*, *Retzia Salterii* var. *Baylei*. More sparsely *Meristina didyma*, *Leperditia phaseolus*, *Conocardium* sp. etc., and *Eurypterus Fisherii* (first found by SCHMIDT in 1857) are met with.

Beneath the *Ilionia*-bearing bed, but probably closely related to it, there is, in places, a marly shale containing masses of well preserved fossils, as *Chonetes striatella*, *Rhynchonella Wilsonii*, *R. nucula*, *Spirifera elevata*, *Meristina didyma*, *Tentaculites*, *Beyrichia*, etc. This bed seems to be the oldest one in the area in question. Generally it is to be found at or below sea-level, as NNE. of Östergarn church, but farther to the W., as in the NE. part of the parish of Gammalgarn, it is

S. l.
Cr. l.
I. l.
Cr. l.

Fig. 26. Section showing *Ilionia limestone* (I. l.) thinning out in *Crystalline limestone* (Cr. l.) overlain by *Stromatopora limestone* (S. l.). Etelhem parish. — Photo by the author.

Fig. 27. *Limestone rich in Megalomus* (M. 1.), resting upon *Reef limestone* (in the midst of the fold). Farther off (to the left) the same limestone and *Leperditia grandis*-bearing limestone are overlain by *Stromatopora limestone* (S. 1.). (The »Leperditia shale is not visible.) — Photo by the author in 1908.

Fig. 28. *A Stromatopora bank* overlain by *bedded*, in part *Conglomeratic Crystalline limestone.* Kuppen. Östergarn parish.
Photo by G. Holm.

met with a few metres above the sea, thus probably indicating a gentle dip of the rock.

SW. of Hammarudden (W. of Grogarnshufvud) the strata for some distance form a flat synclinal, showing marly shale with *Chonetes striatella*, *Meristina didyma*, etc. overlain by Marly limestone with *Ilionia prisca* etc., and this again by a somewhat *crystalline limestone with Megalomus.* (In Kräklingbo *Ilionia* and *Megalomus* are locally found in one and the same bed.)

Since this sequence of strata is also observed at some other places (as, e. g., in the parish of Kräklingbo) it is evident, that SCHMIDT was right in emphasizing the fact that the *Megalomus bed* in Östergarn is really in situ near the sea-level, and is not faulted down, as LINDSTRÖM and DAMES had thought.

DAMES (l. c.) says that *Megalomus* is met with in the higher limestone-bed of Östergarn (in Gannberget), but nobody else has found it there. To judge from its occurrence in Ardre, it is probable that DAME'S observation is correct and that, in Östergarn also, *a younger zone with Megalomus* really exists above the above-mentioned marly limestone with *Leperditia*, which may be considered as a higher part of *the Ilionia bed.* Probably, therefore, *the Megalomus banks* have a local development and the genus *Megalomus*, as is suggested by SCHMIDT, may have more than one species or variety and many occur at at least two separate levels in Gotland. On the other hand, *Megalomus* is never met with in the southernmost parts of Gotland, a fact which may also illustrate its local occurrence.

As LINDSTRÖM had already presumed in 1888, it is probable, that *the Ilionia limestone* of southern-most Gotland and of Ardre and Östergarn, may be parallelized, since they have such fossils as *Ilionia prisca*, several species of *Orthoceras*, *Leperditia phaseolus*, etc. in common. If this is right, then the next older bed (with *Chonetes striatellă*, *Meristina didyma*, *Retzia Baylei*, *Rhynchonella nucula*, *R. diodonta*, etc.) may be regarded as synchroneous, not with the bed c of LINDSTRÖM, as was thought by him, but with one or some of the beds such as *the Rizophyllum bed* in Lau (see above) immediately *beneath the Ilionia limestone* of more southern districts.

Of *the youngest strata of Östergarn and its neighbourhood*, it is worth mentioning, that, apart from *Megalomus* (according to DAMES), no fossils sufficient for the determination of the age of the strata are yet found since the most part of them are *Stromatopora*, fragments of *Crinoids*, and *Bryozoa*.

The same is generally also true of the other hills of this region, as in Torsburgen (between the churches of Ardre and Kräklingbo), where the same varieties of limestone occur. In Herrgårdsklint, SE. of Torsburgen, however, the reddish-brown *Ascoceras limestone* is found at the top. It contains, *inter alia*, *Spirifera Schmidtii* (var.).

To the N. and NW. of Kräklingbo the solid rock is chiefly built up of *a greyish or brownish-grey marly limestone*, sometimes replaced by *crystalline limestone*. The former rock contains *Ilionia prisca* (a somewhat smaller form than that in Östergarn) and, with it, *Spongiostroma Holmii* is sometimes common. Partly together with, partly also at a somewhat higher level than this, *Solenopora* cfr. *gotlandica* ROTHPL. and, more rarely, *Retzia* sp., *Rhynchonella nucula*, a few *Corals* (*inter alia Halysites* sp.), *Stromatopora*, etc. are met with.

This *Ilionia*-bearing bed extends towards the North at least as far as the parish of Hörsne and towards the W. to NW. of Ala church. Through this last locality it is connected with the above-mentioned occurrences in Ardre and Etelhem. Further W. I have not yet found *Ilionia* itself, but limestones, which doubtless might be parallelized with the *Ilionia* bed, have a wide extention there.

As has been said before, *Pentamerus* cfr. *conchidium* occurs *in the Ilionia and Megalomus beds in* Ardre, Östergarn and Kräklingbo. It occurs also in similar beds in the parishes of Ala, Sjonhem and probably also Vänge, though *Ilionia* and *Megalomus* are not found there, but are replaced by such »Ilionia-fossils» as *Siphonostroma* and *Solenopora*, which are also found in Norrlanda, Ganthem, Viklau, etc. SW. of this last parish *Pentamerus conchidium* becomes gradually more and more common and in Hejdeand Klinteberget reaches its highest development. It occurs both in *a marly* and in *a crystalline limestone.* The same is also the case in the parish of Lojsta. In both these places the Reef-limestone of this horizon contains, *inter alia*, such fossils as *Orthis rustica, O. Bouchardii, Spirifera Schmidtii*, etc.; all of which are characteristic of the *Ilionia* reef-limestone and of the somewhat older beds in the SE. and S. parts of the island, as at Lau, Hoburgen, etc. *Most likely, therefore, all these beds might be approximately synchronous.* This is probable also from the circumstance, alluded to above, that the strata which rest upon the *Ilionia-conchidium bed* of these northern areas, viz. the characteristic *Ascoceras limestone*, are equivalent to the strata which rest upon the *Ilionia* bed of more southern districts. In places (as in Lye, Sandarfve kulle in Fardhem parish, etc.), as is shown by LINDSTRÖM's valuable monographs of the Gastropoda (1884), the Ascoceratidæ (1890) etc., the *Ascoceras* limestone is rich in delicate fossils. *Greyish-white Crinoidal limestones*, more or less rich in *Stromatopora* etc., occurs at nearly the same horizon as the *Ascoceras* limestone and have a large extent also within these northern parts of the map. Sometimes a white, finegrained or crypto-oolitic, bedded limestone with occasional *Megalomus*, is met with as an equivalent of the crystalline limestone just mentioned. As far as I can see this fine-grained limestone, has its principal development near the marly reefs and shows transition forms into them. Such, *inter alia*, is the case in the higher parts of Klinteberget, where they rest on the *Conchidium* beds. As shown in figs. 29 and 30, these upper parts of the hill consist principally of Reef-limestone with *Atrypa marginalis* var. *5-costata* etc. and of crystalline limestone, which in the N. and S. parts of the hill are partly or entirely replaced by *fine-grained bedded limestone* (cfr. fig. 31). The fauna of these youngest beds has not yet been studied in greater detail.

The hills of Fröjel etc. consist approximately of the same beds as the higher parts of Klinteberget.

For details of *the lower beds in Klinte and its neighbourhodd* see under.

The north-western part of the map-sheet of "Roma."

We may now glance at the sequence of strata in the north-western part of the map and may later draw a parallel between some of the strata already dealt with.

Tofta. The best sections are to be found in the »klints» (steep cliffs) of Tofta, whose lower parts, consisting chiefly of marl-shale, follow the shore-line, while the upper ones, consisting of limestone, commonly run some hundred of metres farther inland. At Stafs klint the steep includes the whole series (fig. 32).

The sequence of strata at and in the vicinity of Stafs klint is approximately as follows (from younger to older):

1. *Reef-limestone*, passing towards the South into a *fine-grained, somewhat oolitic, in part crystalline, bedded limestone* (see fig. 33). Thickness about 10—15 metres;
2. *Sphærocodium limestone*, a few metres thick;
3. *Marly and crystalline limestone and marl-shale;*

Fig. 29. *Marly Reef-limestone* (R. l.) resting on *Crystalline limestone* (Cr. l.) and the latter on *Marly limestone* with *Pentamerus conchidium* (P. l.) The W. side of Klinteberget. — Photo by the author 1908.

N. S.

M. l.

Fig. 30, showing *Reef-limestone* (farthest N.) passing into *Crystalline limestone*, which rests on a thick bed of *Marly limestone* (M. l.). Klinteberget. — Photo by thute ahor in 1908.

Fig. 31. *A reef of* somewhat *Marly limestone* passing into *fine-grained*, *Crystalline limestone*, in part showing diagonal bedding. Klinteberget. — Photo by G. Holm.

4. *Marl-shale with lenses and bands of marly limestone.*

The beds 3 and 4 are together about 35 metres in thickness.

As to the fauna of these strata the following remarks may suffice.

The lowest bed, a couple of metres above sea-level, contains, *inter alia*, *Goniophyllum pyramidale*, *Cyathophyllum augustum* and *Strophomena Walmstedtii.* According to LINDSTRÖM 1888, these fossils are characteristic of his »Visby-fauna» (the bed c_1). In Tofta *Leptæna transversalis* is also found.

A few metres above sea-level the marl-shale contains, *inter alia*, *Omphyma* sp.

At a height of 11.5 to 13 metres a couple of banks of *marly* and in part *crystalline limestone* (at + and + on fig. 32) occur and are locally replaced by *marly Reef-limestone.* These rocks contain, *inter alia*, *Ptychophyllum patellatum* and *Holophragma calceoloides.* This latter species is characteristic of the upper part of LINDSTRÖM's bed c_1, but has not yet been found outside the »Visby fauna» district (cfr. LINDSTRÖM 1896).

Both these limestone banks which are relatively conspicuous and in the lower part of the klint make clear the gentle and uniform dip of the strata towards the SSW. At Nyrefs udde they are only 2 to 3 metres above sea-level but at Gnisvärd they coincide with it. Here as well as at Nyrefs udde *Ptychophyllum* and *Holophragma* are common, and *Omphyma subturbinata*, *Orthis biloba*, *Leptæna transversalis*, *Strophomena pecten*, etc. are also met with.

Above these horizons, near Stafs klint approximately at *15 to 16 metres above the sea*, the marly shale with lenses of limestone contains, too, *Spirifera exporrecta*, *Leptæna transversalis*, etc.

At a somewhat higher level a crystalline limestone, which, *inter alia*, contains *Atrypa Angelinii* occurs. This horizon is, therefore, a part of LINDSTRÖM's bed *d* (l. c. 1888, p. 159).

In the klint, the strata at higher levels are not easy of access but S. of it, near Blåhäll, there is a new exposure, about 25 to 30 metres above the sea, of a marly limestone poor in fossils but with some *Sphærocodium* (rare), *Rhynchonella* sp., and *Strophomena* sp.

In the steep cliff of Stafs klint, at *about 30 metres above sea-level*, it yielded some specimens of a *marly and crystalline limestone* which also contains *Sphærocodium* and with it, *Proetus* sp., *Ptilodictya* sp., etc.

Immediately below the (uppermost) reef-limestone of the southernmost part of Stafs klint, about 37 metres above sea and at × on the fig. 32, there is a marly limestone, certainly a few metres in thickness, which is very rich in *Sphærocodium*.

The beds now mentioned, from the *Atrypa Angelinii* layer upwards, may be regarded as corresponding to LINDSTRÖM's stratum *d*.

Then in the klint follows the *Reef-limestone* proper, but this is not accessible to collectors. As mentioned above, towards the S. it is replaced by *bedded limestones* a of somewhat varying character, oolitic and fine crystalline. (Fig. 33.) ROTHPLETZ (in a letter) speaks of a specimen, from the lowest part of the bed, as *a Sphærocodium sandstone.* It is poor in fossils and contains only some small brachiopods with smooth surfaces and which are not yet determined. Locally, pebbles of limestone indicate a deposition in shallow water. The limestone at the top of this klint is in places rich in *Bryozoa.*

E. of the klint several varieties of limestone are found. A dense, light, liver-coloured rock contains *Sphærocodium*, *Spongiostroma* and *Solenopora gotlandica* ROTHPL., this latter fossil being the commonest. Farther to the E. crystalline limestone is also met with, and near Homa a finer grained laminated limestone is the predominant rock.

Fig. 32, illustrating *the sequence of strata at Stafsklint*, Tofta parish. The salient part of the steep cliff is *Reef-limestone*, which rests on a bank of *Sphærocodium limestone.* To the right the whole cliff is occupied by *Marl-shale*, more or less rich in *Limestone beds*, two such beds being relatively distinct, at + and + in the slope. — Photo by G. Holm.

Fig. 33, showing the uppermost *fine-grained limestones* in the klint S. of Stafsklint, Tofta parish.
Photo by the author in 1808.

More locally, as SW. of the church of Stenkumla, *a greenish hard limestone* like that of the *Ascoceras limestone* forms the highest parts of this relatively lofty district.

In as much as *Megalomus* limestone exists also NE. of Tofta, e. g. in Follingbo parish in the S. part of the map-sheet of »Visby», some fine-crystalline varieties of limestone which occur in Stenkumla may probably be parallelized with *the Upper Megalomus bed* of more SE. districts.

S. of the high limestone district now under consideration there is a somewhat lower belt, a few kilometres broad, which is occupied by *a brownish-grey marly limestone*, generally poor in fossils. These rocks are most likely equivalent to the *Sphærocodium*-bearing marly limestone above the lower klint of marl-shale, at, and SSW. of Stafs klint.

As far as I can see there are good reasons for correlation of the above-mentioned strata of the more southern and eastern areas of S. Gotland with those of Tofta—Stenkumla where the following beds are represented:

Ascoceras limestone.

Ilionia limestone in which *Ilionia* is replaced by *Spongiostroma* and *Solenopora.*

Oolitic and fine crystalline limestones with *Sphærocodium*, and its equivalent *Reef-limestone.*

Lower *Sphærocodium* bed of a marly limestone.

Marl-shale with *banks of limestone above* (see below).

Now may we, at last, deal with ***the classification of the oldest bed, the marl-shale, in the areas between the map-sheet of »Hamra» and the Tofta district.***

Of all the Gotlandian strata this bed may be said to be the most complex and, as we will see, the difficulties cannot yet be cleared up in any satisfactory way.

In places the marl-shale contains beds of marly limestone or even of flagstone (see below).

As we have already seen, LINDSTRÖM speaks (in 1888) of the *Vestergarn fauna* (c_2) of his bed c, as containing, *inter alia*, the following characteristic fossils: *Leperditia Schmidtii*, *Spirifera exporrecta*, *Whitfieldia tumida* (var.). Of these fossils the two first named species are said to be common to the »Visby fauna».

SCHMIDT, however, has shown, that *Leperditia Schmidtii* KOLM. (= *L. Hisingerii* SCHMIDT) is found only in the bed c_1, while the bed c_2 contains only *L. baltica* (*pectinata*).

Orthis biloba, *Orthoceras annulatum*, etc. are referred to the c-fauna of the so-called Central Gotland area (c_3) which includes Eksta-Fröjel-Atlingbo etc.; and *Dayia navicula*, *Orthis canaliculata*, *Calymmene intermedia* etc. to the so-called *fauna of Petesvik* in Hablingbo (c_4), which includes Fardhem, Hemse, Burs, etc. The three last-mentioned fossils we have already (p. 1408) learnt to know from the marl-shale of more southerly districts.

During my researches I have made observations, which make it probable, that in all these districts the marl-shales can be considered as belonging to *one and the same series of strata and not*, as was thought by LINDSTRÖM, *to one and the same horizon*, or, as according to SCHMIDT, *to different strata which are gradually and regularly younger towards the SE.*

Of this series, the younger bed with *Spirifera exporrecta* which is found 15—16 metres above sea-level in the Tofta section near Stafs klint, seems to have a wide outcrop in the large marl-shale district which extends from Vestergarn towards the NE. to Dalhem (see the map). It includes as the commonest fossils *Leperditia baltica* (*pectinata*), *Spirifera exporrecta*, and *Whitfieldia tumida* (var.).

Farther S., the large marl-shale area from Eksta, Hablingbo, Hemse, etc. in places contains the same fossils as are found near Stafs klint 11.5 to 13 metres above the sea and gradually lower towards the SSW. (see above). Thus I have found *Holophragma calceoloides* (together with *Halysites* etc.) not only in LINDSTRÖM's bed c_1, but in the bed c_4 as far towards the S. as in the parish of Silte, Fardhem etc. (see the map).

The same also is the case with *Leptæna transversalis* which is, as yet, only quoted from c_1, c_2, and c_3 (the Visby and Central Gotland faunas), while *Orthis biloba*, which is quoted only from c_3, is found as far towards the SE. as Hemse etc. (*O. biloba* var. *Verneuiliana*, however, seems to be confined to the Visby district and NE. of it).

Judging from these facts I conclude, therefore, that the bed c of LINDSTRÖM is really not so complex as was thought before, and that more minute researches might prove, that the various horizons of the Visby fauna can be also recognized within the marl-shale of the more southern areas of the island. As yet, however, such a division cannot be accomplished in greater detail for in S. Gotland no deep sections in the marl-shale are to be found.

In some places, beds other than the marl-shale are found, and probably indicate a closer local relationship between the southernmost Gotland and northern districts. Thus in the parishes of Klinte, Fröjel, and Eksta *a sandy limestone* or *fine-grained calcareous sandstone* (a flagstone) was discovered long ago by HISINGER and later on (in 1860) described by LINDSTRÖM, who referred it to his bed c_3. He mentioned *Atrypa cordata* LM, *Chonetes cingulata* LM, *Graptolites*, etc. as its most characteristic fossils.

We may now glance at the relation between this bed and some other strata in Klinte and Fröjel.

During my researches there, in 1908, I found the following sequence of strata, from high to low:

1. *Younger bedded limestones and Reef-limestone* (with *Atrypa marginalis* var. *5-costata*, *Orthis rustica*, etc.).

2. *Marly and crystalline limestone* with *Pentamerus conchidium*, *Orthis rustica*, etc.
3. *Marly limestone*, about 20 to 15 metres in thickness. The fauna is not yet known (see under).
4. *Oolite* (locally), poor in fossils, partly replaced towards the South by limestone with *Sphærocodium.*
5. *Flagstone*, in its lowest and uppermost parts rich in *Atrypa cordata*, *Chonetes cingulata*, *Graptolites*, etc. Several metres in thickness.
6. *Marl-shale* with *Orthis biloba*, *Orthoceras annulatum*, *Leptæna transversalis*, etc.

Of these strata 1 and 2 were mentioned above in speaking of Klinteberget etc. The bed 3, *inter alia*, builds up the high slope which runs S. from Klinteberget (cfr. fig. 30) to Fröjel. This bed, whose fauna has not yet been studied, may be looked upon as a thick, local stratum belonging to the *Ilionia* bed, or, perhaps, since I have found in it a few specimens of *Orthis biloba* and *Spirifera exporrecta*, as an older bed. Then follows the *Oolite* and *Sphærocodium limestone*, which may be regarded either as equivalent to the similar beds of the more southern districts of Gotland and the *Sphærocodium* and oolitic limestones of Tofta, or looked upon as but a local bed belonging to the thick marly limestone division. As far as I know, such an opinion is, however, contradicted of the fact, that *Sphærocodium* is nowhere met with in the true marl-shale division of Gotland.

The flagstone is closely related to the *Mulde marl* (in the parish of Fröjel), well-known for its abundance of well preserved fossils, such as *Whitfieldia tumida*, *Strophomena rhomboidalis*, *S. funiculata*, *Leptæna margaritacea*, *Corals*, *Bryozoa*, *Annelids*, etc., etc. In as much as this marl occurs directly under the *Sphærocodium* limestone and contains *Dayia navicula*, I think it probably belongs to the youngest part of the marl-shale-series, just as is the case with the *Dayia* flags of more southern parts of the island. Like the younger sandstone with clay there, I think that the flagstone and the Mulde marl of Klinte-Fröjel may be looked upon as a local variation of the marl-shale of Central Gotland. Possibly also, like the sandstone with clay, it was deposited during a sinking of the sea-floor, or it may have been somewhat down-folded in late Silurian time.

Finally I will give *a general survey of the sequence of strata of Southern Gotland* in the following table, which, however, as is evident from the above account must not be looked upon as conclusive in every detail.

1 a. ***Ascoceras limestone*** found in many districts within the area in question.

1 b. ***Youngest crystalline*** (*chiefly Crinoid*) ***limestone,*** in places rich in *Stromatopora*, and sometimes replaced by *Reef-limestone* with *Atrypa marginalis* var. *5-costata* etc. Locally this bed is closely related to *the Ascoceras limestone.* In the southernmost part of Gotland it sometimes contains *Trimerella*, which farther N. is replaced by *Megalomus gotlandicus* (*the Upper Megalomus bed*).

2. ***Ilionia or Spongiostroma limestone.*** *Ilionia* itself seems to be limited to the southern and eastern parts of the area, while *Spongiostroma* is found also in the central and northern (NW.) districts. In Ardre Östergarn, Kräklingbo, etc. *a Lower Megalomus bed* with *Leperditia grandis* is met with. In Klinte, Östergarn, etc. all these fossils are in part replaced by *Pentamerus conchidium.* Near Hoburgen etc. the equivalent beds are developed as *marly limestone, fine-grained limestone and Reef-limestone* with *Spirifera Schmidtii, Orthis rustica, Ptychophyllum truncatum* etc. Probably the Rhizophyllum bed in Lau etc. is in part an equivalent.

3. ***Upper Spærocodium bed and Oolite,*** chiefly developed in Southern Gotland (towards the N. as far as När) and to some extent also in Tofta and Klinte (?). In other places, as in Lau, *Rhizophyllum* is common in marly Reef-limestone and also in marl (the canal of Lau).
4. ***Sandstone with clay.*** Only developed within the area of the map-sheet of »Hamra» and in the SE. part of »Roma». Probably this horizon also is equivalent to a part of the *Rhizophyllum bed* etc.
5. ***Lower Sphærocodium bed.*** Chiefly developed in the NW. part of »Hamra» and the SE. part of »Roma», extendiny northwards as far as the parish of När. It is also found in Tofta.
6. ***Dayia flags.*** The distribution approximately follows the outcrop of the bed 5. At the top of the bed a conglomerate is, in places, developed.
7. ***Marl-shale with lenses and bands of limestone.*** Chiefly in the NW. part of »Hamra» and in the S. and NW. parts of »Roma». It can be subdivided into a series of different horizons. Locally, as in Klinte and Fröjel, it includes a bed of *flagstone* with marl.

Tectonics. Within the map-sheet of "Hamra" and in the SE. and E. parts of »Roma» the strata, in the main, have a SW. and NE. strike, and they dip gently towards the SE. The same isgenerally the case also within other parts of »Roma», but in the central and northwestern districts there are a somewhat complex series of dome-shaped or anticlinal folds.

As a summary of this account on the sequence of strata in Southern Gotland I conclude that though LINDSTRÖM's division is in many points correct, in others it is incorrect, and the same may be said of SCHMIDT's division. As is said above the c_{1-4} of LINDSTRÖM (the so called marl-shales) include several different horizons, but they are not, as SCHMIDT has said, ever younger and younger as we pass to the SE. SCHMIDT however is right when emphazing the fact that the sandstone with clay is probably younger than the youngest horizon of the marl-shale.

SCHMIDT's opinion that c_3 may thin out towards the N., or may be replaced by beds belonging to LINDSTRÖM's beds f or g, cannot be correct; though it does seem likely that the whole series including the Lower *Sphærocodium* bed, the Sandstone with clay, the Oolite, the upper *Sphærocodium* bed, and the *Ilionia* bed of the southermost parts of Gotland (i. e. LINDSTRÖMS beds c and d of that district), find their equivalents among the beds d (e) and f of LINDSTRÖM in the NW. part of the district within my map. In such respects, SCHMIDT's opinion that higher lying beds in the NW. are synchroneous with lower ones in the S. may be right. As regards the youngest beds, the crystalline limestones proper, (*the Ascoceras limestone, the Upper Megalomus or Trimerella limestone* etc.), LINDSTRÖM's opinion that they occur in several different districts on the island as contemporaneous beds may be correct.

Finally I may say emphatically, that before we can completely understand the sequence of strata in Gotland, we must have much further help from the palæontologists. SCHMIDT has already pointed out that there are two or more varieties of *Megalomus* and it is probable that the same may be true of several other species which are equally important from the stratigraphical point of view, and I would suggest that a minute study of such forms as *Pentamerus conchidium*, *Leptæna transversalis*, *Spirifera exporrecta*, species of *Halysites*, etc. would be of great value from this point of view.

As an interesting illustration of this I need only mention Prof. ROTHPLETZ's recent treatise on the Calcareous algæ and Hydrozoa of Gotland, which though but lowly organisms are evidently of a great stratigraphical importance.

Table illustrating the probable parallelization of Gotlandian strata in some districts of N. Europe.

Britain (ELLES & SLATER 1906 and acc. to FEARNSIDES).	Kristiania district (KIÆR 1908).	Gotland (MUNTHE 1910).	Estland (SCHMIDT).
Temeside Shales	*Zone 9g*	*Ascoceras bed?*	—
		Megalomus-Trimerella bed	K
Downton-Castle Sandstones	*Zone 9f—a*		
Upper Whitecliffe or *Chonetes Flags*		*Ilionia (Spongiostroma-Conchidium) bed*	
Lower Whitecliffe or *Rhynchonella Flags*			
Dayia Shales			
Aymestry or *Conchidium Limestones*		*Upper Sphærocodium bed*	
Lower Ludlow Shales		*Oolite*	
Wenlock Limestone		*Sandstone with clay*	
		Lower Sphærocodium bed	
		Dayia Flag	
Wenlock shales	*Zone 8d—a*	*Marl-shale series*	I, H
Tarannon Shales & Sandstones	*Zone 7c*		
Upper Llandovery		*Stricklandinia marl* (LINDSTRÖM's bed b)	G_3
Sandstone with Stricklandinia			

The above table which represents my views upon the probable correlation of the strata of Gotland with those of some other parts of N. Europe is in general agreement with the work of KIÆR but I have now no time to discuss it further.

Supplementary remarks.

When the above paper was in type I received from Dr. E. C. N. van Hoepen, Nederlands, a treatise entitled: De Bouw van het Silur van Gotland (On the Silurian Strata of Gotland), Delft 1910.

Dr. Hoepen's researches were made during last summer (1909) and his results agree tolerably well with these of Friedr. Schmidt. He goes however yet farther than Schmidt and, on the whole, regards the strata as ever younger and younger in a SE. or SSE. direction.

Though the treatise contains several new and good observations, I cannot see that Dr. Hoepen's results take as much further forward than heretofore.

Morewer I am of opinion, that it had been better for all concerned, if Dr. Hoepen had not travelled in Gotland unknown to Swedish geologists, for in Gotland there are so many questions to be still solved, that we had been only too glad to hand over to him such problems, of detail, as he cared to solve.

For his useful and kind correction of the proofs-sheets of my paper I am much obliged to Mr. W. G. Fearnsides, of Cambridge, who visited Stockholm during July this year.

Plan for the three days excursion.

1. ***Visby — Hafdhem*** (Marl-shale, *Dayia* flags, Lower *Sphærocodium* bed, Sandstone with clay).

   Hafdhem — Burgsvik — Hoburgen (Sandstone, Oolite, Upper *Spærocodium* bed, *Ilionia* bed, Youngest Crystalline limestone and, possibly, *Ascoceras* limestone). For details of the *abnormal* rocks see above.

Hoburgen* — *Hamra parish (if possible) — ***Burgsvik*** (Sandstone, Passage bed, *Ilionia* bed and its equivalents, the marly reef-limestone).

2. ***Burgsvik* — *Etelhem*** (*Ilionia* bed, *Megalomus* and *Ascoceras* limestones) — ***Lau-kanalen*** (Marl-shale, *Dayia* flags, *Rhizophyllum* marl, *Ilionia* bed etc.) — ***Laubackar*** (chiefly as at the canal).

Lau* — *Ardre [Upper *Megalomus* and *Stromatopora* beds, *Ilionia* limestone, Lower *Megalomus* and *Grandis* bed (with *Pentamerus* cfr. *conchidium* N. of the church)].

Ardre* — *Östergarn (Youngest limestone beds, Lower *Megalomus* limestone and *Ilionia* beds).

Ardre* — *Roma* — *Klintehamn. (Along this route chiefly the *Spongiostroma* limestone may be seen.)

3. ***Klinte parish*** (Marl-shale with *Orthis biloba* etc., Flagstone with *Atrypa cordata* etc., Lower *Sphærocodium* limestone and Oolite, Marly limestone, *Conchidium* beds, Younger Crystalline, fine-grained and Reef-limestones).

[If time allows ***Klinte* — *Hejde*** (*Conchidium* limestone etc.). ***Klinte* — *Mulde*** (Marl rich in fossils)].

Fröjel (or ***Klintehamn***) — ***Stora Karlsö*** (Marl-shale rich in *Omphyma* etc., Younger limestones etc.).

Karlsö* — *Visby (in the cliffs Marl-shale, Bedded and Reef-limestones are to be seen in the distance).

[As regards Quaternary phenomena see Munthe: Studier öfver Gottlands sen-kvartära historia (Studies in the Late-Quaternary history of Gottland). S. G. U. Ser. Ca, N:o 4, 1910. Price 8 kr.].

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Table of Contents.

The Stratigraphy of the Silurian strata of the Visby district.

By

HERMAN HEDSTRÖM.

(With Plates 56—61).

How to interpret the stratigraphical conditions in the Silurian strata of Gothland has for a long time been a question of dispute in which principally two different views have been advanced.

According to one of these views the strata are lying approximately horizontal, and such differences as the sediments, which are lying at the same geological horizon, have to show in different localities are considered to be due to changes of facies of a faunistic and petrographic kind. This idea has been represented by HISINGER, VON HELMERSEN, F. RÖMER, ANGELIN and most of all G. LINDSTRÖM. Later authors such as BATHER, DAMES, STOLLEY, WIMAN, HOLM, and MUNTHE have on the whole, although partly with minor modifications in interpreting certain parts of the sequence of strata, adopted this view.

According to the other conception the Silurian strata of the Visby district and northern Gothland incline on the whole down under those of the middle and southern Gothland, whereby the former are made to represent the older, the latter the younger strata. This interpretation, first advanced by MURCHISON, was afterwards more fully developed and defended by FR. SCHMIDT.

Through the survey-work carried out of late years at Gothland by the Geological Survey of Sweden, in the course of which a mass of new material for observation has been gathered, the question in dispute has been brought nearer to its solution. As regards N. Gothland the work was commenced there under the author's supervision in 1903 and is certainly still far from finished; but the results obtained so far seem yet to be of importance for interpreting the Silurian stratigraphy of Gothland.

In the following pages will be given a short account of a part of the investigations in the Visby district within an area, which the members of the Silurian excursion will visit. As a background for this account we might first take LINDSTRÖM's division and conception of the sequence of the strata in N. Gothland — i. e. that part of the island which is situated north of the topographical sheet Roma (the southern boundary of the topographical sheet Visby) — as well as state the most important points of view in which SCHMIDT's opinion differs from LINDSTRÖM's.

LINDSTRÖM's table of the different divisions of Gothland's Silurian system has the following appearance:

h. Cephalopodan and Stromatoporan strata.
g. *Megalomus*-banks.
f. Crinoid and Coral limestone (conglomerate).
e. *Pterygotus*-stratum.
d. Limestone strata with marl seams.
c. Marl-shales.
b. *Stricklandinia*-schists.
a. Oldest red *Arachnophyllum* schist.

The lowest stratum *a*, which is only found in the shape of boulders, mainly in the vicinity of Visby, rests under the surface of the Baltic and does not therefore belong to the Gothland-strata proper. Its stratigraphical situation and relation to the following members of the series of strata could thus not be more closely ascertained and studied.

Concerning the other sections of the scheme mentioned all the writers seem to be ready to accept and agree that LINDSTRÖM's division of the strata *b* to *e* is on the whole correct, in so far as it refers to the shore sections on the west coast of northern Gothland. It is first when interpreting the strata *f*, *g*, *h*, and trying to fit the marl-shales of Follingbo-Slite into the scheme that the opinions diverge as to the sequence of strata in N. Gothland. The last mentioned marl-shale area is by LINDSTRÖM referred to the marl-shale *c* and by him considered as a facies of this (= »das centrale Gebiet»). On the map accompanying his paper this district has, however, been marked as belonging to section *d*.

DAMES thinks that sections *f*, *g*, and *h* — »the Crinoid limestone, Stromatoporan and Cephalopodan limestone, as well as the *Megalomus*-banks» — are one and the same stratum in the series, and places it under the designation *f*. He divides, however, the Cephalopodan limestone into two strata, a lower and an upper, whereby he gets another stratum beyond *f*, viz. *g*, upper Cephalopodan limestone.

SCHMIDT's position to the matter may be best explained by quoting the question he asks: »Ist es wahrscheinlich, dass dieser doch so hoch liegende und auch faunistisch verschiedene Slite-Follingbo-Mergel die direkte Fortsetzung der am Meer unter den tiefsten Kalkschichten *f* des Visby-klints anstehenden Mergel und Mergelkalke *c* and *d* bildet, und ist es nicht eher anzunehmen, dass er sich zwischen die unteren Visbykalke *f* und die oberen *g* und *h* einschiebt? Dabei ist es doch gar nicht nothwendig, dass der Encrinitenkalk und Korallenkalk von Visby (*f*) sich als solcher unter den Mergelkalken von Follingbo fortsetz. Letztere können sehr wohl die Vertreter dieses Kalks sein, der ja ohnehin auch an der Küste seinen Charakter nicht überall beibehält. Auch möchte ich nicht zugeben, dass der Crinoidenkalk überall auf der Insel das gleiche Niveau einnimmt, was sich von selbst ergiebt, wenn die unter ihm liegenden Mergel nicht gleichzeitig sind.»

The question had got to this point when the survey work was commenced in N. Gothland in the year 1903. From what has been said above it is obvious that the horizon at which one had expected to find some information and discovery concerning the conditions of stratification in N. Gothland under dispute, was LINDSTRÖM's *f*-horizon, which for that reason was made the subject of a more thorough study.

Already in the following year, 1904, the author discovered quite a complete section situated at this level, i. e. below the horizon *g*, the *Megalomus*-banks, and extending downwards in the series of strata to the limestone stratum, which completely agreed with LINDSTRÖM's *d*-stratum in the Visby district. The section is situated to the northern part of Fårösund at the coast of Vialms, in the parish of Fleringe. The combined thickness of the strata is very great and amounts to nearly 20 metres, whereas LINDSTRÖM gives the thickness of his stratum *f* as aproximately only 20 feet. The rocks composing this section did, however, not in any way agree with the description which LINDSTRÖM gave of his *f*-stratum. Without entering upon a closer account of this section on this occasion, its rocks and relatively poor fauna, it may only be mentioned that there are limestone strata, rich in *Stromatoporae*, at several levels within it, that near the bottom of the series a more or less marly stratum occurs, which distinguishes itself by its great quantity of *Spongiostroma Holmi* ROTHPL. and *Leperditia* cfr *phaseolus* HIS., and that the topmost part of the series is remarkable for a layer of 1 meter thick of stratified marl or marly limestone.

After attention had thus been drawn to this hitherto neglected part of the Silurian of Gothland, the author has succeeded in the subsequent years in rediscovering this series of strata in the Visby-district, and in following in the field not only its lower layers, prolific in *Spongiostroma Holmi* Rothpl., but also its topmost marl-seams, which, on account of their generally containing a lot of small *Leperditiae*, have provisionally been called *Leperditia*-shales. The remaining sections of this series are developed in a slightly different manner at different places. Limestones, with plenty of *Stromatoporae*, appear here and there, not only in the lower parts of the series, but also below the *Leperditia*-shale, where, however, as a rule, a lot of oolitic, fine-grained limestone-strata are lying, to which the name »brownish-yellow layers» (brungula lagren) has been applied as a field-term. Some Stromatoporan strata in the lower part are at times replaced by bituminous limestones (and marl-seams), with plenty of small Ostracoda, and some metres above the *Spongiostroma*-level there is at some places a marl-stratum rich in fossils, which is often in close connection with a crystalline Crinoid limestone.

The complex of strata just mentioned is found developed above the cliff along the west coast of northern Gothland from Tofta in the south to Fårösund in the north; it has for some distance been completely followed in its whole extent and surveyed, but some stretches are as yet only partly known. There is consequently no doubt as to the position of the strata in this part of Gothland.

The *Leperditia*-shales are, as mentioned, covered by *Megalomus*-bearing limestone. In the course of the survey work it has been shown that this rock is at several places replaced by reef-limestone, Crinoidlimestone and Cephalopodan limestone etc. occurring at the same level as this but with a different facies development.

This agrees so to say pretty nearly with Dames' conception of the conditions at this level. Bather too seems to have made observations pointing in the same direction.

This part of the upper Gothlandian is to be seen in the large areas of bare rock in the middle part of northern Gothland, from Stenkumla in the south to Follingbo—Hedeby—Bro—Othem—Slite and further northward.

When, in the eastern edge of this area, one gets down to nearly the oldest stratum, one must therefore in all probability meet with the topmost portions of the series of strata described above and which had previously been disregarded. This will certainly be done, although the series has here another petrographical development and a more abundant fauna, wherefore we are somewhat in doubt to start with. What we thus find is that LINDSTRÖM's Follingbo—Slite marl area (composed of marl strata in the upper part with an ever increasing alternation with limestone seams) rests directly below the *Megalomus*-level. That the Follingbo—Slite marl area ought therefore stratigraphically to be parallelized with the said series af strata, which contains more limestone, is a view to which the geological work of later years in northern Gothland has brought us, and which is at present being used as a working hypothesis. Certain characteristics of the fauna east and west of the *Megalomus*-bearing belt in the middle of northern Gothland indicate this. Amongst other things *Leperditia baltica* HIS. p. p. is being met with right from the super-imposed *Megalomus*-strata deep down into the series of strata lying below the *Megalomus*-horizon on either side of the belt just mentioned. This fossil has, on the other hand, not yet been met with in LINDSTRÖM's strata *b* to *d* (in the sections along the west coast).

As will be seen from the accompanying two maps of the ground rock of northern Gothland, the above sketched view differs to a considerable extent from LINDSTRÖM, whilst, to a certain extent, it agrees with that of SCHMIDT.

With the above has been said what most is important stratigraphically, and what has came to light in the course of the geological field-work in northern Gothland of late years. This work is, however, far from finished, and it might therefore be rather premature to parallelize more in details and to treat of the sections open in different places more minutely than what has been done.

That which causes difficulties in parallelizing the strata in Gothland at separate places is the circumstance of these often being developed in a different manner at the same level in the series of strata. It is not enough that the *rocks* are different and reflect the conditions existing in the Silurian sea; this difference from a petrographical point of view is also accompanied by a faunistic difference.

With regard to northern Gothland it is especially the reef-formations which play a predominant part at certain horizons, and which impress their character upon these. Already in the grey marl-shales or lower cliff level (II) small reefs occur, and in the upper portion of the coast sections (III) at Visby, the reefs are specially well developed and prominent, and sections in which the non-stratified reef-limestone is not visible at this level are easily counted. Reef-formations are also frequently found in those strata which belong to the upper Gothlandian. At the sides the reefs often pass over into conglomerate-like limestone or into Crinoid limestone, and at the same level as these there may besides appear pure marls or alternating strata of marl-shales and limestone; sometimes the rocks between the reefs consist of bituminous limestones (and marls), of oolitic limestone strata etc. If we therefore want to arrive anywhere with the study of the Silurian stratigraphy of northern Gothland it will be best to establish special sections whereever it is possible to do so. The sections obtained in this manner nearly always show some differences.

As LINDSTRÖM's scheme of the Gothland strata, as has been mentioned above, does not render the prevailing stratigraphical conditions in nothern Gothland, and can only be used for the lower portion of the Gothlandian in the Visby district, a new classification has to be made. As a consequence of the varying petrographical and faunistic conditions prevailing at the same level these can only in the second place be used as a basis for classifying the Gothland strata.

As an interim classification, and before the area has yet been fully investigated, the following scheme is being used for the survey work that is now going on in northern Gothland:

<table>
<tr><th colspan="6"></th><th>Correspon-dingdivisions in LINDSTRÖM'S scheme.</th></tr>
<tr><td rowspan="2">Upper Gothlandian.</td><td colspan="2">Genuine Upper Gothlandian.</td><td>VII. Non-stratified Reef-limestones or stratified layers such as Crinoid, Stromatoporan, Megalomus-, or Cephalopodan limestones etc.</td><td></td><td></td><td>f, g and h.</td></tr>
<tr><td>»Middle Gothlandian».</td><td>Western facies.</td><td>VI. Leperditia-shales.
V. Brownish-yellow, oolitic strata of limestone.
IV. b. Ostracodan limestone (bituminous) or marl-shales and Crinoid limestone.
a. Bottom-stratum with Stromatoporan limestone and Spongiostroma-layers.</td><td>Middle facies of marl-shales, at the top rich in limestone.</td><td>Eastern or Gothemfacies.</td><td>f, h, c and d (Slite-Follingbo marl.).</td></tr>
<tr><td colspan="3" rowspan="3">Lower Gothlandian.</td><td colspan="3">III. Upper cliff-level of varying composition in different localities. May be developed as reefs all through or only partially, but is sometimes quite absent. For different places opened out have been used by way of subdivision a for the lower, b for the middle and c for the upper part of the level.</td><td>d and e.</td></tr>
<tr><td colspan="3">II. Lower cliff-level. Grey marl-shales with irregular limestone seams, on top with small reefs.</td><td>c.</td></tr>
<tr><td colspan="3">I. Stricklandinia-marl (the shore belt north of Visby).</td><td>b.</td></tr>
</table>

In the Visby district (mainly north of Visby) a greater discordance in the sequence of strata has been noticed between the upper and the lower Gothlandian wherefore the most natural and greatest boundary between the strata ought to be located here.

On the occasion of the silurian-excursion planned to take place after the Geological Congress, when the Visby district is to be visited, the following places will especially be paid a visit:

The shore-belt north of Visby with the *Stricklandinia*-marl; the mountain-slope and quarries north and south ot Visby; the »Waterfall» section; and the sections in the neighbourhood of »Hallbro Castle» in Allehage in the parish of Vesterhejde, south of Visby. In this connection Högklint and the Nygård section at Fridhem will also be visited. As a guide on that occasion the following short data concerning these localities may be of use.

We may here call attention to Pl. 56, containing the named sections in the Gothlandian of the neighbourhood of Wisby, upon which the scheme above partly is based, and to Pl. 57 that represents as well the geological map of LINDSTRÖM as a sketch of the authors views on the stratigraphy of N. Gothland, as far as it can be advanced on the present stage of his work.

Stricklandinia-marl or the strata in the shore-belt north of Visby.

The name *Stricklandinia*-marl first used by LINDSTRÖM may be retained for the present, although the fossil which gave the stratum its name, is not met with everywhere in the minor layers of this horizon, but only in certain strata, where it is generally rather common and form real banks.

The *Stricklandinia*-marl forms the lowest accessible complex of strata of Gothland from Visby in the south to Hallshuk in the north, at which places it slopes down under the surface of the sea. Between these localities the upper limit of the stratum forms a very faintly curved, unevenly running arch, whose highest point observed — on the shore at the boundary between Lummelunda and Stenkyrka parishes — is about 9 metres above the sea. Besides this more connected extent the topmost portions of the stratum have been observed on the surface above sea level along the shore at scattered spots south of Visby, in the parishes of Vesterhejde and Tofta. Here the characteristic fossil *Stricklandinia lirata* Sow. has, however, nowhere been found.

From a petrographical point of view this horizon is composed of greyish-blue, stratified, loose marls with embedded nodules, slightly harder i. e. more calcareous, which partly lie in disconnected rows and may partly form real layers.

In the Visby district the formations belonging to the above are only in sight at the surface of the water and most easily accessible at low water. Originally they were covered with moraine-marl of the same kind as that which is being utilized at the Visby Cement Works, but through the erosion of the sea-waves all the clayey matter has been washed away, the smaller stones have been rolled into beach-gravel, whilst the larger blocks, which the water could not manage, were washed clean and left lying direct upon the solid *Stricklandinia*-marl. The shore to the north of Visby in consequence gets an appearance such as shown in the accompanying figure (see Pl. 58 b).

At Norderstrand, Talludden and the spit of land between Gustafsvik and Snäckgärdsviken the layers are usually accessible as solid rock, and to judge from the fossils, it is about the same horizon that is everywhere in sight. The list of fossils has the following appearance: *Encrinurus* sp., *Bumastus barriensis* MURCH. and *B.* sp., *Bronteus platyactin* ANG., *Leperditia*

Schmidti Kolm., *Primitia* sp., *Orthoceras* sp., *Trochoceras* sp., *Cyrtoceras* sp., *Comphoceras* sp., *Phragmoceras* sp., *Platyceras cornutum* His., *Bellerophon sphæra* Lm., *Tremanotus dilatatus* Sow., *Pleurotomaria qualteriata* v. Schloth., *Euomphalus gotlandicus* Lm., (closed form), *Horiostoma* cfr *Roemeri* Lm., *H.* cfr *globosum* v. Schloth., *Spirifera Marklini* Vern., *Sp. exporrecta* Wahl., *Nucleospira pisum* Sow., *Atrypa reticularis* L., *Pentamerus sphæra* Lm., *Stricklandinia lirata* Sow., *Rhynchonella Wilsoni*, var. *sphæroidalis* M'Coy, *Orthis Visbyensis* Lm., *O. hybrida* Sow., *O. Lovéni* Lm., *O. Davidsoni* Vern., *Strophomena rhomboidalis* Wahl., *Str. imbrex* Pand., var., *Str. Walmstedti* Lm., *Leptaena transversalis* Dalm., var., *Halysites catenularius* L., *H. escharoides* Lam., *Syringopora* sp., *Dinophyllum involutum* Lm., *Palaeocyclus porpita* L., *Pholidophyllum tubulatum* v. Schloth., *Goniophyllum pyramidale* His., *Heliolites interstinctus* L., *Stromatopora tuberculata* Nich., worm-tubes and a lot of undetermined bivalves.

On the outskirt of the beach south of Visby, below the Workhouse, there are some layers that might possibly be referred to the border-layers of this horizon towards those overlying. They contain thus fossils which, like *Spirifera Marklini* Vern., and *Strophomena Walmstedti* Lm., have by Lindström been reckoned as typical of his *b*- stratum (*Stricklandinia*-marl), besides such as *Rhynchonella borealis* v. Schloth. and *Strophomena Lovéni* Vern. which are by him referred to the nearest overlying section. The same is the case with the cliff south of Kopparsvik whilst the fossils of the *Stricklandinia*-marl, such as *Orthis Davidsoni* Vern., *Palaeocyclus porpita* L., *Strophomena Walmstedti* Lm., are met with higher above sea level in the lower portion of the rock laid bare in the marl of the Cement Works.

Profile of the »Waterfall».

The most complete and most easily accessible profile in the Visby district through stratified layers, belonging to divisions II and III in the lower Gothlandian is the one that is exposed in the so called »Waterfall» in »Pallisaderna» south of the town-wall (se Pl. 60 a and b).

In connection with some levelings taken by me, Mr G. Lilljevall made a carefull investigation of this profile in the year 1908, when stratum after stratum was examined from a faunistic point of view. A detailed account of the results of this work is being worked out by me, but is, through sickness intervening not finished. As a guiding summary of this work the following may here be mentioned with reference to attached detailed diagram of the sequence and nature of the strata (se section A on Pl. 56).

Nearest to the surface of the sea to 1 meter above it the strata are covered over by shingle, but from here and to a height of about 30 metres, except for a minor interruption, they have been accessible for observations in the solid rock.

II. Up to a height of about 10 metres above sea level there rests bluish-grey marl, the lower part indistinctly stratified and containing harder lumps of limestone interspersed in the bulk, on top better stratified trough an alternation of layers of a more compact rock richer in lime and layers of grey marl. (See Pl. 61). Here and there reef-forming corals and *Stromatoporae* are embedded; these increase in quantity towards the top and are at certain spots heaped up into real small reefs (see Pl. 60 b).

This part of the series of strata has here been designated as II and might be looked upon as in the main corresponding with Lindström's *c*-stratum as distinguished in the Visby-district. The list of fossils has the follow appearance:

Trilobitæ:

Phacops sp., *Deiphon* sp., *Encrinurus* sp., *Acidaspis Barrandei* Ang., *Calymmene* sp., *Proetus* sp., *Bumastus* sp.;

Ostracoda:

Beyrichia sp., *Primitia* sp.;

Annelida:

Annelidan jaws and bristles, *Tentaculites* sp.;

Cephalopoda:

Orthoceras sp., *Gomphoceras* sp., *Phragmoceras* sp.;

Gastropoda:

Bellerophon sphæra Lm., *Tremanotus dilatatus* Sow., *Pleurotomaria qualteriata* v. Schloth., *P. alata* Wahl., *P. undulans* Lm., *Murchisonia* sp., *Horiostoma Roemeri* Lm., *Cyclonema delicatulum* Lm.;

Brachiopoda:

Dinobolus Davidsoni Salter, *Lingula* sp., *Pholidops* sp., *Spirifera plicatella* L., *Atrypa reticularis* L., *A. imbricata* Sow., *Eichwaldia Capewelli* Dav., *Pentamerus sphæra* Lm., *P. galeatus* Dalm., *Rhynchonella borealis* Schloth., *R. cuneata* Dalm., *R. sphærica* Sow., *Orthis visbyensis* Lm., *O. hybrida* Sow., *O. Lovéni* Lm., *O. biloba* L., var. *verneuiliana* Lm., *O.* sp., *Scenidium* cfr *acutum* Lm., *Strophomena rhomboidalis* Wahl., *S. rugata* Lm., *S. Lovéni* Vern., *S. pecten* L., *S. imbrex* Pand. var., *Chonetes* sp., *Leptaena transversalis* Dalm.;

Bryozoa:

Crepipora lunariata A. Hennig, *Pachydictya macropora* Hng, *Phænopora* sp., *Fistulipora* sp., *Coenites repens* L., *Coenites* sp.;

Echinoidea:

Echinoidean thorns;

Anthozoa:

Calostylis denticulata Kjerulf, *Roemeria Kunthiana* Lm., *Pachypora lamellicornis* Lm., *Favosites Forbesi* Edw. H., *F. Fougti* E. H., *Heliolites interstinctus-decipiens* M'Coy, *H. spongodes* Lm., *Plasmopora calyculata* Lm., *P. scita* E. H., *Halysites catenularius* L., *H. escharoides* Lam., *Cyatophyllum mitratum* His., *C. calceoloides* Lm., *Dinophyllum involutum* Lm., *Syringopora* sp., *Ptychophyllum patellatum* v. Schloth., *Pholidophyl-*

lum tubulatum v. SCHLOTH., *Omphyma* sp., *Goniophyllum pyramidale* HIS., *Cosmiolitus halysitoides* LM., *Stromatopora tuberculata* NICH., *S. typica* NICH. a. o.

III. Border strata. Between 10 and about 13 m. above the sea there rests a fairly coarse-crystalline, yellowish-grey limestone, partly composed of Crinoid gravel and water-worn fossils, sometimes a real Crinoid limestone. In some of the coast sections this limestone is absent, but is always developed as soon as reef-formations appear at the same level, and is the more distinctly marked with thicker limestone banks, the bigger and more numerous the reefs are. The layers on top of the reefs incline outwards from these while the layers below the reefs dip down under them. This stratum is the in many instances very good to serve as a guiding and indicating stratum because, when developed, it appears within section III on its boundary towards II. The fossil list looks as follows:

Trilobitæ:

Phacops Stokesi MILNE EDW., *Encrinurus punctatus* WAHL., *Trochurus* sp., *Deiphon* sp., *Lichas* sp., *Calymmene* sp., *Phaëtonides* sp. (*rugulosus* LM?), *Bumastus* sp.;

Ostracoda:

Beyrichia sp., *Primitia* sp.;

Annelida:

Tentaculites sp., *Annelidan* jaws;

Cephalopoda:

Orthoceras sp.;

Gastropoda:

Bellorophon sphæra LM., *Pleurotomaria alata* WAHL., *Horiostoma globosum* v. SCHLOTH;

Pelecypoda:

Pterinea sp.;

Brachiopoda:

Dinobolus Davidsoni Salter, *Pholidops* n. sp., *Spirifera plicatella* L., *Athyris? læviuscula* Sow., *Nucleospira pisum* Sow., *Atrypa reticularis* L., *A. imbricata* Sow., *A.? Angelini* Lm., *Eichwaldia Capewelli* Dav., *Rhynchonella borealis* v. Schloth., *R. diodonta* Dalm. (small form), *R. sphærica* Sow., *R. exigua* Lm., *R. cuneata* Dalm., *Scenidium acutum* Lm., *Orthis visbyensis* Lm., *O. hybrida* Sow., *O. biloba* L., var. *verneuiliana* Lm., *O. punctata* Vern., *O. biforata* Vern., *Streptorhynchus nasutus* Lm., *Strophomena rhomboidalis* Wahl., *S. imbrex* Pand., var., *S. rugata* Lm., *S. pecten* L., *S. Lovéni* Vern., *Leptæna transversalis* Dalm., *Chonetes* sp.;

Bryozoa:

Fenestella sp., *Ptilodictya* sp., *Crepipora lunariata* Hng.;

Crinoidea:

Callicrinus costatus His.;

Anthozoa:

Calostylis denticulata Kjerulf, *Favosites* sp., *Heliolites interstinctus decipiens* M'Coy, *H. interstinctus* L., *Plasmopora scita* E. H., *Propora tubulata* Lonsd., *Halysites catenularius* L., *Thecia Swinderenana* Goldf., *Lindströmia Dalmani* E. H., *Pholidophyllum tubulatum* v. Schloth.;

Stromatoporidæ:

Stromatopora sp.

The subsequent series of strata from about 13 to 29,6 *m* above sea level may, on account of its petrographical nature, be divided into three parts passing into each other without any sharp demarcation, viz a lower part (from about 13 to about 20,5 *m* above sea level) chiefly composed of grey marls interstratified with disconnected irregular seams and lumps richer in lime, a middle part (from 20,5 to about 24,5 *m* above sea level) composed of grey marly shales in more regular alternation with more distinctly marked, thicker and more compact limestone-seams, and an upper part (from 24 *m* to 29,6 *m* above sea level) formed of stratified limestones almost without intermediate marl layers. These limestones are in their lower part oolitic and become gradually coarser and at the same time nodulous and conglomerate-like towards the top. Several of the layers in this upper part have a diagonal cleavage which upon the surface of the layer manifests itself in the shape of tracks like the ripple of waves.

From a faunistic point of view there does not appear to be any very great dissimilarity between the different parts of the series of strata. *Atrypa? Angelini* LM. occurs throughout it beginning in the previously mentioned border stratum. It should, however, be mentioned that *Orthis basalis* DALM. seems principally to be confined to the layers at a level of 13 to 14 *m* above sea level, whilst *Rhynchonella nucula* SOW. together with a lot of characteristic species of *Strophomena* appear first in the middle and upper, calcareous and oolitic layers. As to recognizable layers within the series of strata may be mentioned that at 17 *m* above sea level there occurs a characteristic, loose, more easily disintegrated marl stratum (Pl. 60 a.) and that at 24,1 *m* above sea level there is a layer distinguished by its plenitude of *Atrypa reticularis* L. The list of fossils has the following appearance:

Trilobitæ:

Phacops Stokesi M. EDW., *Ph.* sp., *Encrinurus punctatus* WAHL., *Acidaspis Barrandei* ANG., *Trochurus* sp., *Calymmene tuberculata* BRÜNNICH, *Proetus granulatus* LM., *P. signatus* LM. *Illænus* (*Bumastus*) sp., *Phaëtonides rugulosus* LM.;

Merostoma:

Pterygotus (20,1—20,2 *m* above sea level;

Ostracoda:

Beyrichia sp. *Primitia* sp.;

Cirrhipedia:

Turrilepas sp.;

Annelida:

Annelidan jaws and bristles, *Tentaculites* a wide sp.;

Cephalopoda.

Orthoceras sp., *Ophidioceras* sp., *Gomphoceras* sp., *Cyrtoceras* sp.;

Pteropoda:

Conularia cancellata SANDB., *C. lævis* LM., *C. bilineata* LM., *C.* sp.;

Gastropoda:

Platyceras cornutum HIS., *Bellerophon sphæra* LM., *B. globulus* LM., *Tremanotus* sp., *Pleurotomaria limata* LM., *P. alata* WAHL., *P. Lloydi* SOW., *Murchisonia attenuata* HIS., *M. cingulata* HIS., *Loxonema* sp., *Horiostoma discors* SOW., *H. Roemeri* LM., *Cyclomena striatum* HIS.;

Pelecypoda:

Pterinea sp., *P. demissa* CONR.?, *Cypricardinia*, sp., *Ambonychia* sp., *Goniophora cymbæformis* SOW., *Grammysia* sp.;

Brachiopoda:

Lingula sp., *Discina* sp., *D. striata* SOW?, *D.* sp., *Pholidops* sp., *Spirifera plicatella* L., var., *S.* sp., *S.* sp. (a little, close-striated species), *Meristina didyma* DALM., *M.* sp., *Atrypa reticularis* L., *A. imbricata* SOW., *A.? Angelini* LM., *Eichwaldia* n. sp., *E. Capewelli* DAV., *Pentamerus* sp., *Rhynchonella borealis* v. SCHLOTH., *R. cuneata* DALM., *R. nucula* SOW., *R. sphærica* SOW., *R. diodonta* DALM., *Eatonia* sp., *Scenidium acutum* LM., *S.* sp., *Orthis basalis* DALM., *O. hybrida* SOW., *O. biloba* L., var. *verneuiliana* LM., *O. punctata* VERN., *O. biforata* VERN., *O.* sp., *Stropho-*

mena rhomboidalis Wahl., *S. imbrex* Pand., var., *S. pecten* L., *S.* sp., *S.* n. sp., *Leptæna transversalis* Dalm., *Chonetes striatella* Dalm.;

Bryozoa:

Fenestella reticulata His., *F.* sp., *Ptilodictya lanceolata* Goldfuss., *P. flabellata* Eichw., *P. triangularis* Hng. *Crepipora* sp.?, *Vincularia* sp.;

Echionoidea:

Echionidean thorns;

Crinoidea:

Eucalyptocrinus ovatus Ang., *Callicrinus Sedgwickianus* Ang., *Herpetocrinus convolutus.*;

Anthozoa:

Favosites gotlandicus L., *F.* sp., *Heliolites (interstinctus), decipiens* M'Coy., *H. decipiens* M'Coy., *Halysites catenularius* L., *Zaphrentis? vortex* Lm., *Z. conulus* Lm., *Cyathophyllum calceoloides* Lm., *Lindströmia Dalmani* E. H., *Acervularia* sp., *Pholidophyllum tubulatum* v. Schloth.;

Graptolithæ:

Monograptus sp.;

Stromatoporidæ:

Stromatopora sp., *Solenopora* sp.

At 29,6 to 30 *m* above sea level there rests in the section a complex of layers consisting of marl-shales and limestones, of a grey, red or black colour, most often quite pronouncedly bituminous. This small part of the series of strata has by Lindström been singled out as a separate stratum, the *Pterygotus*-stratum, and what has made the section of the »Waterfall» most famous is the discovery of a scorpion, *Palæophonus nuncius* Thor. & Lm. at this spot. The most characteristic fossils in these strata are *Pterygotus osiliensis* Fr. Schmidt, *Conularia aspersa* Lm. and two species *Eatonia*, Furthermore the following fossils have been found: *Encrinurus punctatus* Wahl., *Phacops Musheni* Salter., *Ph. Downingiae* Murch., *Calymmene tuberculata* Brünn., *Phaëtonides Stokesi* Murch., *Lichas ornatus* Ang., *Leperditia* (a small species), and a lot of small *Ostracoda*, *Beyrichiæ*, *Entomis* etc., *Conularia lævis* Lm., *Discina* sp., *Spirifera plicatella* L. *Athyris*(?) *læviuscula* Sow., several species of *Strophomena*, one Crinoid, *Thecia Swinderenana* Edw. & H. and *Acervularia luxurians* Eichw., as well as plenty of Annelidan jaws.

To detach this stratum as a separate section from the remaining part of horizon III in the »Waterfall» on account of the petrographical dissimilarites of this »*Pterygotus*-layer», does not seem feasible, as a similar petrographical development of the rocks occurs already at the beginning of horizon III at other localities, for example in the coast-sections in the parishes of Lummelunda and Stenkyrka. Nor is it possible to keep the »*Pterygotus*-stratum» apart on faunistic grounds, inasmuch as even in the »Waterfall» as well the *Pterygotus* as one of the *Eatoniae* are now found at lower levels. For the present it might therefore be best to leave a division of horizon III alone until some more facts and data for the elucidation have been gathered.

IV. The *Pterygotus*-stratum is covered by a conglomerate with water-worn gastropoda such as *Trochus*, *Pleurotomaria* etc. and which besides contain portions of *Spongiostroma Holmi* Rothpl.

This conglomerate layer reminds us in certain respects of the discordance-layer in Lindström's old quarry to the south of Gustafsvik (see below) and belongs, with pretty great certainty, to the same level as that, i. e. to the bottom of horizon IV. Higher up in the channel of the »Waterfall» there is a limestone bank with large *Stromatoporae;* this too belongs to horizon IV. The section here illustrated does not reach so far up as the last mentioned layer.

The Cliffs North and South of Visby.

It is more rarely that horizon III in the Visby district is developed in the form of stratified rocks. Besides in the »Waterfall» just described there occur stratified rocks at this level in a profile that somewhat differs from the profile of the »Waterfall» and is accessible in the Nygård stream at Fridhem to the south of Visby.

In most instances a part, often the greater part or the whole of horizon III is developed in the shape of non-stratified reef-limestone. From Galgberget (Gallows Mountain) northward to Korpklint and from the »Waterfall» southward past Kopparsvik such is the case, and in the town of Visby itself there lies the reef-excrescence of Kyrkberget (Church Hill) or »Klinten».

In the vicinity of Visby the reefs are comparatively large, stretching in a horizontal direction often for $^1/_2$ or 1 kilometre. A few Swedish miles (1 Swedish mile = 10 *km.*) to the north of Visby in the parishes of Lummelunda and Stenkyrka the reefs are very much smaller, forming the steep, small cliffs prominent in the coast sections, whilst the outlines of the coast in the stratified layers lying between the reefs are cut in the form of an arch towards the land. (This is also seen in fig. 1 from Högklint, S of Visby.)

The reefs are composed of non-stratified accumulations of chiefly *Stromatoporae*, in addition to which there occur, but less plentifully, some corals of the genera *Halysites*, *Heliolites*, *Favosites* etc., as well as some Bryozoaries etc (fig. 2.) The marl nests occurring in the reefs are frequently paying lodes for fossils. Here one may thus find Crinoid crowns, Gastropoda, Brachiopoda etc.

The reefs can show a lot of particularly beautiful erosion phenomena. Almost exclusively confined to the reefs are the »raukar» or stone giants characteristic of Gothland, wherefore the reef-limestone has also been called »rauk»-limestone;

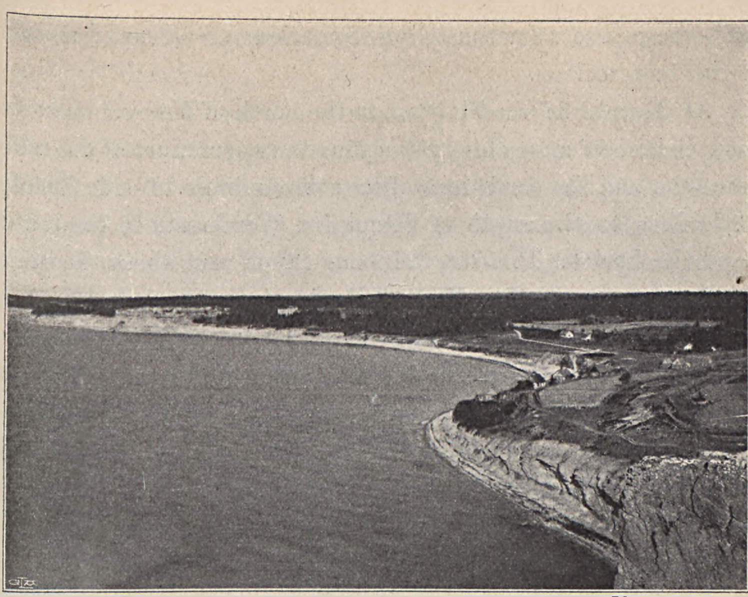

Photo G. HOLM.

Fig. 1. View from Högklint towards the north (Fridhem). The shore precipice is formed of the lower cliff horizon (II), except at the cliff visible in the back-ground where also the upper cliff-horizon, the reef-limestone is visible.

Photo G. HOLM.

Fig. 2. Detail of the reef-limestone from the reef at Högklint.

furthermore the numerous cave formations are situated mostly in the reef-horizon.

At Korpklint (see Pl. 58 a), to the north of Visby, one has a good chance of more closely studying the appearance of the reef-limestone and the conditions of its surroundings. Inside Snäck-gärdsviken to the south of Korpklint there rests in the lower slope the horizon II with the same fauna and about the same development as in the »Waterfall», i. e. grey marl-shales with more calcareous lumps and seams embedded, in the upper part here and there with minor reef-excrescences. Close to and on top of these minor reefs are lying more regular limestone-seams, which towards Korpklint in the north become rich in Crinoid fragments and increase in thickness, thus forming a real Crinoid limestone. The Korpklint-reef itself rests for the greater part upon these thick Crinoid limestone banks, which form the border-layers between horizons II and III, in which horizon the reef-formation is to be included. At Korpklint the entire horizon III, but to the north and south of Korpklint only the upper part of horizon III is developed as reef-limestone. Conditions analogous with Korpklint exist at Högklint, Galgberget (Pl. 59 etc.)

The lower part of the reef is thus equivalent to the Crinoid limestone nearest to the reef, further away from the reef there occur fine to dense, flakey limestones and finally marl-shales with limestone-seams (LINDSTRÖM's horizon *d* in the Visby district). The middle and upper parts of the reefs are replaced by conglomerate-like and oolitic limestones, or by bituminous limestone and marl-layers which may commence already directly upon horizon II. The last mentioned formation is especially well developed in the Lummelunda—Irevik area fig. 3 (to this belongs also the *Pterygotus*-stratum of the »Waterfall») and the oolitic limestone-facies may for example be observed in the quarries at Galgberget, to the north of Visby, at the limestone-quarry belonging to the Cement Works, and in the old quarries south-east of the Hospital, to the south of Visby.

At the last mentioned places portions of horizon IV are also visible. In LINDSTRÖM'S old quarry in the rock precipice south of Gustafsvik there appear at the limit between divisions III and IV a greyish-green, thin marly and gravelly, water-worn layer, containing, amongst other things, worn Gastropoda of the genera *Trochus*, *Pleurotomaria*, *Horiostoma* etc. This layer rests upon an oolitic limestone be-

Photo G. HOLM.

Fig. 3. Irevik, western side.

longing to horizon III cutting off the strata of the latter. (See section B 1 on Pl. 56.) There is thus a discordance marked here between horizons III and IV, (see fig. 4.) a discordance which is still more prominent in old quarries to the north-east of Skälsö. On top of the border-layer mentioned there rest some more or less marly limestone layers, remarkable for their abundance of *Spongiostroma Holmi* ROTHPL. and *Leperditia phaseolus* HIS., besides which there occur, in more exceptional instances, small Ostracoda (*Beyrichia* sp.) and small Gastropoda (*Holopea* sp.) in the marly seams. Certain layers are rich in *Stromatoporae* and form Stromatoporan limestone.

The layers with *Spongiostroma Holmi* Rothpl. are particularly characteristic guiding layers and may be followed along the whole of the cliffs of the Visby district, now rising to this precipice, now departing from the same. In the quarries at Bingerskvarn, to the north of Visby, and in the old quarries south-east of the Hospital, to the south of Visby, they are especially typical. (See sections B. 3 and B. 4 on Pl. 56). At the last mentioned place we get a trifle higher in the series of strata, inasmuch as the layers with *Spongio-*

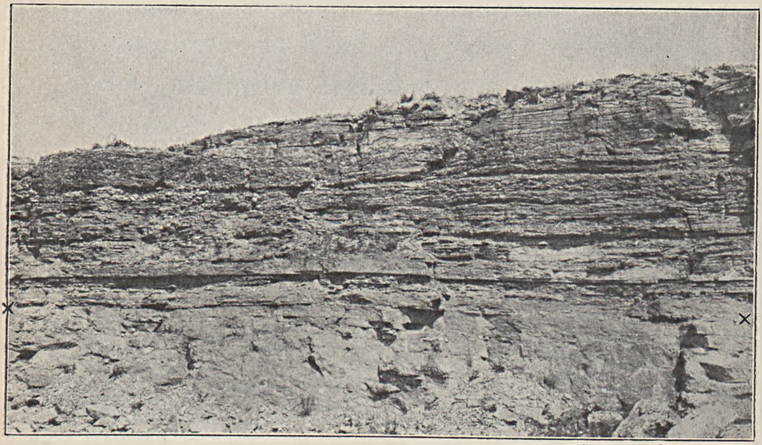

Photo by the author.

Fig. 4. Section in an old quarry (Lindström), S. of Gustafsvik, showing uppermost the horizon with *Spongiostoma Holmi* Rothpl. (IV a), below there rests oolitic limestone, belonging to the upper part of the lower cliff level. Between the two white crosses runs the line of discordance between these two horizons.

stroma Holmi Rothpl. are covered by an Crinoid limestone, which is in close connection with the appearance of a marl relatively rich in fossils and the occurrence of reefs. It has also been shown that this horizon, the upper part of horizon IV, is of a varying nature at different places.

The fossils most characteristic of the marl just mentioned are: *Rhynchonella nucula* Sow., *R. diodonta* Dalm., *Orthis biforata* Vern., *Spirifera* (2 species), *Atrypa reticularis* L., *A.*

imbricata Sow., var. *lamellosa* Lovén, plenty of *bryozoan* fragments, *Athyris laeviuscula* Sow., *Favosites Forbesi* Edw. H. etc.

»Hallbro Castle Hill.»

The continuation upward of the strata just mentioned may in the Visby district best be studied at »Hallbro Castle Hill» in Allehage, in the parish of Vesterhejde, south of Visby. (See sketch-map, fig. 5). The profile-series C 1 to C 8

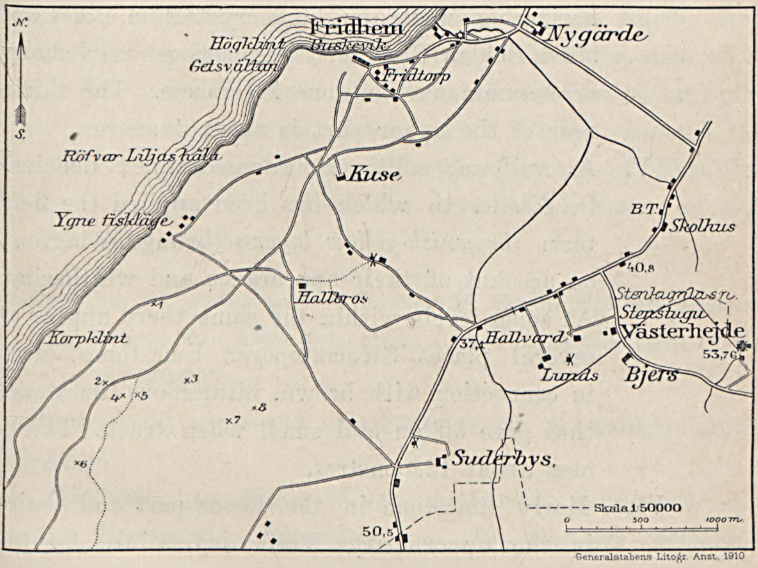

Fig. 5. Sketch-map of Hallbro »Castle Hill», parish of Vesterhejde. The figures refer to the sections C 1 to C 8 on Pl. 56.

originates from places that are situated comparatively close to each other on the northern part of the hill. The thickness and position of the various layers to each other are determined by levellings and measurements to the *Spongiostroma*-horizon on the one side, on the other side to the upper parts of the *Leperditia*-shales. By uniting the different minor sections the following series of strata is obtained:

Lowest **IV.** The lower part consists of marl and limestone with a lot of *Spongiostroma Holmi* Rothpl stuck in it, which in its turn rests upon a transition layer and the Lower Gothlandian complex of strata, which is everywhere well exposed in the coast sections from Högklint southward to Tofta. The thickness of the *Spongiostroma*-layers may be estimated at 4 to 5 metres.

The upper part of this horizon is of a different petrographic (and faunistic) character at different places. Sometimes there rests upon this horizon a white or blue crystalline limestone often rich in Brachiopoda, sometimes marl-shales or bituminous limestone layers etc. The thickness of the upper part is about 4 metres.

V. A uniform, oolitic limestone-complex deficient in fossils, to which has been applied the field term »*brownish-yellow layers*» (brungula lagren), on account of their appearance and weathering. At some levels within the same there appear at several places Stromatoporan limestones, often in connection with brown, bituminous limestones that give off an evil smell when struck. Thickness about 12.0 metres.

VI. Marly limestone in the lower part and shales in the upper part. These layers are for the present comprehended under the name *Leperditia*-shales. Thickness about 1.8 metre.

This *Leperditia*-shale is quite a constant and typical guiding layer, and has also been used as such on the occasions of the geological field work.

On top **VII.** *Megalomus*-bearing limestone, often deficient in or without *Megalomus*, whose appearance is due to the nature of the rock; may partly be developed as Crinoid limestone and shales, partly as reefs. This *Megalomus*-horizon occupies stratigraphically the same position as the *Megalomus*- and Cephalopoda-bearing layers at the railway between Visby and Storvede known of old.

The complexes of horizon IV to VII described above could, as has been stated, be followed above the edge of the cliff partly in a connected whole, partly in scattered bare rocks, from the parishes of Westerhejde and Tofta in the south right up to Fårösund in the North. Exposed rocks of not only IV *b* but also of V and VI have thus been observed at several places east of the town of Visby, between the town and the limestone-plateau of Skrubbs-Österby, where the layers VII, known of old, are found.

Fossils from the lower part of horizon IV (IV a) »Hallbro Castle».

Leperditia cfr *phaseolus* His., *L.* sp., *Spongiostroma Holmi* Rothpl.

Fossils from the upper part of horizon IV (IV b) »Hallbro Castle».

***Trilobitae*:**

Encrinurus punctatus Wahl., *Lichas* sp., *Calymmene* sp., *Proetus* sp., *Bumastus* sp., *Bronteus* cfr *polyactin* Ang.

***Ostracoda*:**

Leperditia sp., *Primitia* sp.

***Gastropoda*:**

Pleurotomaraia alata Wahl.

***Pelecypoda*:**

Cypricardinia cfr *lammellosa* Lm. in museo.

***Brachiopoda*:**

Spirifera sp., *Meristina didyma* Dalm., *Atrypa reticularis* L., *A. imbricata* cfr var. *lamellosa* Lovén., *Rhyn-*

chonella diodonta Dalm., *R. nucula* Sow., *R. borealis* v. Schloth., *Eatonia* sp., *Orthis biforata* Vern., *Strophomena rhomboidalis* Wahl., *S. funiculata* Mc Coy.

List of fossils from V »the brown-yellowish layers» at »Hallbro Castle».

Trilobitae:

Phaëtonides sp.

Ostracoda:

Leperditia baltica His. p. p.

Gastropoda:

Pleurotomaria cfr. *robusta* Lm., *Murchisonia moniliformis* Lm., *M.* sp., *Horiostoma globosum* v. Schloth.

Pelecypoda:

Pterinea cfr *retroflexa* Wahl., *Goniophora* sp.

Brachiopoda:

Spirifera sp., *Strophomena* (several species).

List of Fossils from VI Leperditia-schists at Hallbro Castle.

Ostracoda:

Leperditia baltica His. p. p., *L.* sp. (some small forms).

Gastropoda:

Tremanotus sp., *Murchisonia* cfr *cingulata* His., *Pycnomphalus acutus* Lm., *Horiostoma discors* Sow., *H. globosum* v. Schloth., *H. acutum* Lm., *H. angulatum* Wahl.

Brachiopoda:

Spirifera sp. and a smooth, glossy brachiopod.

Anthozoa:

Favosites Forbesi Edw. H.

Stromatoporidæ:

Stromatopora sp.

List of Fossils from VII (the Megalomus horizon) at »Hallbro Castle».

Trilobitae:

Phacops sp., *P. imbricatula* Ang., *Deiphon* sp., *Encrinurus punctatus* Wahl., *Lichas* sp., *Trochurus* sp., *Calym-*

mene sp., *C. tuberculata* Brünnich., *C. spectabilis* Ang., *Phaëtonides* sp., *Proetus* sp., *Bumastus* sp.

Ostracoda:

Beyrichia sp., *Leperditia baltica* His. p. p.

Annelida:

Tentaculites sp.

Cephalopoda:

Orthoceras sp., *Phragmoceras* sp., *Cyrtoceras* sp.

Pteropoda:

Conularia sp.

Gastropoda:

Platyceras cornutum His., *P. cyathinum* Lm., *Bellerophon globulus* Lm?, *B. squamosus* Lm?, *B. trilobatus* Sow., *Tremanotus* sp., *Pleurotomaria Lloydi* Sow., *P. bicincta* Hall, *P. æquilatera* Wahl., *P. alata* Wahl., *Murchisonia* sp., *Loxonema* sp., *Trochus cavus* Lm., *Horiostoma globosum* v. Schloth, *H. caronatum* Lm., *H. acutum* Lm., *H. angulatum* Wahl., *Holopea* sp., *Holopella* sp.

Pelecypoda:

Conocardium sp., *Megalomus* sp., *M. gothlandicus* His.

Brachiopoda:

Monomerella sp., *Trimerella* sp., *Discina* sp., *Spirifera plicatella* L., *S.* sp., *S.* n. sp., *Atrypa* sp., *A. reticularis* L., *A. imbricata* var. *lamellosa* Lovén, *Pentamerus galeatus* Dalm., *Rhynchonella nucula* Sow., *R. borealis* v. Schloth, *R. diodonta* Dalm., *R. Wilsoni* Sow., *R.* sp., *Orthis elegantula* Dalm., *O. biforata* Vern., *Strophomena rhomboidalis* Wahl., *S.* sp., *Chonetes* sp.

Bryozoa:

Ptilodictya lanceolata Goldfuss.

Anthozoa:

Favosites Forbesi Edw. H., *Halysites catenularius* L., *H.*

escharoides Lamarck., *Thecia* sp., *Zaphrentis conulus* Lm., *Z.* sp.

Graptolithæ:

Monograptus sp.

GEOLOGISKA FÖRENINGENS

I STOCKHOLM

FÖRHANDLINGAR.

BAND 32. Häftet 6. **November 1910.** N:o 272.

Mötet den 3 november 1910.

Antal närvarande 30.

Ordföranden, hr Högbom, hälsade Föreningens ledamöter välkomna till det första sammanträdet för vintern.

Härefter meddelades, att sedan maj-mötet aflidit ingeniörerna A. von Mickwitz, Reval, och A. Lundblad, Stocksund.

Till nya ledamöter hade Styrelsen invalt:

Ingeniören C. A. Falk, Ålsäng,
på förslag af hr W. Petersson,

Gårdegaren G. G. Bárdarson, Island,
på förslag af hr Holm,

Civilingeniören E. O. Engström, Stockholm,
på förslag af hrr J. G. Andersson och Wallén, samt

Fil. kand. G. Frödin, Upsala,
på förslag af hr A. G. Högbom.

Ordf. meddelade vidare,

att K. Maj:t den 14 maj 1910 beviljat Föreningen ett understöd af 750 kr. såsom bidrag till fortsatt utgifvande under året af Föreningens Förhandlingar, samt

att Föreningen genom Styrelsen framfört sina lyckönskningar per telegraf till d:r L. Holmström, Åkarp, samt personligen till d:r E. Erdmann, då dessa nyligen fyllde 70 år.

Framlades å Styrelsens vägnar det förslag, att första delen af stadgarnas § 8 lydande sålunda: »Ledamot, som på en gång erlägger afgift för *tio år* — —» måtte ändras till:

»Ledamot, som på en gång erlägger *150 kronor* — —». Förslaget bordlades till december-mötet.

Hr Holmquist höll föredrag *om den sörmländska granatgneisens petrografi och geologi.*

Föredr. redogjorde inledningsvis i korthet för äldre uppfattningar om granatgneisens geologi och framhöll, att man hittills allmänt ansett denna gneisbildning otvifvelaktigt vara af sedimentärt ursprung och att, sannolikt till följd häraf, densamma blifvit föga studerad. Under sina geologiska arbeten i Sörmlands kusttrakter hade föredr. för en del år sedan börjat syssla äfven med granatgneisen. Då så småningom studiet af bergarten utsträckts till att omfatta hela Södertörn, och exkursioner gjorts äfven inom västligare delar af Sörmland, visade det sig, att granatgneisen i flera afseenden var förtjänt af den allra största uppmärksamhet.

Den inom Södertörn med Vermdön och mellersta delarna af Sörmland så godt som allenarådande granatgneis-typen utmärkes af en stor grad af likformighet. Det är en heterogenkornig slirig gneis af mörk violettbrungrå färg, ständigt innehållande grofstruerade, sliriga ådror eller körtlar, mera sällan ögon, af ljust gulgrå fältspatmassa med kvarts. Den för bergartens igenkännande mycket karakteristiska violetta färgtonen härrör från fint inblandad *granat.* Detta mineral är äfven ofta tillstädes som stora korn eller kristaller, hvilka strimvis äro strödda i bergarten och ej sällan sitta inväxta uti de nämnda ådrorna. Rikedomen på granat är mycket typisk för hela granatgneisens gebit, och man finner detta mineral äfven i de sura, d. v. s. på mörka mineral fattiga bergartstyper, som i underordnad mängd förekomma inom dess område liksom ock i de större ansamlingar af grofkornig pegmatit (ej gångformig), som kunna påträffas där.

Jämte granat är *cordierit* ett i gneisen allmänt förekommande mineral, som stundom framträder makroskopiskt och sällan saknas i de mikroskopiska preparaten. *Sillimanit* har iakttagits i vissa prof från granatgneisområdet men torde ej tillhöra dess hufvudsakliga bergart. Detsamma gäller äfven *grafiten*, som dock är allmännare och stundom mycket rikligt förhanden. Den iakttages ofta uti den typiska granatgneisen vid mikroskopisk undersökning såsom silfverglänsande kristallblad och ses ej sällan makroskopiskt t. o. m. uti de ofvannämnda kvartsfältspat-ådrorna. Då den uppträder rikligt, är det såsom beståndsdel i *fahlbandslika* skikt eller zoner, som genomskära gneisen och äro att uppfatta såsom lokala förändringar af denna och alltså icke som inneslutna lager af annat ursprung än granatgneisen själf. Dessa bildningar — fahlband torde vara deras rätta beteckning — äro ock rika på kismineral, *svafvelkis*, *magnetkis*, och därför i bergytan starkt förvittrade och grusiga med rostiga och gröngula anflog.

Granatgneisen själf visar *aldrig någon verklig skiktstruktur*. Med hänsyn därtill, att denna gneis allmänt anses vara en sedimentgneis, är frånvaron af skiktstruktur anmärkningsvärd, ty då urbergets öfriga bergarter mestadels — äfven då de äro som kraftigast metamorfoserade — hafva i behåll en del primära, ännu igenkännliga strukturdrag, så kunde man naturligtvis hafva skäl att vänta, att granatgneisen någonstädes skulle visa dylika strukturrelikter. Såvidt föredr. funnit, är detta emellertid aldrig fallet. Men däremot innehåller granatgneisen *brottstycken* af leptitiska, amfibolitiska eller kvartsitiska gneiser, och dessa, i synnerhet de förstnämnda, äro ofta vackert skiktade. Sådana brottstycken hafva iakttagits och beskrifvits redan af L. PALMGREN,[1] och de iakttagas allmänt i skärningar i granatgneisen, t. ex. särdeles tydligt och vackert i järnvägsskärningarna emellan Nynäs och Nickstaviken.

I Södertörns kusttrakter, t. ex. på Gålö och i Dalarö skärgård, förekomma flerstädes otvifvelaktiga gneisgraniter, d. v. s. metamorfoserade graniter, hvilka innehålla granat

[1] Beskrifning till geologiska kartbladet »Årsta», S. G. U. N:o 50 (1874), sid. 18.

och äfven strukturellt närma sig den typiska granatgneisen. I de särdeles instruktiva skärningar, som finnas i granatgneis invid Nynäs Hafsbads anhaltstation, framträda strukturella drag, som påminna om de starkast deformerade gneisgraniternas, samtidigt som inneslutningar visa sig i bergartens massa. Strukturen är här, såsom oftast, starkt lineärt utvecklad.

Dessa under de fältgeologiska studierna allt klarare framträdande sakförhållanden hade kommit föredr. att tvifla på, att den gängse uppfattningen om den sörmländska granatgneisens ursprung var den riktiga, ehuruväl han från början fullständigt delat denna uppfattning. De nämnda sakförhållandena, granatgneisens homogenitet inom det vidsträckta området, bristen på relikta skiktstrukturer, den allmänna förekomsten af heterogena brottstycken af samma slags bergartstyper, som uppträda i de sammanhängande superkrustala stråken, och slutligen förekomsten af strukturtyper af intermediär ställning i förhållande till granatgneis och granatförande gneisgranit framkallade den tanken, att ifrågavarande granatgneis i självfva verket vore en starkt regionalmetamorfoserad granit.

Mot denna slutsats strede emellertid bergartens kända lerjordsrika sammansättning och halt af grafit. Vid en närmare granskning af förstnämnda förhållande hade föredr. kommit till den slutsatsen, att endast två analyser finnas, som med någon sannolikhet kunna anses representera den inom hufvuddelen af Sörmland rådande granatgneistypen. Dessa visade lerjordshalterna 15,70 och 14,69 %. En tredje analys, visande 19,22 % lerjord, är utförd af ett prof[1] från Skylvalla i Gåsinge socken, som dock ej fullt motsvarar den typiska granatgneisen. Ifrågavarande gneis håller alltså sannolikt 15 à 17 % lerjord, en halt som både uppnås och öfverträffas af många graniter.[2] Men härtill kommer, att denna lerjordshalt hos

[1] Rester af detta analysprof finnas förvarade i Geologiska Undersökningens museum.

[2] Se »Studien über die Granite von Schweden». Bull. of the Geol. Inst. of Upsala, Vol. VII, 1906.

granatgneisen motsvaras af en ganska låg alkalihalt (4 à 6 %) och en föga betydande kalkhalt (1 à 3 %), hvilket är afsevärdt mycket mindre än de motsvarande halter, som utmärka friska graniter. Det måste därför medgifvas, att den typiska granatgneisens kemiska sammansättning, enligt de båda anförda analyserna, är mera öfverensstämmande med en lerbergart än med en granit. För att undgå den motsägelse, som alltså förefinnes emellan otvetydiga fältgeologiska förhållanden och den kemiska sammansättningen, har man att efterse, huruvida ej den senare kan hafva blifvit påverkad af den kraftiga och säregna regionala metamorfos, som träffat bergarten. Utförda analyser af de kataklastiska bergarterna vid Torneträsk utvisa, att lerjordshalten hos dess sönderpressade och af epidot och klorit uppfyllda graniter och syeniter är ansenligt högre än hos de friska typerna. Å andra sidan visar sammansättningen af den blandade gången på Utöns östra strand,[1] att alkalihalten i denna starkt förskiffrade bergart blifvit i hög grad reducerad. De kataklastiska bergarterna i våra fjälltrakter hafva en mycket vidsträckt utbredning och ansenlig (hundratals meters) mäktighet, och det hade därför synts föredr. berättigadt att antaga, att vid vissa slag af regional metamorfos äfven betydande förändringar af eruptiva bergarters kemiska sammansättning kunna inträffa.

En annan fråga är, huru grafithaltens närvaro i granatgneisen skulle kunna förenas med det antagandet, att denna gneis till sin hufvudmassa vore en ortogneis, d. v. s. af infrakrustalt ursprung. Den allmänna vetenskapliga uppfattningen om grafitens bildning synes vara, att denna kan ske på flera helt olika vägar. En del förekomster af grafit hafva sålunda bildats genom metamorfos af bitumen- eller kolhaltiga lagerbergarter. Men grafit har äfven iakttagits såsom en primär beståndsdel[2] uti elæolitsyenit och i pegmatit samt före-

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[1] G. F. F. **32** (1910): 908, analystabellen, n:is 12, 13.

[2] F. W. Clarke: The Data of Geochemistry. U. S. G. Surv. Bull. **330**: (1908) 266.

kommer uti järnbasalten vid Ovifak och, enligt ÖBERG, uti Rådmansögabbron. Enligt STUTZERS öfversikt[1] äro de bekanta grafitförekomsterna vid Batugol i Sibirien att räkna som magmatiska och förekomsten på Ceylon såsom en gångbildning. Enligt WEINSCHENK äro de böhmiska och bayerska grafitförekomsterna att anse som från djupet härstammande pneumatolytiska impregnationer.[2]

Såsom redan framhållits, är sörmlandsgneisens grafithalt hufvudsakligen bunden vid fahlbandsartade förskiffringszoner i bergarten och uppträder i dessa fahlband tillsamman med kismineral. Det synes därför ingalunda oantagligt, att den kan ha bildats epigenetiskt, motsvarande WEINSCHENKS teori.

Hvarken i de kemiska förhållandena eller i förekomsten af grafit kan sålunda något ovedersägligt stöd vinnas för den meningen, att den sörmländska granatgneisen uppkommit på sedimentär väg, och därför bör den synpunkten icke tillmätas någon afgörande betydelse vid sidan af det sakförhållandet, att denna gneis i fält förhåller sig som en på inneslutningar rik granit, som undergått en synnerligen kraftig regionalmetamorfisk ombildning.

Med anledning af föredraget uppstod en liflig diskussion, i hvilken deltogo hrr BÄCKSTRÖM, HEDSTRÖM, G. DE GEER, GAVELIN, WALLROTH, HÖGBOM och *föredraganden.*

Hr BÄCKSTRÖM hade icke sett de af dr HOLMQUIST omnämnda skärningarna vid Nynäs men hade studerat skärgården och fastlandet kring Trosa, där såväl granatgneisen som de med densamma associerade leptiterna och kalkstenarna äro synnerligen väl blottade. Talarens intryck härifrån var beträffande granatgneisens utgångsmaterial, att detta haft en sedimentbergarts kemiska sammansättning och icke en magmabergarts, d. v. s. bestått af genom vittring förändrade mineral — samma uppfattning som de flesta andra urbergsgeologer, inklusive dr HOLMQUIST själf, också hittills haft. Beträffande metamorfosens art ville tal. säga, att han motsträfvigt gått med på den s. k.

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[1] Zeitschrift f. prakt. Geologie XVIII (1910): 10.

[2] Abhandlungen der Akademie der Wissenschaften, II Cl., XIX Bd, II Abt., München 1897.

franska skolans, hos oss af SEDERHOLM med så stor talang utvecklade uppfattning om kontaktmetamorfosens öfvergång på de stora djupen till en regional kontaktmetamorfos, om han än trodde, att den s. k. injektionen af granitiskt material oftast borde tolkas på annat sätt, samt att betydelsen af en insmältning af äldre bergarter i stor skala ännu icke vore bevisad. Härvid hade för tal. erfarenheterna från granatgneisen spelat en stor roll. Af allt hvad tal. sett motsvarade granatgneisen mest hans föreställning om huru en genom intensiv kontaktmetamorfos på stort djup förändrad sedimentärbergart, skulle se ut.

För att förklara motsatsen mellan granatgneisens förmodade karaktär af magmabergart och dess kemiska sammansättning hade dr HOLMQUIST framställt en teori, som tal. måste beteckna såsom äfventyrlig. Det strede emot all hittills vunnen erfarenhet, att en sådan genom tryckmetamorfos åvägabragt utlakning af alkalierna förekom annat än i jordskorpans öfversta delar, liksom äfven att den kunde ha en så regional karaktär.

Beträffande slutligen dr HOLMQUISTS uttalande, att det icke vore så säkert, att icke granatgneisen vore bildad på ringa djup, så trodde tal., att dr HOLMQUIST stode ganska ensam om en sådan uppfattning. De urbergsgeologer, som vi skatta högst, torde nog vara ense med tal. om att granatgneisen bär prägeln af en *djupmetamorfos.*

Hr. HEDSTRÖM hade icke funnit, att lektor HOLMQUIST i sitt föredrag alls hade berört kalkstenarnas uppträdande i granatgneisformationen, ett förhållande som väl icke helt och hållet bör förbigås vid ett försök till tolkning af granatgneisens genesis. Förekomsten af kalkstenar såsom större och mindre linser och mer eller mindre afbrutna lager i granatgneisen, sammanställd med de af föredr. nämnda för denna bergartskomplex egendomliga förhållandena, såsom befintligheten af partier (föredragandens »brottstycken») af en hel del olika, ofta till sitt ursprung superkrustala bergarter, gneisens växlande beskaffenhet på närliggande ställen, vidare dess stora lerjordshalt och från de vanliga graniterna afvikande kemiska och mineralogiska sammansättning i allmänhet, synes bestämdt tala mot, att granatgneisen är att uppfatta såsom en ortogneis.

För sin del hade tal. den uppfattningen, att hela denna bergartskomplex utgjordes af en blandning af ett flertal bergarter, hvilka genom en intensiv metamorfos (»ultrametamorfos») erhållit sin nuvarande beskaffenhet. Han ville sålunda icke förneka, att graniter kunna förekomma inom granatgneisen, sannolikt bör man väl vid ett noggrant studium kunna få fram verkliga granitiska partier (och möjligt vore, att hr HOLMQUIST stött på just sådana). Det syntes tal., som om de s. k. »brottstyckena» kunde tolkas på ett annat sätt, eller såsom kvarblifna, mindre metamorfoserade rester af den ursprungliga bergarten.

Tal. anmärkte slutligen, att han besökt en hel del kalkstens- och dolomit-förekomster inom granatgneisens utbredningsområde, t. ex. Vrå, Oaxen, flera förekomster i närheten af Trosa etc., och det vore väsentligen deras uppträdande och förhållande till sidostenen, som föranledt honom att för tolkningen af granatgneisen inom dessa trakter antaga en dylik intensiv regionalmetamorfos.

Hr G. De Geer hade i trakten af Fairhaven på Spetsbergen iakttagit icke obetydliga förekomster af kornig kalksten, omedelbart omgifna af granit, som kanske kunde tänkas hafva uppkommit af sedimentärt material, i hvilket fall sammansättningen ju därom borde kunna lämna upplysning. Att inom den kalkförande sörmlandsgneisen lika väl som inom järngneisen såväl sedimentärt som eruptivt material i följd af genomgripande metamorfos kunnat erhålla en gemensam och likartad tryckstruktur, vore nog hvad man kunde förmoda. Redan inom Södermalms område har man sedan många år kunnat öfvertyga sig om, huruledes tydlig granit gradvis öfvergår i tryckskiffrig gneis, hvaremot man naturligtvis ej utan vidare kan afgöra själfva materialets ursprungliga härkomst. I samband härmed framhölls, att denna gneisiga tryckstruktur icke hade något att göra med den smala hälleflintliknande brecciezon, som tal. för länge sedan påträffat utefter en spricklinje långs Lännerstaviken och Moranedet.

Hr Gavelin framhöll, att arkitekturen inom granatgneisområdet synbarligen erbjöde sådana analogier med arkitekturen inom gneisterritoriet längre söderut, inom södra delarna af Östergötlands och norra delen af Kalmar län, att det enas genesis nog finge tydas i öfverensstämmelse med det andras.

Inom det södra gneisområdet hade tal. funnit öfvervägande »intrusiva» relationer mellan de olika gneiskomponenterna, angifvande, att dessa befunnit sig i ett halfmagmatiskt och partiellt magmatiskt tillstånd, förrän de blifvit hvad de nu äro. Smärre relikta partier och brottstycken af bergarter, som petrografiskt öfverensstämma med leptiterna inom Åtvidaberg-Västervik-zonen, ett delvis förefintligt fältsammanhang mellan detta och gneisterritoriet samt Loftahammar-graniternas och grönstenarnas relationer till detta hade bibragt tal. den uppfattningen, att gneisområdet fått sina nuvarande väsentliga karaktärer genom *en till gränsen för återuppsmältning och partiell återuppsmältning drifven regional metamorfos af en äldre berggrund, som bl. a. inneslutit leptit, Loftahammar-granit samt gabbro och diorit.* Ett starkt stöd för denna uppfattning af gneisterritoriets bildningssätt utgjorde äfven den omständigheten, att tal. vid gränsen mellan den otvetydigt sedimentära kvartsit-leptit-serien och vissa intrusiv i densamma funnit bergartsassociationer utbildade genom »ultrakontaktmetamorfos», hvilka i smått uppvisade samma fenomen och relationer, som i större, regional skala förefunnos inom gneisterritoriet.

Denna sin uppfattning af det södra gneisterritoriets genesis ville tal. öfverföra äfven på det af föredr. skildrade granatgneisområdet.

Hr WALLROTH påpekade, att tillvaron af grafit i granatgneisen vore väl förenlig med antagandet, att gneisen vore af magmatiskt ursprung.

Hr HÖGBOM ville, med instämmande i hufvudsak i de invändningar mot föredragandens tolkning af granatgneisen, som nyss gjorts af hrr BÄCKSTRÖM och HEDSTRÖM, framhålla, att bergartens kemiska karaktärer: den låga alkalihalten, kisernas och grafitens fahlbandsartade förekomst, inlagringarna af kalkstenar och amfibolitiska skiffrar m. m. vore vida mera förenliga med dess tolkning som en paragneis än som något slags orthogneis. Det vore visserligen sant, som föredr. påpekat, att man hade mycket få kemiska analyser af bergarten — något som väl närmast berodde därpå, att den på grund af sin ytterliga inhomogenitet vore föga tacksam som analysobjekt — men den mineralogiska sammansättningen, med den ofta höga halten af cordierit, granat och sillimanit, gåfve tillräckligt tydliga vittnesbörd om dess para-karaktär. Då bergarten ansetts såsom derivat af ett verkligt lerartadt urbergssediment, så har man naturligtvis ej därmed förnekat, att den kunnat vara i hög grad inmängd med intrusivt eruptivt material. Utan att behöfva betrakta alla de mera saliska grofkristalliniska komponenterna i den inhomogena blandningsbergart, som granatgneisen är, såsom odisputabla granitiska intrusioner, torde man dock kunna antaga, att sådana spela en mycket viktig rol såsom en sorts inslag i den väfnad, hvars botten utgöres af det sedimentära materialet. Föredraganden hade i frånvaron af skiktstruktur sett ett argument mot bergartens sedimentära härledning. Häremot kunde invändas, att om bergarten varit ett ler-sediment, den eventuellt förefintliga skiktbyggnaden genom de starka metamorfiska processerna kunnat förstöras, såsom ju fallet är i regel i t. ex. glimmerskiffrar. I själfva verket torde, frånsedt det injicierade materialet, bergarten närmast motsvara en glimmerskiffer eller glimmerskifferartad leptit utaf den karaktär, som utmärker de, så att säga, relikta brottstycken, som så allmänt förekomma i de pegmatitartade sliriga utbildningsformerna af bergarten. Föredraganden hade framhållit bergartens homogenitet i stort sedt. Det bör dock härtill anmärkas, att flerestädes det intrusiva och kanske delvis äfven sekretionsartade inslaget af grofkristalliniska kvarts-fältspatblandningar träder tillbaka och att bergarten då antar mera leptit- eller glimmerskifferartadt utseende (t. ex. »granulitartad gneis» på TÖRNEBOHMS kartor). Granatgneisen torde vara genetiskt närmast att jämföra med en del ådergneiser, t. ex. de ångermanländska (»Hernögneisen»), som endast äro genom en intensiv granitinjektion omvandlade glimmerskiffrar och mörka leptiter.

Den af föredr. särskildt betonade granathalten i vissa med granatgneisen förbundna pressade granitiska bergarter vore icke något argument för den förres härledning ur en granit. För att komma till det resultat, att granatgneisen vore ett derivat af granit, har föredr. måst gripa till den mycket vågade hypotesen, att hela denna gneisarea genom någon utlakningsprocess blifvit beröfvad en god del af sin alkalihalt, och att dessa utlakade alkalier nu troligen vore att återfinna i skärgårdens pegmatiter! Att som föredr. öfverföra de till tektoniska störningszoner (glidplan, öfverskjutningsplan o. d.) begränsade kemiska omsättningarna på bergartsmassor af hundratusentals kubikkilometer är dock väl bra nog starkt. Ett sådant betraktelsesätt förefaller åtminstone åtskilligt mera äfventyrligt än det som i granatgneisens nuvarande kemiska karaktärer tycker sig kunna spåra något af dess ursprungliga natur af lersediment.

I sitt svar på de gjorda invändningarna framhöll hr HOLMQUIST nödvändigheten af att beträffande granatgneisen icke lita till vare sig allmänna teorier eller gängse föreställningar. Det vore nödvändigt att grunda uppfattningen af detta intressanta komplex på mer ingående fältiakttagelser än som hittills i detta fall förekommit. Gent emot dr HEDSTRÖM framhöll föredraganden, att kalkstenarna liksom ock de inom granatgneisområdet förekommande järnmalmerna kunna uppfattas såsom af den ursprungliga graniten omslutna superkrustala bildningar. Föredraganden hade funnit, att normala leptitgneiser åtföljde nämnda järnmalmer och erinrade om, att dylika på samma sätt i mellersta Sverige omslutas af graniterna. Det vore alldeles missledande, att såsom hrr HÖGBOM och HEDSTRÖM ville, beteckna kalkstenarna såsom inlagringar i granatgneisen. Föredraganden bestred vidare påståendet, att granatgneisen stode i något genetiskt samband med glimmerskiffrar och leptiter. Denna uppfattning, till hvilken äfven föredr. ursprungligen anslutit sig, hade visat sig vara ett misstag, ity att dylika bergarter alltid med skarpa gränser äro skilda från den typiska granatgneisen. Beträffande den metamorfos, som präglat granatgneisen, ville föredraganden framhålla, att de stora tektoniska linjernas förlopp inom det uppländska och sörmländska kustlandets berggrund angifver, att exceptionella regionala förhållanden här utvecklat sig, hvilka åstadkommit förskiffring och väldiga omböjningar af de nuvarande gneis- och gneisgranitmassiven. Granatgneisen hade just sin plats, där dessa omböjningar kommit till stånd, och dess struktur utmärktes af en i minsta detalj gående deformation och veckning af bergartsmaterialet. Dessa båda förhållanden kunde väl tänkas stå i samband med hvarandra på så sätt, att granatgneisen vore en utomordentligt kraftigt metamorfoserad granit. Å andra sidan kände man föga till, huru långt en granits metamorfiska ombildning under dylika betingelser skulle kunna gå. Man hade hittills hufvudsakligen följt graniternas regionala förändringar endast till gneisgranitstadiet, uti hvilket den ursprungliga granitstrukturen i viss mån ännu är iakttagbar. Enligt föredr:s uppfattning går dock graniternas regionala ombildning i många fall vida längre. Tal. framhöll äfven nödvändigheten af att en utförligare kemisk undersökning af granatgneisen komme till stånd.

Hr GRÖNVALL förevisade en stuff af *Tosterups-konglomeratet*, insamlad på kongress-exkursionen den 8 september 1910, hvari bland bollarna af silurisk skiffer märktes en boll af märgelskiffer med egendomliga hål, utfyllda med kritmärgel. Föredr. tydde dessa hål som borrade af borrmusslor och framhöll den stora öfverensstämmelsen mellan detta fynd och några blockfynd, som han gjort på Bornholm (publicerade i Medd. Dansk. Geol. For. N:o 13. Kbhvn 1907. S. 13—24). I sammanhang härmed lämnade föredr. en kort öfversikt öfver Skånes och närliggande Östersjötrakts geologiska historia.

I anslutning till meddelandet yttrade sig hrr G. De Geer, Hedström, Munthe och *föredraganden.*

Hr Hedström kunde icke gå med på föredr:s utan vidare undersökning framställda tolkning att groparna i bollen i det kringskickade profvet af Tosterups-konglomeratet vore förorsakade af borrmusslor. Dylika gropar kunna mycket väl hafva uppkommit på annat sätt, t. ex. vara förorsakade af andra organismer än musslor eller åstadkomna genom kemisk eller mekanisk åverkan. På Gotland till exempel förefinnas liknande gropar allmänt på sådana kalkstenshällar, som legat under myrarna och genom utdikning blifvit blottade. På Gotland kunna de icke vara förorsakade af borrmusslor, emedan några sådana icke finnas där. För att illustrera deras utseende kringskickades några prof af *Spongiostroma Holmi* Rothpl. dels med och dels utan sådana urgröpningar. Den sannolikaste förklaringen till deras uppkomst vore, att de utetsats förmedelst humussyror eller bildats genom inverkan af recenta kalkalger. Hvilken tolkning, som var den riktigaste, vore ännu oafgjordt.

Hr Grönvall vidhöll gent emot ofvan gjorda uttalanden sin tydning af dessa hål, som förorsakade af borrmusslor, såsom den mest sannolika.

Hr Hedström framhöll ytterligare, att, sedan nu föredr. närmare angifvit det skäl, som bestämdt honom för den nämnda tolkningen, och detta skäl vore groparnas form (de voro bredare i botten än i mynningen), man icke kunde draga några säkra slutsatser endast af formen, ty då borde ju t. ex. äfven jättegrytorna uppfylla föredragandens fordringar på hål, gjorda af borrmusslor.[1]

[1] Tal. ville slutligen tillägga, att ett enstaka snitt (och något annat var det här ej tal om) kan träffa äfven jämnbreda gropar och gropar med vidare mynning på sådant sätt, att de i snittet se ut att vara bredast i botten. (Senare tillägg.)

Hr MUNTHE trodde, i likhet med dr HEDSTRÖM, att de ifrågavarande groparna riktigast kunde tolkas såsom korrosions- (eller möjligen äfven korrasions-) fenomen än såsom orsakade af borrmusslor, enär de företedde sådan växling i form. Däri syntes de öfverensstämma med postglaciala korroderade kalkstenar, som tal. anträffat bl. a. vid draggning utanför Gotlands kuster.

I anslutning härtill visade tal. prof på stycken af en i märgelskiffern å södra Gotland funnen Stromatopor med talrika ungefär vinkelrätt mot ytan gående rörlika hål, fyllda med den ursprungligen omgifvande märgelns lösare material. Häri träffades i regeln en liten *Lingula* (*L.* cfr *minima* Sow.) eller fragment af denna. Möjligt vore därför, att hålens tillkomst betingats af denna brachiopods uppträdande. Tal. skulle göra fenomenet till föremål för en närmare undersökning, hvarför meddelandet vore att betrakta såsom endast preliminärt.

Sekreteraren anmälde för intagande i Förhandlingarna:

L. H. BORGSTRÖM: Mineralogiska notiser 7—10.

O. TENOW och C. BENEDICKS: Om de s. k. basiska utsöndringarna i Upsala-graniten och om klotgranitens bildningssätt ur fysikalisk-kemisk synpunkt.

Sekreteraren uttalade önskvärdheten af att eventuella rättelser och tillägg till det digra bandet 32 af Föreningens Förhandlingar måtte insändas i god tid under december månad.

Som gåfva har Föreningen mottagit:

KJELLÉN, RUDOLF: Sveriges jordskalf. Försök till en seismisk landsgeografi. Göteborg 1910.

Eine vorläufige Mitteilung von Prof. J. F. POMPECKJ über die Altersfrage der Juraablagerungen Spitzbergens.

Von

A. G. NATHORST.

Wie in meinem vor einigen Tagen erschienenen Aufsatz über die Geologie Spitzbergens bemerkt wurde,[1] konnte ich in demselben kein zeitgemässes paläontologisch-stratigraphisches Schema der dortigen Juraablagerungen mitteilen, und zwar weil Professor J. F. POMPECKJ damals mit der Bestimmung der Fossilien noch nicht fertig war. Ich musste mich deshalb auf eine Übersicht der verschiedenen Horizonte und ihres relativen Alters beschränken, ohne dieselben in die stratigraphische Altersreihe genau einpassen zu können. Laut einer brieflichen Mitteilung POMPECKJS von 1903, die kurz wiedergegeben wurde, wollte es jedoch erscheinen, als umfassten die betreffenden Ablagerungen Spitzbergens die Reihe vom oberen Oxford bis zum Neocom.

Soeben nach dem Drucke meines Aufsatzes erhielt ich aber von Prof. POMPECKJ eine vorläufige Mitteilung, die ich mit seiner Erlaubnis unten folgen lasse. Wie aus dieser Mitteilung erhellt, ist die Annahme des Vorkommens der *Aucella Keyserlingi* TRAUTSCH. sp. auf Spitzbergen nicht richtig; die Art, die er 1903 für diese hielt, hat sich später als *A. cf. terebratuloides* LAH. erwiesen. Damit fällt das

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[1] A. G. NATHORST: Beiträge zur Geologie der Bären-Insel, Spitzbergen und des König-Karl-Landes. Bull. Geol. Inst. of Upsala. 10. 1910.

vermeintliche neocome Alter der betreffenden Ablagerung von selbst weg, und die Divergenz, die zwischen den Aussagen einerseits der Tierfossilien, andererseits der Pflanzenfossilien zu existieren schien, besteht nicht mehr, denn der Paläobotaniker kann nichts dagegen einzuwenden haben, dass die Ginkgoschichten und die Elatidesschichten dem Portlandien angehörig oder nur wenig jünger sein müssen. Ebensowenig hat er etwas dagegen zu bemerken, dass die Dentalienschichten, die ja jünger als die pflanzenführenden Schichten sind, vielleicht in das Neocom hinaufreichen können. Die inzwischen erschienenen Arbeiten PAVLOWS und SOKOLOWS hatten, wie mir POMPECKJ schreibt, einige Modifikationen der ersten Bestimmungen nötig gemacht. »Die Untergrenze musste ich aufwärts schieben», sagt er, »da für Formen wie *Aucella Bronni* und *Cardioceras alternans* (und *Nathorsti*) nach den neueren stratigraphischen Arbeiten von ILOWAISKY und PAVLOW die Wahrscheinlichkeit, sie zu Oxford s. str. zu stellen, zu gering geworden war.» Der Jura Spitzbergens beginnt demgemäss mit dem Séquanien, nicht mit dem Oxfordien.

Über die in meinem Schema (l. c., S. 368) der Juraablagerungen Spitzbergens aufgestellte unterste Stufe 1 a, die im Bellsund am Reindeer Point, an der Ingebrichtsen Bucht, in den Låga Kullarne und am Ufer östlich vom Frithiof-Gletscher ansteht, und zu welcher offenbar auch der schwarze Schiefer westlich von der Festung gehört, dessen Fauna von LUNDGREN beschrieben wurde, äussert sich POMPECKJ folgendermassen:

»Die petrographisch gleichen Gesteine dieser Lokalitäten sind durch ihre Fossilien, besonders durch die Aucellen aus der Verwandtschaft der *Aucella Bronni* (TRAUTSCH.) LAH. und durch die Cardioceraten, unter denen ich *C. alternans* v. BUCH sp. wiedererkenne, sicher oberjurassischen Alters. Eine genaue Fixierung des Horizontes unterlasse ich, da sowohl für die Aucellen als für die Cardioceraten nach russischen Vorkommnissen ein Spielraum: Séquanien-Kimeridgien möglich ist.

Der *Aulacostephanus cf. subeudoxus* Pavl. (leider nur ein Fragment) würde eher für Kimeridgien s. str. sprechen.»

Von meiner Stufe **1 b** am Fusse des Ulla-Berges und im Heim-Berge sagt Pompeckj, dass dieselbe »nach der in ihr enthaltenen Aucelle, welche ich am ehesten mit *A. terebratuloides* Lah. (z. T. mit der Pavlow'schen *var. expansa*) vergleichen kann, dem jüngsten Jura (Portlandien e. p.? Aquilonien Pavl.) bis dem Neocom zuzurechnen ist. Genauere Fixierung ist hier auch leider unmöglich.»

Nun folgen die schwarzen Schiefer **1 c** ohne Fossilien und die Sandsteinreihe, die die Ginkgoschichten (**2 a**), die Elatidesschichten (**2 b**) und die Lioplaxschichten (**2 c**) umfasst. Diese können also sehr wohl noch zum Portlandien oder zu einer wenig jüngeren Stufe gehören.

Über der Sandsteinreihe lagern die Dentalienschichten (**3**). Diese bieten nach Pompeckj »die grösste Schwierigkeit und das am wenigsten befriedigende Resultat in Bezug auf die Altersbestimmung».

»Das einzige, stratigraphisch etwas sicherere Fossil ist die isoliert in einem losen Sandsteinstück (12)[1] am Ufer zwischen dem Swedenborg-Berg und dem Celsius-Berg gefundene *Aucella Pallasi* Lah. (*mosquensis* Pavl.). Sie würde für mittleres Portlandien sprechen, wie Pavlow das Portlandien auffasst. Von der gleichen Lokalität (12) liegen petrographisch mit dem die *A. Pallasi* (*mosquensis*) enthaltenden übereinstimmende Gesteine in mehreren Stücken vor. In diesen Gesteinen kommt mehrfach vor die an *Yoldia arata* Whiteaves am meisten erinnernde (die gleiche ganz eigenartige wellige Skulptur tragende) *Leda* (*? Yoldia*) *tenuiruncinata* n. sp. Diese (und ihr morphologisch sehr nahe stehende Stücke) kommen des öfteren vor in den petrographisch mehr oder weniger übereinstimmenden resp. nahestehenden Ge-

[1] Die Ziffern geben die den Lokalitäten gegebenen Nummern der an Pompeckj gesandten Stücke an. Hier habe ich auch die Namen der Lokalitäten hinzugefügt. A. G. N.

steinen des Celsius-Berges (12 a), des Fyrkanten-Berges (1 und 2) und (lose Geschiebe) der Braganza-Bucht (6 A, 6 C). Hieraus wird die Zusammengehörigkeit dieser Gesteine mit 12 wahrscheinlich, resp. möglich. Diese *Leda* scheint mir eher für untere Kreide als für Jura zu sprechen, da die einzige ihr nahe stehende *Yoldia arata* auf Queen Charlotta Island in der Kreide vorkommt.

Dazu tritt im Gestein 6 A von der Braganza-Bucht mit *Leda tenuiruncinata* häufig auf eine *Nucula Van Mijeni* n. sp. Diese mag der *Nucula borealis* Tullberg nahe stehen, sie zeigt aber auch sehr grosse Ähnlichkeit mit flacheren Exemplaren der *Nucula ovata* (Mant.) Woods, deren Alter ein untercretazisches ist.

Weiter sind in den Gesteinen des Fyrkanten-Berges (1) Fragmente eines grosswüchsigen, grobrippigen Ammoniten vorhanden, der wohl zur Gruppe des *Perisphinctes scythicus* gehören könnte und dann für Wolgastufe spräche; aber das Stück zeigt in seinen zu groben Rippen und in der Art der Rippenspaltung die auffallendste Ähnlichkeit mit dem von Nikitin dem Albien zugezählten *Hoplites jachromensis* Nik. Leider war weder eine unverletzte Externseite freizulegen, noch waren Lobenlinien zu erkennen. Sichere Bestimmung ist also ausgeschlossen.

Möglicherweise könnte also das Gestein 1 und die mit ihm petrographisch (2) wie faunistisch verbundenen Gesteine 4 (am Ufer des Fyrkanten-Berges anstehend) durch die ganz eigenartige hochgewölbte schiefe Form des *Pecten? sp.*, ferner 6 A, 6 C (Braganza-Bucht), 12, 12 a (Swedenborg-Berg), 16 (Geschiebe in Stordalen) als seine obere Altersgrenze sogar das Albien erhalten. Eindeutig bestimmende Fossilien fehlen leider.

Die Gesteine der Fundstellen 3 (Talus des Fyrkanten-Berges), 6 D (Braganza-Bucht, lose), 13 (Fyrkanten-Berg), 14 (Geschiebe, Van-Keulen-Bay) wurden mangels exakt bestimmender Fossilien lediglich nach ihrem petrographischen Charakter den ebengenannten Gesteinen zugestellt. Ob dem *Dentalium cf. Moreanum* eine wirklich entscheidende Rolle zukommt, lässt sich nicht entscheiden.

Sehr merkwürdig ist der Ammonitenabdruck in 14, der nach der Form seiner Rippen und der Andeutung von Spiralskulptur eine *Schlönbachia*(?) oder auch eine *Mortoniceras* sein könnte, dann also nicht auf älteste Kreide deuten würde. Auffallend ist es, dass in den Sandsteinen 6 B (Braganza-Bucht, lose) so merkwürdig wenig Formen vorkommen, die mit anderen Lokalitäten übereinstimmen.

Leider ist es nicht möglich zu entscheiden, ob die verschiedenen Gesteine verschiedenen Horizonten oder nur verschiedenen Facies der gleichen Stufe angehören. Nehmen wir nur e i n e Stufe an, deren Alter ich nach dem Vorhergehenden nicht anders angeben kann als **? Portlandien (-untere Kreide),** so treten folgende Faciesdifferenzierungen besonders scharf hervor:

1:o) reine Sandsteinfacies: 3, 4, 6 B, 6 D, 12, 13, 14, 17;

2:o) Sandstein mit Kreuzschichtung und mit eingeschalteten Lumachellen (während in 1 die Muscheln zerstreut liegen): 1, 2, 6 C und vielleicht 16, sowie 12 z. T.

3:o) Sandstein mit massenhaft eingeschalteten Muscheln: 6 A und 12 a.

Durchweg handelt es sich also um typische Flachmeerbildungen mit reichlichster Zufuhr von terrigenem Detritus. In der Fauna ist das paläontologisch bei weitem wertvollste Stück der aus einem Sandstein (6 B) herauspräparierte *Pentaceros Nathorsti* n. sp.»

Zu dieser Darstellung Pompeckjs sei nur bemerkt, dass, wie ich in meinem Aufsatz hervorgehoben habe, und wie ganz besonders aus dem Profil des Fyrkanten-Berges (l. c., S. 363, Fig. 60) hervorgeht, mehrere fossilienführende Horizonte innerhalb der Dentalienschichten vorkommen. Inwieweit dieselben auch faunistisch verschieden sind, bleibt noch zu erforschen; bei der überaus kurzen Zeit, die uns 1898 zu Gebote stand, war es leider nicht möglich, eine genaue stratigraphisch-paläontologische Untersuchung der Dentalienschichten durchzuführen, was also der Zukunft vorbehalten bleibt. Nunmehr dürfte eine solche Untersuchung leicht ausgeführt werden können.

Nachstehend folgen die von POMPECKJ mitgeteilten Tabellen über die von ihm bestimmten Versteinerungen. Dass *Pecten validus* zu den Dentalienschichten gehört, scheint mir von besonderem Interesse, und es soll nicht vergessen werden, dass es nach den Angaben LINDSTRÖMS erscheinen wollte, als käme auch seine *Aucella mosquensis* v. BUCH mit dieser Art am Kap Agardh zusammen vor.

Die Feststellung des Horizontes für *Perisphinctes triplicatus* dürfte auch von Bedeutung sein, weil die Angabe NORDENSKIÖLDS über das Vorkommen desselben in der Schieferserie westlich von der Festung dadurch bestätigt wird.

Stockholm, den 30. Juli 1910.

I. **Spitzbergen.** Versteinerungen vom Alter des *Séquanien-Kimeridgien.*	Van-Keulen-Bay. Geschiebe a. d. Moräne. 5.	Van-Keulen-Bay. Reinderpoint. 8.	Van-Keulen-Bay. Ingebrichtsen-Bucht. 9.	Van-Mijen-Bay. Im Mitterhuk. 11.	Van-Mijen-Bay. Ufer ö. v. Frithiof-Gletscher. 18.	Van-Mijen-Bay. Lose am Ufer ö. v. Frithiof-Gl. 19.
Pecten spitzbergensis Lundgr. *var. 5-costata* n. v.	.	—	.	.	.	.
» *? cf. intertextus* Roem.	.	—	.	.	.	.
» sp.	.	—	.	.	—	.
Aucella Bronni (Trautsch.) Lah.	.	—	.	.	—	.
» » » » var.	.	.	—	.	.	.
» (» var.) *reticulata* Lundgr.	.	—	.	.	.	—
» » cf. var. *lata* Lah.	.	.	.	.	—	.
» sp. (a. d. Gr. d. *Auc. Pallasi*)	.	.	.	.	—	.
Astarte sp. (a. d. Gr. d. *Ast. cordata* Rouill.)	.	—	—	.	.	.
» sp.	.	.	—	.	—	.
Plectomya cf. rugosa (Röm.) de Lor.	.	—	.	.	.	.
Pholadomya? curta n. sp.	.	.	—	.	?	?
Panopaea cf. antiqua d'Orb.	.	.	.	.	—	.
» ? sp.	.	.	.	.	.	—
Corbula sp.	.	.	—	.	.	.
Thracia sp.	—	.	.	.	.	.
Scurria cf. oblonga Desh.	.	.	—	.	.	.
Cerithium sp.??	.	.	.	.	—	.
Natica sp.??	.	.	.	.	—	.
Dentalium sp.	.	.	.	.	—	.
Cardioceras Nathorsti Lundgr. sp.	.	—	—	.	.	.
» » var. *robusta* n. v.	.	—	—	.	.	.
» » var.	.	—	.	.	.	.
» *alternans* v. Buch. sp.	.	.	—	—	.	.
» *interruptum* n. sp.	.	.	.	—	.	.
Perisphinctes cf. triplicatus Lindstr.	.	.	.	.	—	.
» *sp. indet.*	.	.	.	.	—	.
Aulacostephanus cf. subeudoxus Pavl.	.	.	.	.	—	.
» sp.	.	.	.	.	—	.
Belemnites sp. (? a. d. Verwandtschaft d. *Bel. porrectus* Phill.)	.	—	.	.	.	.
» *sp. indet.*	.	—	.	.	.	.

II. **Spitzbergen.** Versteinerungen, vom Alter des *Portlandien-Néocomien.*	Van-Keulen-Bay. Heim-Berg. 7.	Van-Keulen-Bay. Ulla-Berg. 10.
Aucella cf. terebratuloides Lah. (*cf. var. expansa* Pavl.)	—	—

III.

Spitzbergen.

Fossilien vom Alter des

? Portlandien (-unt. Kreide.)

	Van-Keulen-Bay. Fyrkanten-Berg. *Anstehend.*	Van-Keulen-Bay. Fyrkanten-Berg. Gesch. am. Ufer.	Van-Keulen-Bay. Fyrkanten-Berg. (Talus).	Van-Keulen-Bay. Fyrkanten-Berg. Am Ufer, *anstehend.*	Van-Mijen-Bay. Braganza-Bucht (Geschiebe). Schwarzgrauer feinkörniger (Kalk)-Sandstein.	Van-Mijen-Bay. Braganza-Bucht (Geschiebe). Graue-graugrüne feinkörnige Sandsteine.	Van-Mijen-Bay. Braganza-Bucht (Geschiebe). Grauer, plattiger Sandst. mit *Muschellagern.*	Van-Mijen-Bay. Braganza-Bucht (Geschiebe). Gelbgrünlicher Sandstein mit *Dentalium.*	Van-Mijen-Bay. Lose am Fuss des Swedenborg-Berges u. am Ufer zwischen dem Swedenborg- und dem Celsius-Berg.	Van-Mijen-Bay. *Anstehend* am Celsius-Berg.	Van-Keulen-Bay. Fyrkanten-Berg.	Van-Keulen-Bay. Geschiebe.	Van-Keulen-Bay. Ulla-Berg.	Van-Keulen-Bay. Stordalen, lose.	Van-Mijen-Bay. Lose am Celsius-Berg.
	1.	2.	3.	4.	6 A.	6 B.	6 C.	6 D.	12.	12 a.	13.	14.	15.	16.	17.
Pecten validus LINDSTR.	.	—	.	.	.	.	.	.	.	.	.	.	.	—	.
» ? sp.	.	.	.	—	.	.	.	.	.	.	.	.	.	.	.
Entolium obliquum n. sp.	.	—	.	.	.	—	—	.	?	.	.	.	.	.	.
» sp. (*cfr demissum* GF.)	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Avicula cf. semiradiata FISCH.	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.
Ostrea sp.	.	.	.	.	.	.	—	.	.	.	.	.	.	.	.
Leda (Yoldia?) tenuiruncinata n. sp.	—	.	.	.	—	.	—	.	—	—	.	.	.	.	.
» *cf. tenuiruncinata* n. sp.	—	—	.	.	—	.	.	.	.	.	.	.	.	.	.
» *subparallela* n. sp.	.	.	.	.	—	.	.	.	—	.	.	.	.	.	.
» sp.	.	.	.	.	.	.	.	.	—	.	.	.	.	.	.
Nucula van Mijeni n. sp.	.	.	.	.	—	.	.	.	.	.	.	.	.	.	.
» *sp. indet.*	.	.	—	.	.	.	.	.	.	.	.	.	.	.	.
Cucullaea sp.	.	.	.	.	.	.	.	.	—	.	.	.	.	.	.
Aucella Pallasi LAH. (*mosquensis* PAVL.)	.	.	.	.	.	.	.	.	—	.	.	.	.	.	.
» sp. (*? volgensis* LAH.)	.	.	.	.	.	.	.	.	.	.	.	.	—	.	.
» *sp. indet.*	.	.	.	.	.	—	.	.	.	.	.	.	.	.	.
Cf. Unicardium excentricum DE LOR.	.	.	.	.	.	—	.	.	.	.	.	.	.	.	.
Protocardium sp.	.	.	.	.	—	.	.	.	.	.	.	.	.	.	.
Cyprimeria sp. 1 (*cf. Cyprina Syssolae* KEYS.)	.	.	.	.	—	.	.	.	—	—	.	.	.	.	.
» sp. 2 (*cf. Cyprina anglica* WOODS aut *Cypr. inconspicua* LINDSTR.	.	.	.	.	—	.	.	.	—	.	.	.	.	.	.
»*Cyprina*» *inconspicua* LINDSTR.	—	.	.	.	.	—	.	.	.	.	.	.	.	.	.
» *Brongniarti* (RÖM.) DE LOR	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.
» sp.	.	—	.	.	.	.	.	.	.	.	.	.	.	.	.
» aut *Cyprimeria div.* sp.	.	.	.	—	.	—	.	.	.	.	.	.	.	.	.
Tancredia polaris n. sp.	.	.	.	.	.	—	.	.	—	.	.	.	.	.	—
Astarte sp.	.	.	.	.	.	.	.	.	.	—	.	.	.	.	.
Natica sp.	—	.	.	.	—	.	.	.	.	.	.	.	.	.	.
? Eulima sp.	—	.	.	.	—	.	.	.	.	.	.	.	.	.	.
Actaeon cf. Frearsi D'ORB. sp.	.	.	.	.	—	.	.	.	.	.	.	.	.	.	.
Dentalium cf. Moreanum D'ORB.	.	.	.	.	.	—	.	—	—	.	? —	? —	.	.	.
» *? Lindströmi* LUNDGR.	.	.	.	.	.	.	—	.	.	.	.	.	.	.	.
» sp.	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentacrinus sp.	.	.	.	.	.	—	.	.	.	.	.	.	.	.	.
Pentaceros Nathorsti n. sp.	.	.	.	.	.	—	.	.	.	.	.	.	.	.	.
Ammonitenreste:															
1) *Perisphinctes* a. d. *scytichus-Gr.* oder *Hoplites cf. jachromensis* NIK.	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2) unbestimmbare Fragmente	.	.	.	.	.	—	.	.	.	.	—	.	.	.	.
3) *Cardioceras??* aut *Schlönbachia* aut *Mortoniceras??*	.	.	.	.	.	.	.	.	.	.	.	—	.	.	.
Belemnitenfragmente	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fischwirbel	—	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Bemerkung zu den Bestimmungen der Muscheln: Mit wenigen Ausnahmen (6 A) liegen die Muscheln in Steinkernen, Skulptursteinkernen, Abdrücken vor. Es gelang daher bei den allermeisten Stücken nicht, genügende Orientierung über die Organisation des Schlosses zu gewinnen. Die Bestimmungen mussten daher ± unsicher bleiben. Vage Identifizierungen auf Grund oberflächlicher äusserer Ähnlichkeiten wurden vermieden.

Die von der Lokalität 20 (Van Keulen-Bay, Gebirge westl. v. Penckgletscher) vorliegenden Fragmente sind zu ungenügend, um das Alter zu fixieren.

Om de s. k. basiska utsöndringarna i Upsalagraniten och om klotgranitens bildningssätt ur fysikalisk-kemisk synpunkt.

Af

O. Tenow och C. Benedicks.

I. Inledning.

Då vi innevarande sommar vistades i trakten af Flottsund (Fyrisån), gjorde vi ett besök vid Skarholmen utanför Graneberg, där den ene af oss (Tenow) tidigare observerat bildningar, som föreföllo vara brottstycken af annan bergart i Upsalagranit. Under ifrågavarande besök hade vi tillfälle att såväl bese som fotografera och insamla åtskilliga prof, som icke lämna något tvifvel öfrigt angående förekomstens natur af inneslutningar.

Graniten visar den för Upsalagraniten typiska blå kvartsen och öfverensstämmer i sitt utseende för öfrigt med denna; dock innehåller den något mera glimmer än vanligtvis är fallet med Upsalagranit. Förekomsten utgöres af en mängd stora block, som ej kunna hafva blifvit långt transporterade. I dessa förekomma nu rikligt större och mindre inneslutningar af annan bergart. Fig. 1 visar ett dylikt större block af Upsalagranit, hvilket på midten innehåller ett 30×50 *cm* stort, skarpkantigt bergartstycke samt en mängd andra inneslutningar af varierande storlek, i allmänhet med skarpa gränser och skarpa kanter, särskildt hos de större.

Fig. 1. Block af Upsalagranit med 30 × 50 *cm* stort, skarpkantigt brottstycke och andra inneslutningar af varierande storlek.

Fig. 2. Upsalagranit med brottstycken, delvis med basisk anrikningszon och yttre surare smältzon.

Figg. 2, 3 och 4 visa andra dylika inneslutningar. Ett rätt tydligt skarpkantigt stycke synes å fig. 2; de å den större stenens öfre yta synliga ljusa fläckarna äro lafvar. Å ett större block, liggande ett stycke ut i vattnet och därför vid vårt besök ej bekvämt att fotografera, voro inneslutningarna så talrika, att bergarten nästan liknade en breccia.

De inneslutna styckena äro af väsentligen två slag, hvilket man lättast ser då de äro stora. Dels förekommer en utprägladt skiffrig, *glimmerrik gneis* (glimmerskiffer), se t. ex. fig. 3, öfre inneslutningen, som påminner ytterst starkt om den söder om Upsalamassivet förekommande gneisen (Alsike, Stafsund, Ekebo). Dels förekommer, ehuru i mindre mängd än gneisen, en *dioritartad bergart.* Liknande diorit ha vi anträffat i block nära Ekhamn; den liknar starkt den vid Ultuna förekommande och är möjligen identisk med denna. Stundom innehålla de större brottstyckena sprickfyllnad af kvarts, som icke fortsätter ut i omgifvande granit (jmfr fig. 1).

Vid slag skiljer sig inneslutningen stundom från graniten omkring.

Af det anförda torde med tillräcklig tydlighet framgå, att vi här ha att göra med *en förekomst af typiska brottstycken af äldre bergarter, som blifvit insmälta i Upsalagraniten.*

Beträffande brottstyckenas närmare detaljer ha vi att anmärka följande. Å sådana ställen, som varit utsatta för atmosferiliernas inverkan, iakttages oftast, att de inneslutna brottstyckena äro starkt anfrätta längs en smal kant utmed graniten, så att en ofta djup fåra förefinnes. Se fig. 1, å det stora blockets öfversida; fig. 3 visar dylika djupa fåror. Å friskare brottytor kan man iakttaga, att denna lättare angripna, yttre zon har mörkare färg, eller m. a. o. förefaller vara mera basisk än den inre delen. Detta är möjligt att iakttaga öfverst å figg. 2 och 4.

Närmast kring brottstyckena framträder ofta en ljusare färgton hos graniten, tydligt synbar å fig. 2; speciellt brukar dylik iakttagas, då den nyssnämnda mörkare zonen i brottstyckena är tydlig.

Fig. 3. Brottstycken: upptill tydlig glimmerskiffer eller gneis; nedtill med tydlig anfrätningskontur.

Från dessa typiska brottstycken finnas på samma lokal, och ofta i samma block, alla öfvergångar till de annars i Upsalagraniten så ofta förekommande s. k. *basiska utsöndringarna*, hvilka i detalj blifvit beskrifna af prof. HÖGBOM.[1] Dessas vanligaste utseende öfverensstämmer alldeles t. ex. med fig. 5.

[1] Geol. För. Förh. **10** (1888), 219; **15** (1893), 251.

Fig. 4. Upsalagranit med brottstycken; i de öfre tydlig basisk anrikningszon kring en inre kärna.

Fig. 5. Upsalagranit med brottstycken, företeende det vanliga utseendet af s. k. »basiska utsöndringar».

II. Brottstyckens förhållande i en magma ur fysikalisk-kemisk synpunkt.

Det föregående gifver oss anledning att ingå på frågan, huru ett brottstycke förhåller sig, då det införes i en smälta. Låt oss för enkelhetens skull antaga, att brottstycket har samma sammansättning som smältan, t. ex. motsvarande abscissan *a* å smältdiagrammet fig. 6. Å detta antaga vi, likaledes för enkelhetens skull, att bergarten blott består af två beståndsdelar, en mera basisk *A* (t. ex. hornblende eller glim-

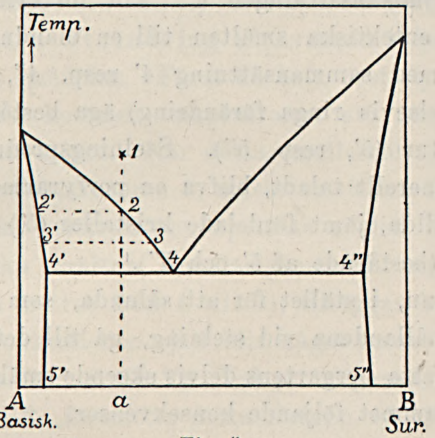

Fig. 6.

mer) och en surare *B* (t. ex. fältspat eller kvarts); härvid antages det allmänna fallet, att *A* och *B* i smält tillstånd äro blandbara i alla proportioner, men i fast endast i inskränkt mån. Hvarje abscissa mellan *A* och *B* motsvarar alltså en viss sammansättning (abscissan *a* t. ex. 20 % *A* och 80 % *B*). Ordinatorna motsvara temperaturer. Då man utgår från en blandning af sammansättningen *a* i smält tillstånd, hvilket t. ex. motsvarar punkten 1 inom området för smälta, och låter temperaturen sjunka, kommer, som bekant, vid en viss temperatur, motsvarande punkten 2, smältan att delvis stelna; de basiska kristaller, som därvid utskiljas, ha sammansättningen 2'. Härigenom förändras den ursprungliga smältans sammansättning, så att den blir mera sur (närmar sig den eutektiska sammansättningen, som motsvarar punkten 4). Då temperaturen vidare sjunker under punkten 2, t. ex. till 3, har förändringen gått så långt, att smältan fått den mot abscissan 3 svarande surare sammansättningen och den utsöndrade fasta delen den sammansättning, som svarar mot abscissan 3'. När slutligen afkylningen fortskridit till den eutektiska temperaturen, har den ursprungliga smältan förändrats, så att den har den eutektiska sammansättningen, svarande mot punkten 4, under det de utskilda kristallerna fått sammansättningen 4'. Vid fortsatt värmeförlust stelnar den eutektiska smältan till en blandning af två beståndsdelar med sammansättning 4' resp. 4'', hvilka sedan (med jämförelsevis ringa förändring) äga bestånd vid vanlig, låg temperatur (5', resp. 5''). Stelningsprodukten kommer alltså att, generellt taladt, blifva en porfyrartad bergart med primärt utskilda, jämt fördelade kristaller (5') i en eutektisk grundmassa (bestående af 5' och 5'').[1]

Om vi nu, i stället för att sålunda, som vanligen sker, betrakta förhållandena vid stelning, gå till det motsatta förloppet, den fasta bergartens delvis skeende smältning, så framgår af diagrammet följande konsekvenser.

Vi antaga, att vi ha ett fast brottstycke af sammansättningen *a* (alltså mer basisk än den eutektiska), hvilket nedsänkes i en tillräckligt varm smälta, som vi till en början antaga också ha sammansättningen *a*. Brottstyckets temperatur kommer då att långsamt stiga, och detta fortast på utsidan. Så snart denna uppnått den eutektiska temperaturen (4), kommer en påtaglig förändring att äga rum: massa med eutektisk sammansätttning kommer att smälta, men inom smältzonen befintliga basiska beståndsdelar, af sammansättningen 4', komma att kvarblifva osmälta. Dessa fasta basiska beståndsdelar komma i allmänhet på grund af kapillärkrafterna att ej falla

[1] På grund af långsam afkylning blir denna primära stelningsstruktur sällan bevarad.

isär, utan lägga sig intill, attraheras utaf den ännu osmälta kärnan af brottstycket.

Fortsätter nu upphettningen af brottstycket, kommer den yttre, eutektiska smältzonen alltmera att tilltaga i bredd, samtidigt med att den (genom kapillärkrafterna uppkomna) basiska konkretionen kring (den kvarvarande delen af) brottstycket tilltager i tjocklek. Detta fortfar, tills den oförändrade midtdelen helt och hållet försvunnit, då vi — förutsatt att ingen diffusion utåt äger rum — få följande tillstånd: ytterst den omgifvande smältan af sammansättningen *a*, där innanför en surare (eutektisk) smältzon och slutligen innanför denna en basisk utsöndring af hvarandra kapillärt attraherande fasta smådelar. Först då hela brottstycket på detta sätt förändrats, kommer temperaturen att nämnvärdt stiga utöfver den eutektiska. När detta emellertid ägt rum och vi uppnått t. ex. temperaturen 3, måste en större eller mindre del af den basiska konkretionen upplösas af den kringliggande, förut eutektiska smältan, som därigenom blir mer basisk (sammansättningen ändras från 4 till 3); tilläggas kan, att därvid den basiska konkretionen själf blir något surare (sammansättningen ändras från 4' till 3'). Vid ytterligare temperaturstegring, upp till 2, fortsätter detta förlopp, så att den basiska konkretionen alltmer resorberas; vid punkten 2 försvinner sista spåret däraf, samtidigt med att den surare zonen omkring fått sammansättningen *a*, hvilket enligt antagandet är den omgifvande bergartens sammansättning. Först härmed är brottstyckets fullständiga smältning afslutad och dess spår i smältan utplånade.

Om brottstycket skulle vara mera basiskt än den smälta magman, så blir den hufvudsakliga förändringen den, att den basiska konkretionen blir relativt rikligare, samt att den ännu ej försvunnit, då smältzonen omkring fått den kringliggande magmans sammansättning. Vid ytterligare temperaturstegring blir här smältzonen mera basisk än magman; och slutligen smälter stycket fullständigt och fördelas genom diffusion.

Ha brottstycke och magma båda eutektisk sammansättning, så inträda inga koncentrationsändringar, utan stycket smälter som en enhetlig kemisk förening i sin smälta.

De öfriga möjliga fallen med två beståndsdelar *A* och *B* behandlas utan svårighet med diagrammets tillhjälp i enlighet med det föregående.

Äro beståndsdelarna 3 (eller flera), såsom i flertalet bergarter, blir den väsentligaste komplikationen den, att den basiska konkretionen, som samlas kring den osmälta delen af brottstycket, kan successivt bestå af skilda mineral.

Men äfven i vårt enklare fall med blott två beståndsdelar kan — detta bör särskildt framhållas — en upprepad skiktning komma till stånd. Om nämligen kapillärkrafterna mellan de skilda delarna af konkretionsskiktet äro stora (såsom fallet torde vara vid riklig förekomst af små glimmerfjäll), så kommer skiktet att kunna få en viss stabilitet, som motsätter sig fortsatt inåtförflyttning af detsamma (dylikt glimmerskikt kommer att förhålla sig ungefär som ett äggskal).[1] Följden blir, att vid fortsatt värmetillförsel (särskildt då denna är kraftig) smältningen kan inträda äfven *innanför* detta skal; härigenom uppkommer en repetition af det förut beskrifna fenomenet, resulterande i en mångfald likartade skikt; detta utan att man såsom förklaring för repeterad skiktning behöfver tillgripa öfverkylningsfenomen.

I enlighet med den föregående framställningen har man alltså anledning att särskilja följande enkla *typer* af basiska brottstycken, som omsmälts i en magma (något mer basisk än eutektikum).

1. Brottstycken som endast i sina allra yttersta delar undergått märkbar förändring. (Se den skematiska fig. 7, 1).

2. Brottstycken med oförändrad kärna men tydligt utvecklad basisk konkretionszon, omgifven af sur (eutektisk) smältzon. (Fig. 7, 2).

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[1] Angående storleken af de kapillärkrafter, som kunna uppträda, jmfr ATTERBERGS undersökningar öfver plasticitet och hållfasthet hos finpulvriserad glimmer.

3. Inneslutningar utan någon oförändrad kärna, eljest lika med 2. (Fig. 7, 3).

4. Inneslutningar, där smältzonen resorberat en del af konkretionskärnan, så att den blifvit lika basisk som den omgifvande magman. (Fig. 7, 4).

5. Inneslutningar, hvilkas basiska konkretion börjat sprida sig genom upplösning i magman. (Fig. 7, 5).

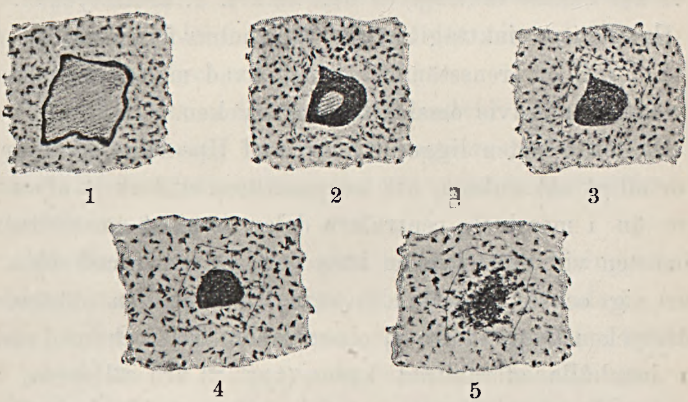

Fig. 7.

III. Tillämpning af den teoretiska utredningen.

1. De basiska utsöndringarna i Upsalagraniten.

Om vi antaga, att Upsalagranit är nära eutektisk, men med något öfverskott af basiska mineral, kunna vi nu förklara de företeelser vi möta såväl vid Skarholmens brottstycken som vid flertalet af de inom Upsalagraniten vanliga basiska utsöndringarna.

Hvad då Skarholms-förekomsten beträffar, så innehåller den, som nämndt, stora skarpkantade brottstycken, på hvilka endast det yttersta lagret undergått någon märkbar förändring. Den surare smältzonen är knappast märkbar; den basiska konkretionszonen, hvilken lättare påverkas af vittring, yttrar sig genom en smal vittringsgraf, som gifver skarp kontur åt brottstycket (ex. fig. 1, stora stycket i midten samt det något till höger om detsamma synliga).

De långt allmännare mindre styckena, som gifvetvis lättare kunnat antaga högre temperatur än de större, visa högre grad af differentiering; de utvisa i regeln sur smältzon, jämförelsevis bred basisk konkretionszon samt oförändrad inre kärna. Nästa smältningsstadium, utan någon oförändrad kärna, ha vi här endast iakttagit å helt små f. d. brottstycken.

Hvad som iakttagits vid Skarholms-förekomsten, står alltså i full öfverensstämmelse med hvad man teoretiskt har att vänta för delvis omsmälta brottstycken.

Då förekomsten ligger i kanten af Upsalamassivet, är det ej orimligt att antaga, att temperaturen där varit afsevärdt lägre än i massivets centralare delar, hvarest omsmältningsfenomenen vid brottstycken böra vara längre framskridna. Så visar sig också förhållandet vara. Väsentligen oförändrade brottstycken (typ. 1) äro ej observerade. Till och med sådana som innehålla oförändrad kärna (typ. 2) äro sällsynta, men exempel därpå torde vara de som af prof. Högbom afbildas G. F. F. **10** (1888). 229, figg. 10 och 11. Inneslutningar utan kärna (typ. 3) äro mycket vanliga i massivets centrala delar. Utmärkta afbildningar förekomma i prof. Högboms cit. arbete figg. 3, 4 och 5 samt i hans senare arbete G. F. F. **15** (1893), 252, fig. 1. Inneslutningar utan surare zon (typ. 4) äro likaledes mycket vanliga, se t. ex. fig. 2 i Högboms förra arbete. Inneslutningar i upplösningstillstånd (typ. 5) äro ytterst vanliga; dylika finnas afbildade å samma ställe, fig. 6 och 1.

Upsalagranitens s. k. basiska utsöndringar exemplifiera alltså på ett synnerligen tillfredsställande sätt de omvandlingstyper för basiska brottstycken, som man enligt den skizzerade teorien har att vänta. Vidare framgår, att det knappast kan anses lämpligt att bildningarna ifråga benämnas *basiska utsöndringar;* ty de kunna icke ha bildats genom någon sorts kemisk differentiationsprocess ur magman, såsom det låge nära till hands att antaga till följd af denna benämning, utan äro de fastmera genom kapillära krafter uppkomna af brottstycken vid deras smältning i enlighet med fysikaliska kemiens kända lagar.

Af de trenne skäl, som prof. HÖGBOM anfört (se G. F. F. 15 (1893), 251) mot att främmande brottstycken föreligga, är det första, att ett visst samband existerar mellan t. ex. svafvelkishalten hos vissa inneslutningar och den omgifvande granitens svafvelkishalt; men detta blir en nödvändig följd af den framställning, vi lämnat, då äfven detta mineral måste kunna utlösas ur brottstyckena.

Prof. HÖGBOMS andra skäl, att bredvid liggande inneslutningar ofta visa sig *icke höra tillsammans*, öfverensstämmer ju till fullo med vår iakttagelse, att olika bergarter förekomma som brottstycken.

Det tredje, eller att massan närmast utsöndringarna ofta är surare än omgifvande granit, innebär ju endast, enligt hvad vi i det föregående visat, att Upsalagraniten är något mer basisk än den motsvarande eutektiska blandningen.

Prof. HÖGBOMS åsikt, att inneslutningar äro basiska utsöndringar, bildade inom granitmagman *innan denna ännu stelnat*, öfverensstämmer tillfullo med vår ofvan framställda uppfattning.[1]

2. Om klotgranitens bildning.

Ett möjligen allmännare intresse tillkommer den gjorda fysikalisk-kemiska behandlingen af brottstyckens förhållande i en magma, därför att den möjliggör en förklaring till *klotgraniternas* gåtfulla uppkomst. Den för klotgraniterna karakteristiska zonstrukturen blir nämligen en naturlig konsekvens af vår teori, redan om vi blott antaga 2 beståndsdelar hos graniten, en basisk *A* och en sur *B* (se fig. 6). Har nämligen ett antal ungefär likstora brottstycken af en dylik bergart af någon orsak inkommit i en smält magma (denna har t. ex. vid

[1] Vid tidpunkten för prof. HÖGBOMS arbete kom det också hufvudsakligen an på att gifva bevis för granitens magmatiska ursprung; det slags diagram, som här funnit användning, är äfven af senare datum.

sitt uppträngande passerat ett regelbundet spricksystem, eller har ett större inkommet block regelmässigt spruckit sönder), och har denna ej för hög och ej för låg temperatur, så komma brottstyckena genom inträdande smältning och differentiering i enlighet med ofvanstående framställning att samtliga erhålla en likartad zonstruktur. Man bör kunna särskilja: 1) omgifvande magma; 2) en yttre zon af eutektisk sammansättning; 3) en konkretionszon, mera basisk eller mera sur än eutektikum, samt 4) eventuellt en kärna af den mer eller mindre oförändrade moderbergarten. Dessutom kan under vissa förutsättningar, jämf. sid. 1512, repetition af dessa zoner uppträda.

Antaga vi tre eller flera mineralbeståndsdelar i st. f. ofvannämnda två, så kommer zonen 3 att kunna bestå af flera olika lager, gifvande en lämpligen komplicerad byggnad. Det detaljerade fastställandet af dessa olika lager blir en för hvarje bergart speciell fråga.

Att brottstycken verkligen ligga till grund för klotgraniternas bildning, torde de geologiska förhållandena ofta gifva vid handen. I Kangasniemis klotgranit hafva vi själfva haft tillfälle iakttaga kvarvarande brottstycken; dylika förekomma här i regeln inom hvarje klot, enligt B. Frosterus.[1]

Enligt hvad lektor P. J. Holmquist för oss påpekat, förekommer klotgranit äfven företrädesvis vid kontakter, där annars breccior skulle väntas. Af de teorier, man tillgripit för att förklara klotgranitens bildning, kan särskildt förtjäna nämnas prof. Bäckströms.[2] Denne forskare anser uppenbart, att kloten en gång förelegat som smälta droppar, utan att dock någon orsak till utskiljandet af sådana kunde angifvas. Denna Bäckströms uppfattning får sin närmare belysning genom vår utredning. Det förefaller oss däremot vanskligt att afgöra, huruvida hans mening, att stelnandet af kloten skett utifrån, generellt taget kan vara riktig.

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[1] Bull. da la Commiss. Géol. de la Finlande N:o 4, Helsingfors 1896.
[2] Geol. För. Förh. 16 (1894), 107.

3. Eruptiva gångars förhållande.

En annan ganska allmän geologisk företeelse, som hittills väl ej fått någon förklaring, är det förhållande, att kring *eruptiva gångar*, särskildt pegmatiter, stundom utbildas en egendomlig zonstruktur. Å fig. 8 angifver *b* själfva den synliga pegmatitgången, kring densamma äro utbildade ofta starkt basiska skikt *cc'* (ofta ren hornblende). Sålunda tyckes den sura pegmatitgången på ett paradoxalt sätt ha åstadkommit en basisk anrikning kring sig. Synnerligen typiska dylika gångar har den ene af oss (TENOW) iakttagit flerstädes, särskildt i Lappmarkerna.

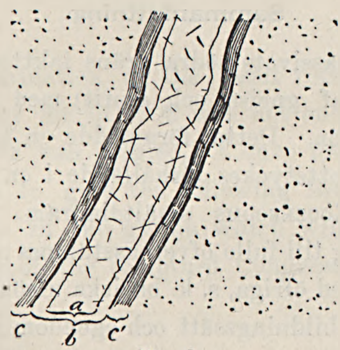

Fig. 8.

Från vår teoretiska ståndpunkt kan emellertid förklaringen vara enkel nog. *a* å fig. 8 är en ursprunglig spricka, t. ex. i en granit som är mera basisk än motsvarande eutektikum. Om nu genom denna spricka en *tillräckligt het* smälta upptränger (som sannolikt redan har eutektisk sammansättning), så kommer den omgifvande graniten att smälta närmast sprickan. I enlighet med hvad vi tidigare utvecklat, sker härvid en uppdelning af den smältande graniten i två lager: närmast sprickan smält eutektikum, närmast graniten fast, basiskt material, som adhärerar vid väggen. Är då gångens material stadd i sakta rörelse, kommer det bildade, smälta eutektikumet att uppblandas därmed, under det rörelsen är för svag att bortrycka det adhärerande basiska materialet. Efter sedermera inträdt stelnande kommer gångens ursprungliga bredd *a* att ökas till *b*, och förekomsten erhåller det beskrifna utseendet. Ju varmare den uppträngande massan varit (åtminstone till en viss gräns) och ju mera basisk bergarten omkring är, desto bredare blir det basiska anrikningsskiktet, under det att för stark rörelse hos gångmassan bör kunna åstadkomma, att äfven detta skikt medryckes, så att bergarten icke företer någon nämnvärd förändring kring gången. Naturligtvis ställa sig förhållandena i naturen härvidlag ganska olikartade, och äfven andra faktorer kunna ju inverka.

Sammanfattning.

Vid Upsalamassivets södra gräns iakttogs i graniten inneslutna block (af gneiss och diorit) med mer eller mindre utpräglad smältzon. Detta föranledde en kort, teoretisk utredning af ett brottstyckes förhållande i en smälta, väsentligen enligt ett ROOZEBOOMS smältdiagram. Konsekvenserna häraf ha visat sig till fullo öfverensstämma med såväl nämnda förekomst, som med öfriga, s. k. basiska utsöndringar i Upsalagraniten, hvilkas bildningssätt och egendomligheter härigenom få sin förklaring.

Äfven vinnes genom denna utredning en förklaring till klotgraniternas struktur och till en del eruptiva gångars utbildningssätt.

Ekebo pr Upsala, juli 1910.

Preliminary list of plant remains found in the Hernö gyttja.

By

Henr. Munthe.

As the examination of the fossil remains of the Hernö gyttja collected by me in 1908 was not ended when the Congress-guide n:o 12 was printed,[1] I have found it appropriate now (aug. 1910) to give the following list of *plant remains* as yet met with in the gyttja which will be demonstrated during the visite of the combined Congressexcursion A8 and A6 at Hernösand.

Species marked with an * are new for the gyttja and found by Mr. Karl Afzelius in Stockholm.

Fungi.

Cenococcum geophilum Fr. Common. (Sernander det.).

Algæ.

Botryococcus Braunii Kütz. Not rare (Lagerheim).
Chrysomonadineæ. Cystæ of more than 30 species (Lagerheim).
Diatoms. About 70 species (cfr Munthe: Geol. Fören. Förh. 1904).

[1] Munthe in A. G. Högbom: Quartärgeologische Studien im mittleren Norrland. G. F. F. **31** (1909): 578—587. Cfr Munthe: Om den submoräna Hernö-gyttjan och dess ålder. G. F. F. **26** (1904) and l. c. **31** (1909).

Characeæ.

One spore. (SERNANDER).

Musci. (S. BERGGREN).

Amblystegium fluitans (L.) DE N.
» *intermedium* LDB.
» *sarmentosum* (WAHLENB.) DE N. Common.
» *turgescens* JENS.
Barbula rubella (HOFFM.) MITT.
Polytrichum alpinum L.
Schistophyllum osmundoides (SW.) LA PYL.
Sphærocephalus palustris L. Rather common.
» *turgidus* (WAHLENB.) Rather common.
Swartzia montana (LAM.).
Sphagnum palustre L.

Pteridophyta.

Botrychium Lunaria SW. 1 spore (LAGERHEIM).
Isoëtes echinosporum DUR. Macrospores (SERNANDER).
» *lacustre* L. Macrospores (SERNANDER).
Lycopodium annotinum L. Several spores (LAGERHEIM).
» *clavatum* L. Many spores (LAGERHEIM).
? » *complanatum* L. Many spores (LAGERHEIM).
» *Selago* L. 2 spores (LAGERHEIM).
**Pteris aquilina* L. [? according to NATHORST; cfr. MUNTHE G. F. F. 12 (1890): 15—16].
Selaginella selaginoides (L.) LINK. Macro- and microspores (LAGERHEIM, SERNANDER).

Phanerogams.

**Alnus glutinosa* (L.) GÆRTN. 1 fruit.
**Batrachium* sp. Numerous fruits.
Betula nana L. A few fruits etc. (SERNANDER).
**Betula odorata* BECHST. Fruits etc. rather common. (SERNANDER).

? *Betula odorata* × *nana*. (SERNANDER).
**Chenopodiaceæ*. A few seeds.
Cyperaceæ (*Carex* etc.). Numerous fruits.
**Hippuris vulgaris* L. Numerous fruits.
**Juniperus communis* L. 1 seed.
**Myriophyllum* sp. 1 fruit.
**Menyanthes trifoliata* L. Seeds not rare.
Pinus silvestris L. Numerous pollen grains. (SERNANDER).
Picea excelsa (LAM.). » » » (LAGERHEIM).
Potamogeton filiformis PERS. 8 fruits (SERNANEER).
(Numerous fruits which most probably belong to this species are found by AFZELIUS).
**Potamogeton prælonga* WULFEN. 1 fruit.
**Ranunculus repens* L. 1 fruit.
**Salix* sp. 1 capsule.
**Sparganium* sp. 4 fruits.

As regards the *animal remains* met with in the gyttja cfr. MUNTHE 1904. Here may only be added that Dr. MJÖBERG during later, preliminary examinations has found several remains of *insecta* belonging not only to the before described two extinct species but also to some other species which will be mentioned further on.

Stockholm aug. 1910.

GEOLOGISKA FÖRENINGENS
I STOCKHOLM
FÖRHANDLINGAR.

BAND 32. Häftet 7. December 1910. N:o 273.

Mötet den 1 december 1910.

Närvarande 31 personer.

Ordföranden, hr HÖGBOM, meddelade, att sedan förra mötet Föreningens Ledamot från 1872 professor A. W. CRONQVIST, Stockholm, aflidit, samt ägnade några ord åt minnet af honom såsom geolog och medlem af Föreningen.

Till nya Ledamöter hade Styrelsen invalt:

Fil. studerandena ALF HANNERZ och CARL MALMSTRÖM, Upsala,
på förslag af hr Sernander;

Fil. kand. E. K. A. BERGLUND, Upsala,
på förslag af hr Hamberg;

Bergsingeniören C. G. GRANSTRÖM, Malmberget,
på förslag af hr Holmquist, samt

Jordbrukskonsulenten, fil. kand. H. FUNKQUIST, Upsala,
på förslag af hr A. G. Högbom.

Det från november-mötet hvilande förslaget om ändring af § 8 af Föreningens stadgar (se G. F. F. Bd. 32, sidd. 1485—1486) blef af Föreningen antaget, och beslöts, att den ändrade bestämmelsen skulle omedelbart träda i kraft.

Ordf. framlade och motiverade å Styrelsens vägnar ett förslag om inval af *Korresponderande Ledamöter* af Föreningen. Förslaget bordlades till januarimötet 1911.

Meddelades, att Föreningen genom sin Styrelse framfört sina lyckönskningar till professor A. G. NATHORST med anledning af dennes 60-årsdag den 7 november.

Vid därefter förrättadt *val af Styrelse för år 1911* utsågos:
till *ordförande* hr Gunnar Andersson,
» *sekreterare* » H. Munthe,
» *skattmästare* » G. Holm
samt till *öfriga styrelseledamöter* hrr H. Bäckström och J. G. Andersson.

Till *revisorer* af innevarande års räkenskaper och förvaltning utsågos hrr P. Geijer och P. Quensel med hr H. Johansson som suppleant.

Nästa möte utsattes till torsdagen den 12 januari 1911.

Hr A. G. Högbom höll föredrag *om fjällgeologiens och urbergsgeologiens ställning i vårt land.* (En uppsats i ämnet kommer att inflyta i ett följande nummer af Förhandlingarna.)

I anslutning till föredraget yttrade sig hrr Hamberg, G. De Geer, Holmquist, Svenonius och *föredraganden.*

Sekreteraren anmälde för intagande i Förhandlingarna:

S. L. Törnqvist: Graptolitologiska bidrag.

C. G. Granström: Fynd af gedigen koppar i Gellivare Malmberg.

Vid mötet utdelades n:r 272 af Föreningens Förhandlingar.

Mineralogiska notiser 7—10.

Af

LEON. H. BORGSTRÖM.

7. Selenhaltig Lillianit från Iilijärvi.

Uti den västligaste af Iilijärvi gamla skärpningar träffas som en sällsynthet det i föreliggande uppsats beskrifna mineralet tillsammans med blyglans, kopparkis, magnetkis, arsenikkis, pyrit och zinkblende, grå kvarts, rödaktig andalusit i ovanligt stora kristaller, hvit och svart glimmer samt gediget guld i små fina flittror. Mineralet förekommer i på blyglans relativt rika ställen af malmen men äfven i kvartsådror.

Dess färg är ljust blågrå till silfverhvit; ljusare än blyglansen och mera blåaktig än den i samma stuffer närvarande arsenikkisen. Den bildar i malmen insprängda aflånga korn af till ett par *cm* i längd, hvilkas begränsning oftast är oregelbunden, men stundom tydligt polyedrisk, i hvilket fall deras form på stuffens ytor oftast är en aflång rektangel. Mineralets brottyta visar en trådig struktur liknande den på skapolitens vanliga brottytor, hvilken struktur tydligen beror på goda genomgångar parallellt med kristallernas längdriktning. På några lösbrutna splittror kunde vinkeln mellan ett par genomgångar mätas med reflexionsgoniometer, och erhöllos värdena 89° 57′ och 89° 56′, hvarför här tydligen föreligger spjälkbarhet efter två mot hvarandra vinkelräta riktningar. Sannolikt förefinnes spjälkbarhet också efter andra riktningar i samma längszon, ehuru de icke äro lika goda och icke heller kunde mätas på goniometern. Utom de redan nämnda spjälkningsriktningarna märkes en otydlig spjälkbarhet, vinkelrät mot de båda först beskrifna. Ehuru denna spjälkbarhet var föga framträdande för blotta ögat, gaf den en någorlunda god reflex på goniometern, så att mätningarna endast med c:a 4′ skiljde sig från en rät vinkel. På grund af de observerade spjälkningsriktningarna kunna vi med bestämdhet säga, att mineralet är rombiskt eller tetragonalt. Mineralets hårdhet är låg, endast 2—2 1/2. Det är så pass sprödt, att det med lätthet låter pulverisera sig i agatmortel, men det kännes mildt vid skrapning med knif och gifver i ristan ett svart pulver, medan ristans botten blir glänsande, hvilket tyder på en viss grad af plasticitet. Som redan blifvit antydt, är strecket svart och matt eller har en svag gråaktig glans. Mineralets specifika vikt bestämdes genom vägning i luft och vatten till 7,22.

Upphettadt i slutet rör dekrepiterar mineralet ej, utan smälter lugnt redan i den lysande bunsenlågan; ej ens en till hvitglödgning stegrad temperatur framkallar något sublimat. Vid upphettning i öppet rör märkes SO_2- och Selenlukt, hvarjämte ett svagt antimonbeslag bildas. På kol för blåsrör erhålles ett starkt beslag, som längre från profvet är hvitt, närmare profvet gult, och blir grannrödt vid behandling med KJ + S. Om mineralet smältes på kol invid en pärla borsyreglas, bildas endast ett helt svagt, hvitt beslag (som mikrokemiskt gaf reaktion för Sb men ej för As). Heparreaktion erhålles synnerligen lätt. Genom en långvarig upphettning på kol för blåsrör afdrifvas mineralets öfriga beståndsdelar, så att endast ett litet silfverkorn blir kvar.

Allt material till den kemiska analysen erhölls af ett enda stycke, som mätte c:a 0,5 × 0,5 × 1 *cm.* Specifika vikten är bestämd på en del af det analyserade mineralstycket. Det syntes klokare att till analys använda en mindre mängd sorgfälligt med loup genommönstrad substans än att taga en större mängd, som icke kunde erbjuda samma garantier för renhet. Analys I utfördes på 107 mg, hvilka enligt JANNASCH metod upphettades i en brom-kolsyre-ström, hvarvid de flyktiga produkterna uppfångades i med vatten utspädd klorvätesyra, hvilken vätska blifvit försatt med något vinsyra. Separationen af flyktiga och icke flyktiga metallbromider var fullständig, men analysen tillät icke bestämmandet af S och Se. För Analysen II behandlades 248,8 mg substans med rykande salpetersyra. Uppslutningen förlöpte också på detta sätt lätt och fullständigt. Ur den erhållna klara lösningen fälldes Ag med HCl, S med Ba, öfverskottet Ba med H_2SO_4 och Se med SO_2. Hvardera $BaSO_4$-fällningarna gjordes i utspädd lösning och voro fria från Pb och Se. I filtrater efter Se fälldes Pb som sulfat under tillsats af alkohol, hvarefter de öfriga metallerna bestämdes på vanligt sätt. Tyvärr sprang den porslinsdegel, i hvilken SO_4-fällningen glödgades, hvarför Pb icke bestämdes i Analys II, likaså misslyckades Sb-bestämningen i detta prof. Analysernas resultat framställas i följande tabell.

Analysens n:r	I.	II.	I + II.		
Använd mängd	107,0 mg	248,8 mg	—		
Pb	43,83	—	43,83	0,2118	0,2663
Ag	1,19	0,58	0,88	0,0041 [1]	
Cu	3,21	2,09	2,65	0,0209 [1]	
Zn	0,82	0,17	0,49	0,0075	
Fe	0,78	1,69	1,23	0,0220	
Bi	25,60	27,25	26,43	0,1268	0,1710
Sb	5,30	—	5,30	0,0442	
S	—	15,93	15,93	0,4969	0,5344
Se	—	2,97	2,97	0,0375	
		Summa:	99,71	%	

Den kemiska analysen gifver atomförhållandet $R_1^{II}R_2^{I} : R^{III} : SSe = 1{,}500 : 0{,}963 : 3{,}003$. Mineralet kan alltså tillskrifvas

[1] Beräknadt motsvara R^{II}.

formeln $Pb_3Bi_2S_6$ eller $3PbS.Bi_2S_3$, där en del Pb är isomorft ersatt af Ag, Cu, Zn och Fe samt en del Bi af Sb och slutligen en del S af Se.

Mineral med en sammansättning snarlik Iilijärvi-mineralet äro beskrifna från ett par fyndorter. Så har RAMMELSBERG[1] 1862 publicerat en analys af ett mineral från Hvena koboltgrufva i Närke, hvilken, sedan 5,61 % koboltglans och 3,67 % kopparkis afräknats från de funna analystalen, mycket nära öfverensstämmer med formeln $3PbS.Bi_2S_3$. RAMMELSBERGS redogörelse för mineralets fysiska egenskaper är tyvärr mycket knapp, i det han angifver sp. v. 6,145 samt säger, att mineralet liknar antimonglans. Han synes dock förutsätta, att SÄTTERBERGS[2] beskrifning på kobellit, $2PbS.Bi_2S_3$, från samma fyndort gäller äfven för det år 1862 analyserade mineralet. SÄTTERBERG åter skildrar sitt mineral som glänsande, mörkgrått, likt den i handeln förekommande antimonsulfiden, men med starkare metallglans. Brottet är stråligt, hårdheten låg. Streck och pulver rent svarta. Sp. v. 6,29 — 6,32.

H. F. och H. A. KELLER[3] hafva analyserat ett mineral med sammansättningen $3PbS.Bi_2S_3$, där en del Pb är ersatt af Ag. De gifva emellertid ingen annan beskrifning än att mineralet har stålgrå färg och metallglans samt är finkornigt och gifver ett mörkgrått till svart streck. Senare gaf H. F. KELLER[4] åt detta mineral namnet Lillianit efter dess fyndort Lillian Mine i Californien. Slutligen har G. LINDSTRÖM[5] 1889 analyserat ett mineral med formeln $3PbS.Bi_2S_3$, hvilket påträffats vid Gladhammar i Kalmar län. Detsamma hade Sp. v. = 7,00 — 7,07 och liknar i så hög grad Bjelkit från Nordmarken, att LINDSTRÖM på grund af utseendet tog detsamma

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[1] Journ. Pr. Chem. 1862, s. 340.
[2] Kgl. Vet. Ak. Afh. Stockholm. 1839, s. 188. Pogg. Ann. LV. 635.
[3] J. Am. Chem. Soc. 7, 1885, s. 194. Neues Jb. f. Min. etc. **2**, 1886, 79.
[4] Zeitschr. für Krystallographie. **17**, 1889, s. 67.
[5] Geol. För. Förh. XI, 1889, s. 171.

för Bjelkit; det är stängligt, blygrått till tennhvitt och starkt glänsande.

Af alla dessa tre mineralfynd liknar mineralet från Gladhammar mest det af författaren undersökta mineralet, i det att såväl alla omnämda yttre egenskaper som den specifika vikten öfverensstämma. LINDSTRÖM säger icke, om den ringa mängd material, han haft att tillgå, tillåtit honom att göra något prof på Selen, hvilket element väl kunde tänkas vara tillstädes i ett mineral med den höga specifika vikt, som han uppmätt. RAMMELSBERGS mineral hade sp. v. = 6,145 (eller enl. SÄTTERBERG, om verkligen, som RAMMELSBERG tyckes tro, samma mineral beskrifvits af denne, 6,29—6,32). Denna sp. v. är rätt sannolik hos ett mineral, som liksom RAMMELSBERGS består af ungefär hälften $3PbS.Bi_2S_3$ och hälften $3PbS.Sb_2S_3$, Boulangeritsaltet, ty om antimonföreningen har en sp. v. af 5,75—6,00, så kan ur blandningens funna sp. v., 6,145, det i densamma ingående Bi-saltets sp. v. beräknas till 6,30—6,55 (eller om SÄTTERBERGS värde lägges till grund för kalkylen 6,60—6,85). KELLERS mineral, Lillianiten, är, som redan framhållits, ofullständigt beskrifvet. Genom sin korniga struktur skiljer det sig emellertid från de öfriga, trådiga, mineralen.

Till följd af att kännedomen om de karakteristiska egenskaperna hos de omnämda mineralen är alltför bristfällig, är det omöjligt att med full säkerhet afgöra, om de alla höra till ett och samma mineralspecies, eller om det existerar flera mineral med den kemiska formeln $3PbS.Bi_2S_3$. Det synes på grund af det föregående mycket sannolikt, att Iilijärvimineralet och Gladhammar-mineralet tillhöra samma species, medan Hvena-mineralets afvikande specifika vikt kan gifva skäl till tvifvel, om det bör sammanföras med dem eller ej.

Mahända kunde det vara skäl att utbryta dessa trådiga mineral till ett nytt mineralspecies, skildt från den originala Lillianiten. Då emellertid samtliga här diskuterade mineral äro till sin kristallform ofullständigt kända, föredrager författaren att undvika att betunga mineralogien med ett nytt mineralnamn och låter i likhet med DANA[1] m. fl. namnet Lillianit tillsvidare omfatta alla mineral med typformeln $3PbS.Bi_2S_3$. Förf. vill alltså benämna det här beskrifna nya mineralfyndet endast med ett varietetsnamn, selenhaltig Lillianit.

8. Blyglans från Uskela.

I Uskela socken har sedan 1825 en liten förekomst af blyglans varit känd; vid en analys af detta mineral befanns detsamma äga en anmärkningsvärdt hög halt af silfver samt af antimon. Analysen utfördes på 0,8 gram till utseendet alldeles rena spjälkstycken från det inre af en grofspatig blyglansklump.

Blyglans från Uskela.

Pb	83,21 %
Ag	0,74 »
Fe	0,23 »
Sb	0,90 »
S	13,63 »
Gångart	1,78 »
	100,49 %

9. Titanit från Nuolanniemi.

På ett par stuffer, hvilka af fil. mag. PETRA insamlats i Nuolanniemi fältspatbrott i Impilaks socken, sitta 0,5—3 *cm* stora kristaller af ljusbrun titanit tillsammans med djupsvart, kristalliserad wiikit, kvarts, fältspat och svart glimmer. Titanitkristallerna begränsas af *c* (001), *m* (110) och *n* (111) samt visa tydliga genomgångar parallellt med *n*. Ytorna äro råa, men tillåta dock mätning med reflexionsgoniometer.

[1] System of Mineralogy. 6th Edition. New York 1900.

	Observ.	i DANAS Mineralogy.
(001):(111)	38° 22′	38° 16′
(111):(1$\bar{1}$1)	43° 32′	43° 49′
(111):(110)	27° 23′	27° 14′

Mineralets specifika vikt bestämdes med TOULETS lösning och simmare till 3,591. Denna specifika vikt är något högre än för normal titanit och öfverensstämmer med eucolit-titanitens,

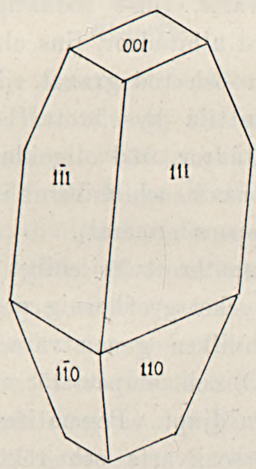

Fig. 1. Titanit från Nuolanniemi.

hvarför en halt af sällsynta jordarter är sannolik, så mycket mera som mineralet förekommer tillsammans med wiikit. Ett af Prof. G. EBERHARD[1] utfördt prof på Sc i detta mineral gaf endast spår, medan yttrium påvisades i tämligen riklig mängd.

10. Wiikit och Loranskit från Impilaks.

Fyndorterna.

Vid Ladogas norra strand har på talrika ställen anträffats grofkornig pegmatit, ur hvilken fältspat blifvit bruten. Inom Mursula och Hunttila byars område i Impilaks socken

[1] Se anm. sid. 1536.

befinna sig flera sådana fältspatbrott, af hvilka de mest betydande äro Lokansaari och Nuolanniemi. Dessa äro belägna på Hunttila bys mark. Det förstnämnda på ön Lokansaari SW om byn; det senare på Nuolanniemi udde S om byn.

Ramsay[1] räknar pegmatiten i denna trakt till de yngre arkäiska graniterna (Sederholm), emedan den visar spår af bergstryck. Han skiljer mellan två typer af pegmatit. Den ena, till hvilken hör Pellotsalo och Mursula byars pegmatitbrott, består af kvarts, ljust rödaktig, hvit eller ljusgrå enkel mikroklin med albitådror, ljus oligoklas, färglös glimmer, svart turmalin och röd granat. Den andra typen, till hvilken räknas Hunttila bys brott, består af kvarts, röd mikroklin med albitådror, röd oligoklas och svart glimmer; den för ställvis monazit och mineral innehållande sällsynta jordarter (wiikitgruppens mineral).

Lokansaari fältspatbrott är enligt Lisitzin[2] anlagdt på en glimmerfattig, mycket grofkornig pegmatit, som bildar en 13 *m* bred gång, hvilken genomtvärar en hornblendegneis, som stryker N 10° O och stupar 75° mot N 80° W. Själfva brottet är 35—45 *m* djupt. Pegmatiten innehåller röd ortoklas, grå kvarts, rosenkvarts och röktopas i ringa mängd, biotit, något muscovit, klorit och svafvelkis jämte euxenit (wiikit) i tre skilda färg- och strukturmodifikationer: en brun, amorf, en svart kristallinisk och en svartbrun med spår till kristallform. Brofeldt[3] beskrifver härifrån biotit i flagor om 0,5 *m* i diameter, samt magnetit, pyrit, klorit, granater samt obetydliga kvantiteter af gul, vaxlik euxenit. Ramsay tillägger till förteckningen på mineralen från denna fyndort monazit och chalkopyrit.

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[1] Wilhelm Ramsay und Allan Zilliacus. Monazit von Impilaks. Öfv. af Finska Vet. Soc. Förh. B. XXXIX. Helsingfors 1897.

[2] G. R. Lisitzin. Några geologiska iakttagelser gjorda i trakten norr om Ladoga sjö sommaren 1889. Medd. från Industristyrelsen i Finl. XIV. Helsingfors 1891, s. 127.

[3] A. Brofeldt. Anteckningar som biträde vid geologiska kartläggningar. Manuskript tillh. Geologiska Kommissionen.

Nuolanniemi fältspatbrott på sydsidan af halfön med samma namn är det största i trakten, enligt BROFELDT 8—10 *m* bredt och 200 *m* långt, deladt i flera afdelningar, hvilka alla gå till ett betydligt djup. Pegmatit-gången stryker N 45° W. Enligt TRÜSTEDTS karta [1] genomsätter pegmatiten här granitgneis. Utom pegmatitens vanliga mineral, mikroklin, kvarts, oligoklas och svart glimmer i stundom stora kristaller, hafva här påträffats gul och svart wiikit samt titanit.

Historik.

Sedan det genom LISITZINS berättelse var kändt, att uti fältspatbrotten vid Hunttila by i Impilaks påträffats ett Euxenit-liknande mineral, besökte prof. RAMSAY 1894 dessa trakter och medförde till Mineralkabinettets samlingar därifrån talrika stuffer, hvilka han förevisade vid ett af Geologiska Föreningens i Helsingfors möten år 1895. Utom monazit demonstrerade han tvenne tantal- och niobrika mineral, af hvilka han påträffat det ena vid Lokansaari, det andra vid Nuolanniemi. Det förra omnämnde han vid sitt föredrag som ett »euxenitartadt mineral», medan han åt det senare gaf namnet »wiikit» efter professorn i mineralogi vid universitetet i Helsingfors F. J. WIIK.

År 1896 beskref M. MELNIKOFF [2] ett nytt mineral, som af PFLOUG hittats i kvarts från Impilaks, och kallade det loranskit efter A. M. DE LORANSKI, föreståndare för Bergsinstitutets i Petersburg mineralogiska museum. Detsamma beskrifves af MELNIKOFF på följande sätt: Det är svart och har en halfmetallisk glans, men blir i tunnslipadt preparat genomskinligt med en gulgrön färg, hvarvid det är optiskt isotropt. Strecket är grönaktigt grått. H = 5, Sp. v. = 4,6. Mineralet löste sig ofullständigt i saltsyra. Analysen [3] gaf: glödgn.-

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[1] O. TRÜSTEDT. Die Erzlagerstätten von Pitkäranta am Ladoga See. Bull. Comm. géol. de Finlande. N:o 19. Helsingfors 1907.

[2] MELNIKOFF. Loranskite, Nouvelle espece minérale. S:t Petersbourg 1896.

[3] Analysen utförd tillsammans med NIKOLAJEFF. Verh. der Russich-K. Mineralog. Ges. Bd XXXV. Protokollen sid. 12. S:t Petersburg 1897.

förlust 8,15 %, Ta_2O_5 47,00, Y_2O_3 10,00, Ce_2O_3 3,00, CaO 3,30, FeO c:a 4,00, ZrO_2 öfver 20 %, S obetydligt, Mn och Ti saknas. Svafvelhalten angifves som ett speciellt karakteristiskt kännemärke för mineralet, hvarigenom det skiljer sig från alla andra niobotantalat, ty den gifver sig lätt tillkänna, emedan H_2S utvecklas, om mineralet öfvergjutes med syra.

År 1897 trycktes resultaten af Ramsays och Zilliacus undersökning af Monazit från Impilaks, hvarvid de äfven berörde förekomsten af euxenitartade mineral tillsammans med monaziten.

I Proceedings of the Royal Academy för 1908 redogör W. Crookes för en analys af »wiikit», hvilken visar en enastående hög Scandiumhalt af öfver 1 %. Det af Crookes undersökta mineralet beskrifves af honom såsom svart, amorft, H = 6, Sp. v. = 4,85, osmältbart för blåsrör. Det angripes något af mineralsyror, sönderdelas vid uppslutning med $HKSO_4$. Vid upphettning afgå helium, vatten, H_2S jämte ett obetydligt hvitt sublimat. Gaserna afgå med explosiv häftighet. Efter dekrepitationen synas på fragmenten punkter, hvilka vid stark förstoring visa sig vara små hexaedriska hålrum. Glödningsförlusten är 5,83 %. Crookes analys är aftryckt på pag. 1541. (Enligt uppgift af Mag. Petra, som levererat åt Crookes materialet till hans undersökning, härstammar det af Crookes analyserade mineralet från Lokansaari.) Wiikiten och dess kemiska sammansättning omnämnas äfven i Crookes »On Scandium» i Phil. Trans. of the R. Soc. of London. Ser. A., vol. 209. London 1908.

Slutligen finnes i Szilard's[1] »Tabeller öfver Uranium- och Thoriummineral» (Le Radium 6, Paris 1908, s. 233) loranskiten upptagen med en halt af 17,6 % Thorium.

Crookes uppgifter angående den af honom analyserade »wiikitens» mineralogiska egenskaper visa på en stor likhet

[1] Originalet ej tillgängligt för förf., som tagit uppgiften ur en rysk öfversättning af Szilard's Tabeller, hvilken utgifvits af Odessa-afdelningen af K. Ryska Tekniska Sällskapet. Odessa 1910.

med de prof, hvilka RAMSAY förevisat såsom »euxenitartadt mineral», samt med »loranskiten», sådan MELNIKOFF beskrifvit densamma. Oaktadt MELNIKOFFS analysresultat i viktiga delar afvika från CROOKES', kan man icke undgå misstanken, att de båda från Impilaks socken härstammande profven tillhöra samma mineral. Man kan dock icke af i litteraturen tillgängliga uppgifter få bestämdt besked rörande identiteten af ifrågavarande fynd. Författaren har därför företagit sig att med ledning af Universitetets i Helsingfors samlingar, hvilka innehålla ett mycket stort antal stuffer af de ifrågavarande tantal- och niobhaltiga mineralen från Impilaks, försöka gifva ett bidrag till kännedomen af deras natur och ställning till hvarandra.

Mineralogisk undersökning.

Tantal-niobmineralen från Impilaks visa en variation i såväl yttre utseende som specifik vikt och kemisk sammansättning, såsom i det följande skall visas, men hafva dock så stor öfverensstämmelse sins emellan, att endast en noggrann undersökning kan ådagalägga, i hvad mån det är berättigadt att bland dem särskilja olika mineralspecies. Materialet från Nuolanniemi visar flera färgvarieteter, från ljusgul genom gulbrun och gråbrun till svart, medan från Lokansaari insamlats endast svarta och mörkbruna varieteter, så när som på en enda stuff, där i svart wiikit uppträdde gula ådror. Af de olika varieteterna valdes ett antal typiska exemplar, för hvilkas undersökning nedan redogöres.

Nuolanniemi typer.

Typ a. Mineralet bildar oregelbundna klumpar af ett amorft utseende med en något matt, hartsartad glans på den mussliga brottytan. Färgen är halmgul och strecket hvitgult. Mycket tunna preparat visa, att mineralet ej är fullständigt homogent, utan att det består af en färglös, klar substans och en grumlig, ogenomskinlig. Färglösa partier bilda en grundmassa, som utfyller mellanrummen mellan de till volym öfvervägande grumliga delarna, hvilka göra intryck af att vara med inneslutningar uppfyllda partier af den klara substansen. De grumliga partierna äro i stort taget jämnt fördelade öfver preparatets yta samt hafva en synnerligen oregelbunden gräns gentemot de ljusa delarna; där emellertid en gräns synes tydligare, bildar den gärna en mot den klarare massan konvex kurva, så att man får intrycket, att de ogenomskinliga partierna äro samlade kring vissa centra. Den färglösa substansen är helt och hållet isotrop, medan de grumliga partierna visa en svag antydan till dubbelbrytning. Sp. v. = 3,844, H = 4,5. Vid upphettning för blåsrör i pincett dekrepiterar mineralet nästan ej alls samt smälter med svårighet i fina spetsar till ett svart, matt glas. Då finmalet pulver af mineralet på vattenbad digereras med klorvätesyra, färgas syrelösningen på en liten stund vackert gul, och mineralet tyckes ganska snart vara fullständigt sönderdeladt af syran under afskiljande af en färglös återstod. Lösningen visar stark titanreaktion med vätesuperoxid. Mineralet gifver en kraftigt urangrön fosforsaltpärla. Dess boraxpärla gifver med saltsyra en klar lösning, hvilken vid kokning med tenn antager en grumlig blå niobfärg. Enligt d:r G. EBERHARD[1] innehåller *a* några procent sällsynta jordarter, medan scandium just jämt kan påvisas. Vattenhalten i mineralet, bestämd enligt PENFIELDS metod, var 10,77.

Typ b. Form, brott och glans som *a*. Färgen gulaktigt grå. Strecket gult. Mineralet förhåller sig som *a* vid upphettning för blåsrör och vid behandling med syror samt gifver samma reaktioner som *a*. Specifika vikten är 3,78. Vattenhalten 11,14 %. Enligt EBERHARD står *b* mellan *a* och *c* i afseende å Sc-halt samt halten af sällsynta jordarter.

Typ c. Form, brott och glans som *a*. Färgen mörkgrå, strecket brungult. I andra afseenden mycket lik *b*. Spec.

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[1] Prof. G. EBERHARD har haft godheten att spektralanalytiskt undersöka särskilda af förf. till honom sända prof af wiikit-mineralen med afseende å deras halt af scandium och sällsynta jordarter.

vikt = 4,02. Vatten = 6,96 %. Enligt EBERHARD är halten af sällsynta jordarter något större än hos *a*, och Sc kan just påvisas. Vid upphettning för blåsrör ljusnar mineralet samt antager *a*:s färg och bibehåller den ljusare färgen efter afsvalnandet.

Typ d. Mineralet bildar de i fig. 5 afritade kristallerna. Färgen är svart och glansen stark på den friska, mussliga brottytan. Strecket ljusbrunt. Tunnslipade preparat blifva så svagt genomskinliga, att mineralets struktur icke kan mikroskopiskt studeras. Sp. v. = 3,95. Vattenhalten 8,09. Vid upphettning dekrepiterar mineralet obetydligt mera än *a*, *b* och *c* samt är liksom dessa efter glödgning gul, smälter med svårighet för blåsrör till ett svart, matt glas. EBERHARD uppger Sc-halten till mindre än 0,01 %.

Typ e. Mineralet bildar en några *cm* tjock kaka, på hvilkens båda gränsytor synes en brun hartslik substans lik *b*. Samma substans skjuter oregelbundet och obestämdt begränsade åderlika flikar in i mineralmassan. Glansen är något metallisk på friska brottytor, som visa en finkristallinisk struktur. Färgen svart. Strecket är svart med en grönbrun ton. Tunnslipade preparat visa en mörk massa med ljusa, genomskinliga, färglösa punkter, hvilka ställvis ordna sig till rader och större grupper, hvarvid de förena sig till oregelbundna ådror. Den genomskinliga substansen är isotrop. Fosforsaltpärlan är smutsigt grågrön till färglös, alltså är uran ej i större mängder närvarande. Boraxpärlans lösning i HCl gaf stark niobfärg med tenn. Mineralet dekrepiterar ej vid upphettning och blir efter glödgning visserligen betydligt ljusare, men icke så ljusgult som *a*—*c*. Efter upphettningen är färgen ojämn, fläckig. Mycket fina spetsar smälta med svårighet till svart, matt glas. Sp. v. = 4,817. H_2O = 4,30 %. Pulver af *e*, som 48 timmar digererats med saltsyra, var mörkfärgadt och synbarligen till största delen oangripet, men lösningen blef svartgröngul och gaf en tydlig titanreaktion med H_2O_2. EBERHARD uppgifver, att denna varietet innehåller åtminstone några tiondedels procent scandium.

De ofvan skildrade wiikit-varieteterna från Nuolanniemi förekomma mest på olika stuffer, skilda från hvarandra. Som redan under *e* omtalats, finnas dock exempel på att de förekomma tillsammans. Så visar en stuff ett nätverk af ljusgul wiikit (*a*) såsom ådror i en svart massa, lik *d*. En del af stuffen intages af förhärskande *a* med kantiga brottstycken af *d*, medan i den andra ändan *d* bildar hufvudmassan, i hvilken *a* inträngt på till största delen parallella springor. *a* är här ögonskenligen att anse för en omvandlingsprodukt af *d*.

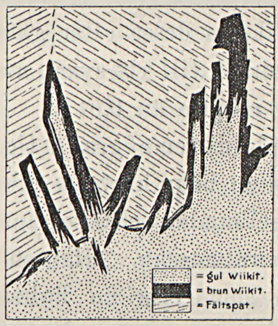

Fig. 2. Wiikit från Nuolanniemi. Naturlig storlek.

Fig. 2 åter afbildar ytan af en stuff från Nuolanniemi, där de centrala delarna af wiikiten visar *a*:s gula färg, medan den yttre zonen är mörkbrun och mest liknar brun wiikit (*h*) från Lokansaari; vi hafva här zonar sammanväxning.

Lokansaari typer.

Typ f. Mineralet har för det mesta en svart, starkt glänsande, splittrig brottyta med metallartad glans, men förekommer tillsammans med och öfvergår omärkligt i en något mindre glänsande, mindre splittrig, asfaltlik varietet. Båda dessa hafva likadana gråsvarta streck, hvilka svagt, men tydligt stöta i brunt och äro betydligt ljusare än mineralet. Ofta är mineralet begränsadt af kristallytor. Sp. v. = 4,666. Tunnslipade preparat blifva icke genomskinliga. Mineralet dekrepiterar rätt häftigt och springer därvid sönder till stycken, stora nog för att ånyo kunna upphettas i pincett för blåsrör, hvarvid de ej mera dekrepitera, utan efter glödgning antaga en smutsigt gul färg lik *a* eller *b*. Fina spetsar smälta med stor svårighet till ett matt, svart glas. Pulver af *f* sönderdelas långsamt af HCl, dock synes sönderdelningen vara fullständig, så att lösningen blir kraftigt gul (uran) samt återstoden färglös. Vid klorvätesyrans inverkan utvecklas H_2S, som märkes på lukten. Pulver, som fick stå med stort öfverskott af HCl på vattenbad flera timmar, afgaf äfven vid slutet af denna tid nog H_2S för att gifva tydlig lukt, hvilket tyder på att sulfiden finnes i en långsamt sönderfallande förening eller mycket intimt inblandad. Lösningen gifver mörk titanbrun färg med H_2O_2. Fosforsaltpärlan blir vackert grön (uran). Boraxpärlans lösning i stark klorvätesyra gifver niobfärgning vid kokning med tenn. $H_2O = 5,09$. Enligt EBERHARD innehåller *f* rikligt med sällsynta jordarter, i synnerhet yttrium. Scandium finnes mera än hos *a*—*c*, men han tror i alla fall icke, att profvet kan innehålla så mycket som 1 %.

Typ g. Mineralet har en stark diamantglans och mörkbrun färg. Brottet splittrigt som hos de starkast glänsande delarna af *f*. Gränserna låta för det mesta tyda sig som kristallbegränsning. Strecket är ljusgult. Tunnslipade preparat blifva helt och hållet genomskinliga och äro isotropa, men visa i alla fall olikartade delar. Hufvudmassan är under mikroskopet brunfärgad. Den genomdrages i flera riktningar af nästan färglösa ådror, hvilka emellanåt förefalla att vara ordnade som spricksystem, emellanåt mera oregelbundna till form och riktning. Den ljusa massans uppträdande tyder på att den representerar en längre gången omvandling än den färgade, som intar en centralställning i förhållande till det ljusa nätverket. Sp. v. = 4,55. $H_2O = 4,59$. Vid upphettning förhåller sig mineralet alldeles som *f*. Enligt EBERHARD kan Sc uppvisas hos mineralet, och innehåller detsamma mycket mera af sällsynta jordarter än *a*—*c*.

h. Mineralet har en asfaltlik till hartsartad glans, mattare än *f* och *g*, och föga splittrigt brott. Färgen är växlande, svart, brun, gul, stundom oregelbundet fläckig i brunsvarta toner. Den gula färgen är mest sällsynt, men på en stuff synas alla färgvarieteter invid och långsamt öfvergående i hvarandra. Strecket visar en med mineralets färg korresponderande variation från svartbrunt och brunt till hvitgult. Mineralet dekrepiterar betydligt mindre häftigt än *f*, men förhåller sig för öfrigt vid upphettning liksom detta mineral. Hos den svarta varieteten är Sp. v. = 4,23, H_2O = 6,96.

Den mineralogiska undersökningen visar, att vi både på Nuolanniemi och på Lokansaari hafva en af ett pigment färgad isotrop substans. Pigmentet är än svart, än brunt och synes lätt förstöras vid mineralets omvandling. Samtidigt som färgen blir ljusare, faller mineralets specifika vikt och stiger dess vattenhalt. Vattenhalten är ungefärligen omvändt proportionell med specifika vikten. Af mineralets kristallform kan slutas, att dess substans vid kristallisationen var anisotrop, så att hvarken den svarta eller den gula wiikiten är det ursprungliga mineralet. Vattenhalten kännetecknar sig redan genom sina växlande värden såsom sekundär. Mineralets förekomst midt uti oförvittrad fältspat samt tillsammans med andra mineral, hvilka eljest lätt förvittra, men här äro oförvandlade, visar, att detsamma synnerligen lätt omvandlar sig. Det är i allmänhet regeln, att mineral, innehållande större mängder sällsynta jordarter, icke anträffas med den molekulära struktur, som svarar mot deras kristallform, utan att de omvandlats till en »amorf», vanligtvis vattenhaltig substans. Detta förhållande blir särskildt anmärkningsvärdt t. ex. hos en af frisk epidot på alla sidor kringvuxen kärnkristall af allanit. Sedan numera blifvit bekant, att element finnas, hvilka »radioaktivt» sönderfalla, är det naturligt att tänka sig, att det främst är närvaron af dylika, som föranleder ett spontant sönderfallande af mineralets kristallbyggnad.

Kemisk analys.

I den mineralogiska beskrifningen af de särskilda typerna ingå redan flera uppgifter angående deras kemiska sammansättning. Tvenne fullständiga analyser finnas dessutom. N:r I, som är utförd af CROOKES, gjordes på material, som efter allt att döma är identisk med typen *f* från Lokansaari, medan N:r II, af HOLMQUIST,[1] hänför sig till typen *a* från Nuolanniemi.

	I.		II.
SiO_2	16,98		8,75
TiO_2	23,36		29,58
ZrO_2	(ngt Zr ingår i TiO_2)		(saknas sannolikt)
ThO_2	5,51		—
Nb_2O_5	(ngt Nb ingår i Ta_2O_5)		23,67
Ta_2O_5	15,91		(saknas sannolikt)
Ceriumjordar	2,55		4,06 (sällsynta jordar)
Yttrium- »	7,64		
Scandium- »	1,17		—
FeO	15,52		7,51 (Fe_2O_3)
UO_3	3,56		7,37
UO_2	—		1,86
Al_2O_3	—		0,74
Mn_3O_4	—		1,28
CaO	1,97	(CaO, etc.) differens	4,86
Fällning med H_2S	—		1,06
H_2O	5,83		11.06 (gl. förlust)
	100,00		101.80

Ingendera af dessa analyser torde gifva alldeles noggranna tal, men man kan i alla fall af dem bedöma den sannolika sammansättningen hos mineralet. CROOKES analys gifver SiO_2 : $TiO_2 + Ta_2O_5$ nära 1 : 1 samt $TiO_2 + SiO_2 + ThO_2 + (NbTa)_2O_5$: $FeO + CaO +$ sällsynta jordarter och uranium ungefär 2 : 1, hvarför mineralet bör betraktas som en med titaniten analog

[1] Analysen är utförd på Kemiskt-tekniska byrån i Stockholm år 1895. På analysattesten finnes antecknadt, att profvet af ERDMANN och LANGLET befunnits icke innehålla helium samt att analysen på grund af de svårigheter, densamma erbjudit, icke gifvit noggranna resultat.

dubbelförening $FeTiSiO_5$, där TiO_2 ersättes af Nb_2O_5, SiO_2 af ThO_2, samt där som baser vid sidan af Fe uppträda hufvudsakligen sällsynta jordarter, utan att det är kändt, på hvilket sätt dessa isomorft inträda i molekylen. Sannolikt är, att R_2^{III} till en del ersätter en grupp FeSi likasom i pyroxensilikatet $R^{II}(FeAl)_2SiO_6$, medan en annan mindre del R_2^{III} ersätter 3 R^{II}. HOLMQUISTS analys låter sig förenas med denna uppfattning af wiikitens sammansättning, och äro öfverensstämmelserna i hufvuddragen mellan dessa båda analyser i betraktande af svårigheten att utföra dem så stora, att de blifva ett starkt stöd för den åsikten, att de båda analyserade substanserna höra till samma mineralgrupp.

Wiikit-mineralen bilda en ny mineralgrupp, som kemiskt står nära å ena sidan titanosilikaten, främst tscheffkinit, från hvilket mineral de skilja sig genom sin NbTa-halt, samt å andra sidan titano- och zirkononiobaten, närmast Polymignit, utan att kunna föras till någondera af dessa mineralgrupper. Det är sannolikt, att bland de af tidigare forskare till dessa båda grupper förda mineralfynden någon del vid noggrannare undersökning, sedan bättre metoder än de nu existerande för åtskiljande af Ti, Nb och Si blifvit utarbetade, skall visa sig höra till wiikit-gruppen. Ett mineral, som tydligen hör hit, är det under namn af »Euxenit från Brevig» af HOFMANN och PRANDTL [1] analyserade mineralet, hvilket bland de som syror uppträdande elementen visar såväl Si som Ti och Nb, samt bland baserna främst sällsynta jordarter och järn jämte aluminium, ty $Nb_2O_5 + TiO_2 : SiO_2$ är, enligt analysen, omkring 1 : 1, och $Nb_2O_5 + TiO_2 + SiO_2$ förhålla sig till baserna ungefär som 2 : 1, då Fe är kalkyleradt som FeO.

Ehuru den mineralogiska undersökningen visat, att alla wiikit-typer bestå af en omvandlad substans, har man all rätt att tro, det de kemiska analyserna äro ett i hufvudsak riktigt uttryck för det ursprungliga materialets sammansättning

[1] Ber: **34**, 1901, 408.

(med undantag af den sekundära vattenhalten). Vi kunna sålunda säga, att det finnes en uranrikare och en yttrium- och scandiumrikare substans. Härmed öfverensstämma äfven resultaten af den spektralanalytiska analysen äfvensom af de kvalitativa profven, hvilka finnas tidigare angifna. Till den uranrikare höra de gula och grå typerna *a* och *c* från Nuolanniemi jämte den svarta kristalliserade från denna fyndort (*d*) samt sannolikt äfven de gula och bruna partierna i *h* från Lokansaari. Som den substans, som allra först af RAMSAY kallats wiikit, hör till *a*, så kunna vi kalla detta uranrikare mineral *wiikit*. Till den andra, yttriumrikare, hör typen Lokansaari *f*, som i likhet med MELNIKOFFS mineral utvecklar H_2S med syror, hvarför de yttriumrikare typerna lämpligen kunna sammanföras under namnet *loranskit*, till hvilket species sålunda typerna *f*, *g* och *h* från Lokansaari samt *e* från Nuolanniemi komma att höra. Då namnet wiikit är det äldre, och då äfven de yttriumrikare varieteterna under detta namn blifvit spridda i utlandets museer samt där beskrifna, föreslår förf., att detta namn bibehålles som gruppnamn för att omfatta alla de nu ifrågavarande mineralen.

Wiikit-mineralens kristallform.

Redan vid den mineralogiska beskrifningen har framhållits, att en del kristaller af hithörande mineral blifvit anträffade. RAMSAY och ZILLIACUS omnämna, att den »euxenitartade substansen» är idiomorf gentemot pegmatitens fältspat. I Universitetets samlingar anträffades mätbara kristaller såväl af loranskit-typerna *f* och *g* från Lokansaari som af typen *d* af wiikit från Nuolanniemi.

Kristallerna voro råa och hade ojämna ytor samt voro delvis svagt deformerade. De bästa kristallerna användes till mätningar med en kontaktgoniometer och gåfvo i nedanstående tabell upptagna resultat. Af mätningarna framgår, att samtliga kristaller otvunget låta hänföra sig till samma rombiska axelförhållande $a : b : c = 0{,}5317 : 1 : 0{,}5046$.

		Lokansaari.		Nuolanniemi.		Beräkn.
		Antal vinklar.	Observ.	Antal vinklar.	Observ.	
a : *x*	100 : 201	1	29°	—	—	27° 47′
x : *x*	201 : 201	—	—	2	122°	124° 26′
e : *e*	101 : $\bar{1}$01	—	—	5	87°	—
a : *e*	100 : 101	—	—	1	46½°	46° 30′
a : *m*	100 : 110	2	29°	1	27°	—
a : *b*	100 : 010	4	89½°	3	90°	90°

De funna värdena afvika icke från de beräknade mera än mätningarnas ofullkomlighet kan förklara.

Kristallerna af loranskit visade kombinationen *a* (100), *b* (010), *m* (110), *x* (201), såsom fig. 3 visar. Wiikitens kristaller voro dels af en liknande typ, fig. 5, med kombina-

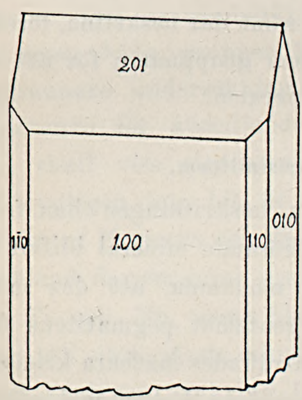

Fig. 3. Loranskit från Lokansaari.

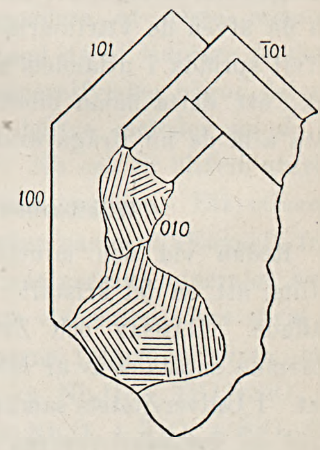

Fig. 4. Wiikit från Nuolanniemi.

tionen *a*, *b*, *m* och *x*, dels hade de en afvikande ändbegränsning, fig. 4, med kombinationen *a*, *b*, *m* och *e* (101).

Påfallande är den långt gående öfverensstämmelsen mellan wiikit-gruppens och samarskitens kristallformer. Dana angifver för detta mineral (101) : ($\bar{1}$01) = 87° och 100 : 110 = 28° 37. Äfven i habitus förefinnes en stor likhet mellan de båda mineralen, såsom framgår vid en jämförelse af figurerna med afbildningen af en samarskit-kristall från Mitchell C:o i DANA's System of Mineralogy samt med BRÖGGERS ritningar af norsk

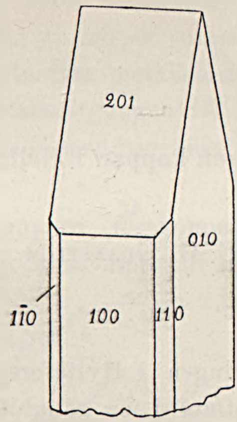

Fig. 5. Wiikit från Nuolanniemi. [2]

samarskit. [1] Denna stora likhet mellan kristallformerna är förvånande, då den sammanställes med olikheten i kemiskt afseende; samarskiten är ett paraniobat, medan wiikiten är ett dubbelsalt, ett siliko-niobotitanat.

[1] Taf. V i Die Mineralien d. südnorw. Granitpegmatitgänge. Videnskabs-Selskabets Skrifter. M.-Naturv. Klasse. 1906, N:r 6. Kristiania 1906.

[2] Originalet till fig. 5 donerades till Universitetet i Helsingfors af mineralhandlaren mag. PETRA, som innehar stora kvantiteter af wiikit. Han meddelade, att på hans föranstaltande af G. A. AAARTOVAARA gjorda försök med en Schmidt'sk elektrometer gifva vid handen, att wiikiten är starkt radioaktiv; de gula varieteterna mångdubbelt starkare än de svarta.

Om fynd af gedigen koppar i Gellivare Malmberg.

Af

C. G. Granström.

Under malmbrytningen i Hvitåforsgrufvan detta år har gedigen koppar påträffats i en gångbildning i malmen, och då det är det första fynd af detta slag i Gellivare Malmberg, torde detsamma vara förtjänt af att offentliggöras.

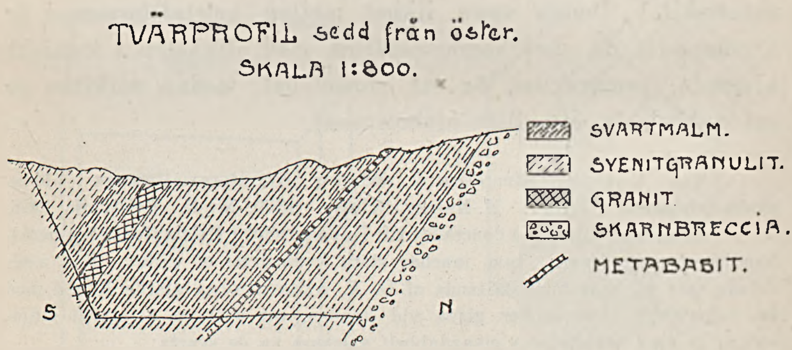

Fig. 1.

Hvitåfors-malmen, tillhörande den grupp malmer, som äro belägna på östra sluttningen af Kaptenshöjden, stryker N 70° V med c:a 50° sidostupning och ligger mellan syenit-granulit i hängandet och skarnbreccia i liggandet. Malmen, svartmalm, är genomsatt af större och mindre granitgångar, förlöpande parallellt med strykningen, samt af en metabasit-gång, som skär snedt öfver malmen emot liggandet. Dess stupning är c:a 45° mot S och med en mäktighet varierande från 0,5—1 *m*.

Metabasiten, som är karakteriserad af prof. A. G. Högbom i beskrifningen öfver Gellivare Malmberg, Geol. För. Förh., häftet 3, 1910,[1] är här af samma typ som inom fältet i öfrigt. Kontakten mellan metabasitgången och omgifvande malm är skölig. Metabasitgången liksom malmen hafva förklyftningsytor parallella med begränsningsytorna samt vinkelrätt däremot.

Den gedigna kopparn förekommer i metabasitgången som krustor med tjocklek upp till några *mm* samt genom-

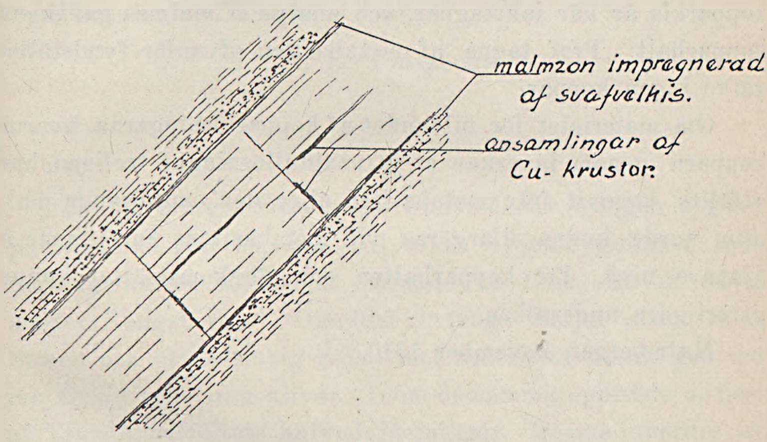

Fig. 2.

skärning af upp till 3 *cm*. Krustorna, som äro sammansatta af xx-individer af upp till 0,1 *mm* storlek, hafva stark metallglans, äro böjliga och smidiga. En del anhopningar hafva skelettliknande utseende.

[1] Analys af typ. metabasit från fältet. Analysen är hämtad från ofvannämnda beskrifning.

SiO_2	52.04 %	CaO	5.33 %	P_2O_5	0.40 %
Al_2O_3	16.28 »	Na_2O	6.41 »	S	0.08 »
Fe_2O_3	6.18 »	K_2O	1.19 »	MnO	0.03 »
FeO	5.69 »	H_2O (+105°)	0.39 »		99.83 %
MgO	4.14 »	TiO_2	1.67 »		

Kopparn påträffades c:a 10 *m* under dagytan dels i metabasitgångens genomgångsytor, företrädesvis i de tvärgående (se fig. 2), dels som små anflog i smärre släppor, äfvensom i friskt brott af metabasiten. Denna impregnation tyckes dock ej sträcka sig längre in än högst 1 *cm*.

Förklyftningsytorna äro förvittrade, och på dessa kan man förutom den gedigna kopparn tydligt iakttaga omvandlingsformen malachit. Idiomorfa xx-er af brokig kopparmalm voro synliga i friskt brott af metabasiten.

På ömse sidor af gångbildningen är malmen tätimpregnerad med svafvelkis till en bredd af c:a 10 *cm*, men ingen kopparkis är här iakttagbar, och analys af malmen gaf ingen kopparhalt. Prof tagna af metabasiten ofvanför fyndstället gåfvo ingen koppar.

Om materialet för bildandet af kopparlösningarna, hvarur kopparn genom inverkan af järnoxidullösningar troligen har utfällts, kommit från metabasiten eller den omgifvande malmen, torde kunna klargöras vid metabasitens anträffande å djupare nivå, där kopparhalten och förekomstsättet kunna ytterligare undersökas.

Malmberget, november 1910.

Till frågan om lagerföljden inom Trondhjemsfältet.

Af

A. E. Törnebohm.

En af Norges Geologiske Undersökelse nyligen utgifven publikation, N:o 56, har till titel: »Fjeldbygningen inden rektangelkartet Rennebus omraade af Carl Bugge, Myntmester, Kongsberg.»[1] Området i fråga börjar strax S om Stören och utbreder sig sedan mot söder hufvudsakligen mellan Örkla och Gula älfvar. Inom detsamma uppträda de flesta af Trondhjemsfältets hufvudafdelningar. Dessas inbördes ordningsföljd har hr Bugge sökt utreda, och därvid har han kommit till ett resultat, som väsentligt skiljer sig från min i mitt arbete om »Centrala Skandinaviens bergbyggnad» (C. S.) framställda uppfattning, hvilken han ock upprepade gånger klandrande omnämner. Då jag emellertid ingalunda känner mig öfvertygad af hr Bugges bevisföring, kan jag ej underlåta att mot den inlägga en gensaga, så obenägen jag än numera är att taga till orda rörande Norges geologi.

Hur väsentlig olikheten mellan Bugges och min uppfattning af lagerföljden är, framgår af omstående jämförelse:

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[1] Karta i skalan 100,000 och åtföljande text.

Törnebohm.	Bugge.
Höilandets grupp,	Gula-gruppen,[1]
Hovin-gruppen,	Stören-gruppen,
Breccia,	Breccia,
Stören-Singsås-gruppen,	(Höilands-skifre),[2]
Brekskiffer-gruppen,	Hovin-gruppen,[3]
Röros skiffergrupp.	Röros-gruppen.

Ännu en annan uppfattning af lagerföljden i samma trakt uttryckes på det i N till bl. Rennebu angränsande bl. Melhus. Dettas färgschema anger följande ordning:

Höilandets grupp,
Hovin-gruppen,
Gula-skiffrarna,
Trondhjem-Stören-gruppen,
Äldsta Trondhjems lag.[4]

Oredan är således fullständig. Det enda, hvarom alla äro ense, är, att Röros-skiffrarna äro äldst, ty de ligga alltid närmast urberget eller seveskiffrarna, samt att Hovin-gruppen är äldre än Höilandets grupp. Dessa båda grupper äro nämligen de enda, för hvilkas åldersbestämning paleontologiska hållpunkter stått till buds. Den förra hänföres numera till etage 5, a, den senare till et. 5, b.[5] Men månne ej ännu nå-

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[1] Motsvarar Brekskiffer-gruppen och Singsås-gruppen, Törnebohm.

[2] Höilands-gruppen inkommer ej på bl. Rennebu, hvarför Bugge ej heller upptager den i sin lagerföljd, men han synes — såsom längre fram skall visas — anse den böra hafva sin plats mellan Hovin- och Stören-grupperna, hvarför jag där insatt den inom parentes.

[3] Bugge använder det äldre skrifsättet »Hovind», hvaremot jag följt det nyare på rektangelbladet Melhus begagnade »Hovin». För likformighetens skull använder jag här endast det senare.

[4] = Röros-skiffer m. m.

[5] Enligt den revision af dessa gruppers fossil, som blifvit företagen af J. Kiær (Norsk geol. tidskr., Bd. I, N:r 3, 1905). Förr antogs Höilands-gruppen tillhöra lägsta öfversilur, et. 6, och Hovin-gruppen et. 4 och 5. Denna Kiærs korrigering inverkar emellertid ej på uppfattningen af lagerföljden, enär Höilands-gruppen fortfarande förblir yngre än Hovin-gruppen.

gon annan god hållpunkt för fastställande af åldersföljden finnes? Jag skall i det följande visa, att så är fallet, men först torde det då vara nödigt att taga en liten orienterande öfversikt öfver förhållandena inom bl. Rennebus nordvästligaste del, där alla de här i fråga kommande afdelningarna finnas.

Låtom oss då tänka oss, att vi vandra från NV mot SO öfver bl. Rennebus nordvästligaste del. För fullständighetens skull må vi dock börja något nordligare på det inom området för bl. Melhus belägna Höilandet. Där träffa vi då Höilandsgruppens skiffrar och fossilförande kalkstenar (et. 5, b). SO om dessa följer Hovin-gruppen (et. 5, a). Lagren inom denna stryka mycket regelbundet NO—SV, stupande i regeln mot SO. De bestå här af gråa skiffrar, lerstenar och sandstenar med underordnade konglomeratlager. Mot SO blifva lagren delvis grönaktiga. Så träffa vi ett lager breccia, ett intressant lager som spelar en betydande roll inom den NV:a delen af Trondhjemsfältet. Om denna breccia säger Bugge alldeles riktigt, att »den bör benyttes som skille mellem Stören- og Hovin-grupperne». Men själf gör han det emellertid ej utan förklarar: »Ved min kartlægning har jeg dog ikke gjennemført saadan adskillelse, da arbeidet vilde blive for vidtlöftigt.»[1] (S. 17.)

SO intill breccielagret gränsar Stören-gruppen. Den består af grönstenar, grönstens-tuffer, gröna skiffrar m. m. samt underordnade lager af kvartsitskiffer. Sedan möter det stora

[1] Ett högst besynnerligt yttrande, då det på bl. Rennebu ej behöfts mer än att följa breccielagret på en nästan rak, omkring 16 *km* lång sträcka. Det var emellertid ett »för vidtlöftigt» arbete för Bugge, hvarför han på kartan utelämnar icke blott breccian, om hvilken han dock — och med rätta — säger, att »den betegner vistnok en diskordans» (s. 17), utan äfven hela gränsen mellan Hovin- och Stören-grupperna, hvilka grupper han målar med en och samma färg, och det fastän de fått skarpt skilda färger på det angränsande bl. Melhus. Men går man *så* tillväga, hvartill skall det då tjäna att utgifva kartor i skalan 1:100 000? På min lilla öfversiktskarta i skalan 1:800 000 finnas breccian och den gräns, som den markerar, utmärkta på hela sträckningen från Levangertrakten till Meldalen, d. v. s. inom en zon som är 10 mil lång och 2 à 3 mil bred.

skifferfält, som KJERULF, och med honom BUGGE, kallat Gulaskiffer. Först träffa vi där en omkr. 500 *m* bred zon af grå fyllit med underordnade lager af svart skiffer, ljus, sockergrynig kvartsit samt kalksten, något kristallinisk och vanligen gråblå, stundom gulhvit. Denna fyllit har jag benämnt Brekskiffer.[1] Öster om denna följer grof, gröngrå till grå, sandstensaktig skiffer med underordnade lager af kvartsig grafitskiffer, hornblendeskiffer, grönstensskiffer m. m. Jag har kallat detta skifferkomplex »Singsås-gruppen» och anser det vara ekvivalent med Stören-gruppen men bildadt på något afstånd från de eruptionscentra, som lämnade denna grupps material.

Dessa äro de hufvudsakliga afdelningarna inom denna del af Trondhjemsfältet. Deras inbördes läge åskådliggöres

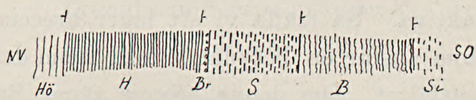

Fig. 1. *Hö* Höilandets grupp, *H* Hovin-gruppen, *Br* Breccia, *S* Stören-gruppen, *B* Brekskiffer-gruppen, *Si* Singsås-gruppen.

på vidstående lilla planskiss, fig. 1. Men hvilken är deras geologiska åldersföljd? Denna kinkiga fråga löser BUGGE till sin egen belåtenhet på ett mycket enkelt sätt. Enär lagerstupningen inom Hovin-gruppen och vidare mot SO är brant sydostlig, så anser han det utan vidare för gifvet, att Hovin-gruppen (et. 5, a) måste vara äldst[2] och de följande grupperna allt yngre och yngre. Han tyckes ej kunna tänka

[1] Efter Brekkammen (C. S., s. 83). I den »English Summary», som är bifogad BUGGES arbete, är emellertid min term »Brek-skiffer-gruppen» återgifven med »Breccia slate group». Men denna öfversättning är fullkomligt oriktig, då min term ej på minsta vis häntyder på breccia, och den är så mycket mer vilseledande, som några rader längre fram i »Summary» termen »Breccia-slate» användes för att beteckna det ofvan omnämnda breccielagret.

[2] Under Hovin-gruppen har BUGGE endast Röros-gruppen. Då kan man fråga, om det är hans mening, att denna skall representera hela kambrium och större delen af undersiluren, eller om han anser, att någon stor lucka i lagerföljden här skall finnas?

sig möjligheten af omböjningar och inversioner; det hela blir för honom en enkel och kontinuerlig lagerföljd, och yngst blifva då Gula-skiffrarna, hvilka han anser »possibly of Devonian age» (sid. 41.)[1] Men härvid möter en liten svårighet. I nordväst gränsar Hovin-gruppen till, och man kan säga öfvergår uti, Höilands-gruppen, hvilken vi veta är yngre. Skulle BUGGES uppfattning af åldersföljden vara riktig, då måste Höilands-gruppen komma in äfven på den motsatta, SÖ:a, sidan af Hovin-gruppen mellan denna och den enligt lagerstupningen öfverliggande Stören-gruppen. BUGGE gör också ett försök att där få in den genom följande något dunkla yttrande (s. 16): »De höieste niveauer[2] i Hovin-gruppen er derimot tildels udviklet som graagrönlige lerskifre med kalkstenslag, hvilke af BRÖGGER er beskrevne fra Höilandet under navn af Höilands-gruppen med fossiler tilhörende et pentamerus oblongusniveau. Lerskifre af denne karakter har jeg fundet umiddelbart nordvest for variolitdraget[3] mellem Kroketvandene og L. Hulsjö.» Detta kan jag ej förstå annorlunda, än att BUGGE vill ekvivalera Höilands-gruppen med den del af Hovin-gruppen, som ligger närmast Stören-gruppen. Men något sådant har BRÖGGER ej gjort. Där förekomma ej heller några kalkstenar, liknande de fossilförande på Höilandet,[4] och några fossilfynd anför BUGGE ej till stöd för sitt påstående, hvarför detta måste anses vara helt och hållet godtyckligt.

Vi vilja nu återvända till breccielagret på gränsen mellan Hovin- och Stören-grupperna och tillse, hvad det möjligen

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[1] Fastän BUGGE anser lagerstupningen vara så afgörande vid bestämmandet af åldersföljden, har han dock ej utsatt några stupningstecken på sin karta.

[2] Härmed menar han dem, som enligt stupningen äro öfverliggande.

[3] En stor grönstensmassa i Stören-gruppen.

[4] På sin karta har BUGGE ej utmärkt mer än en enda kalkstensförekomst inom Hovin-gruppen, men den ligger omkr. 3 *km* från gränsen mot Stören-gruppen. Ej heller BRÖGGER (Om Trondhjemsfeltets midlere afdeling mellem Guldalen og Meldalen, Chr. Vid.-Selsk. Forh. 1877) utmärker på sin karta, den enda någorlunda detaljerade, som finnes inom dessa trakter, några kalkstenar i den på bl. Melhus liggande omedelbara fortsättningen af Hovin-gruppens lager.

kan lära oss. Detta lager har jag sett mångenstädes på sträckningen mellan Levanger och Meldalen. Stundom bildar det mäktiga massor inneslutande stora block af diverse bergarter, stundom är dess mäktighet jämförelsevis liten. Det förundrade mig att i denna breccia så ofta träffa täta, jaspisartade kvartsiter. »Sådana af mörk, violettblå kvartsit och röd jaspis äro så allmänna, att de nästan kunna anses karakteristiska för den» (C. S., s. 86). Till en början kunde jag ej förstå, hvarifrån dessa egendomliga kvartsitiska bergarter kunde härstamma, men så fann jag dem såsom underordnade partier i Stören-gruppen (l. s.). Liknande iakttagelser anföras nu ock af BUGGE. På tal om breccian säger han (s. 17): »Meget karakteristisk er brudstykker af röd eller violet, jaspisagtig kvartsit»; och rörande Stören-gruppen anför han (s. 18), att den innehåller lager af »kvartsitskifer, som flere-steder er jaspisagtig». Jaspisartade lager omnämner han ej från någon annan grupp, och ej heller jag har sett några sådana i denna trakt. Breccian, som ligger i gränsen mellan Hovin-gruppen och Stören-gruppen, innesluter således brottstycken af sällsynta och karakteristiska bergarter, som äro funna såsom inlagringar i den senare gruppen, men ej i någon annan af Trondhjemsfältets afdelningar, och då synes den slutsatsen oafvislig, att Stören-gruppen, hvars gröna hufvudbergarter för öfrigt äfven förekomma såsom brottstycken i breccian, lämnat en del material till denna. Men är så fallet, då måste också Stören-gruppen vara äldre än Hovin-gruppen och lagren i trakten inverterade. Därmed faller BUGGEs endast på lagerstupningen grundade åldersföljd. De närmast Ö om Stören-gruppen liggande skiffrarna, Brekskiffrarna, blifva då icke yngre utan äldre än denna grupp. I de sedan mot Ö följande Singsås-skiffrarna blir stupningen allt mindre brant, hvarför lagren där sannolikt ej äro inverterade. Singsås-gruppen skulle där således vara närmast yngre än Brekskiffrarna och följaktligen motsvara Stören-gruppen, en slutsats hvilken, såsom ofvan är nämndt, ej motsäges af Singsås-gruppens petrografiska karaktär. Nedanstående lilla schematiska profil, fig. 2, förtydligar närmare min uppfattning af förevarande trakts geologiska byggnad.

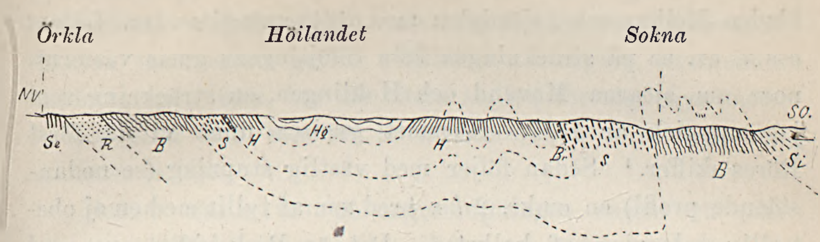

Fig. 2. *Hö* Höilandets grupp. *H* Hovin-gruppen med *Br* Breccia. *S* Stören-gruppen. *Si* Singsås-gruppen. *B* Brekskiffer-gruppen. *R* Röros-gruppen. *Se* Seveskiffer. Längdskala 1 : 400 000.

Till jämförelse hitsättes äfven den schematiska profil (fig. 3), genom hvilken Bugge uttrycker sin uppfattning af traktens geologi. Mot SO sträcker sig denna profil ända till Glommen, således mycket längre än min.[1] Af Bugges profil framgår tydligt, att — såsom ofvan blifvit framhållet — Höilandets grupp

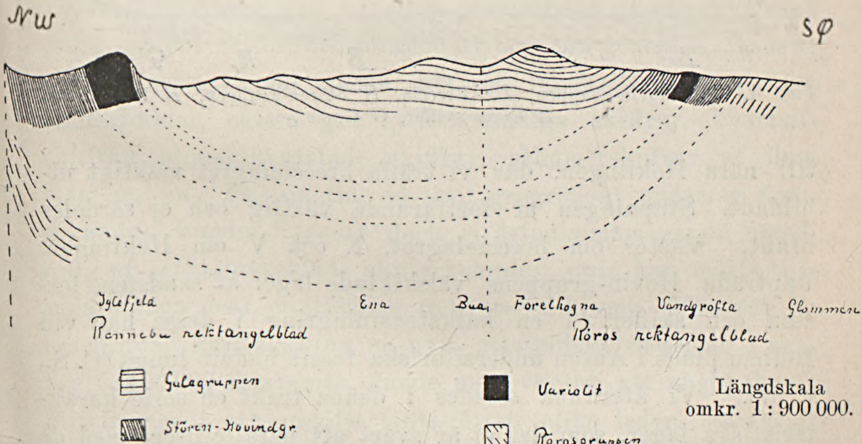

Fig. 3.

har någon plats i hans lagerföljd, och att, enligt den, Hovin-gruppen (et. 5, a) följer omedelbart på Röros-skiffrarna.

[1] Stören-Hovin-grupperna i NV:a delen af Bugges profil motsvara ungefär hvad som synes af dessa grupper i SÖ:a delen af min profil.

Vill man se sig om inom andra delar af Trondhjemsfältet, är det ej svårt att finna ytterligare bevis för att Stören-gruppen är äldre än Hovin-gruppen, såsom den också på rektangelbladen Melhus och Stjördalen med rätta antagits vara. Låtom oss t. ex. se på sträckningen från Sköjtingens gneis västerut, norr om sjöarna Movand och Hoklingen, en sträckning som jag uppgick år 1887. Närmast gneisen finna vi då först Röros-skiffer.[1] Sedan följer med västlig stupning (se nedanstående profil) en omkr. 2 *km* bred zon af fyllit med en ej obetydlig inlagring af kalksten. Det är Brekskiffer, som med SO—NV:lig strykning kommer från den närbelägna Brekkammen. Litet V om Sandviken, N om Movand, öfverlagras Brekskiffern af gröna massor och skiffrar, i hvilka det ej är svårt att igenkänna Stören-gruppen. Denna fortsätter

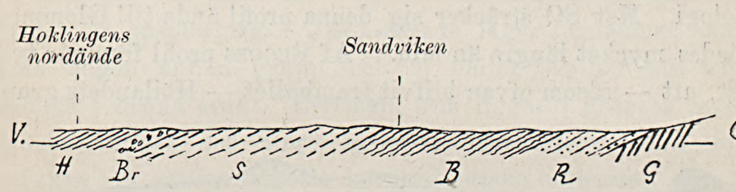

Fig. 4. *H* Hovin-gruppen, *Br* Breccia, *S* Stören-gruppen, *B* Brekskiffer, *R* Röros-skiffer, *G* Gneis.

till nära Hoklingen, där vi träffa breccielagret mäktigt utbildadt. Stupningen är fortfarande västlig och ej särdeles brant. Väster om breccielagret, N och V om Hoklingen, uppträda Hovin-gruppens välskiktade lager af sandsten, lersten och skiffer. I en kalkstensinlagring i dessa har vid Hellem plads i Aasen undersiluriska fossil blifvit funna (C. S., s. 87).[2] Vi återfinna således i denna trakt en serie karakteristiska lager, som det ej är svårt att parallellisera med de ofvan omtalade på bl. Rennebu, men här under förhållanden, som ej tillåta något tvifvel om den verkliga åldersföljden.

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[1] På bl. Levanger karakteriserad såsom »blygraa, glinsende skifer med hornblende og granat».

[2] Till sist öfverlagras Hovin-gruppen här diskordant af Ekne-gruppens konglomerat och sandsten liggande tämligen flackt.

Inför denna profil kan det ju icke tänkas, att Stören-gruppen skulle vara yngre än breccian och Hovin-gruppen.

Flera dylika exempel skulle kunna framdragas, men hvad som redan anförts torde vara nog för att sätta enhvar för trakten intresserad geolog i tillfälle att afgöra, hvilkendera uppfattningen som har de bästa skälen för sig, myntmester Bugges eller min, som för hr myntmesteren är så »vanskelig at fatte» (s. 8).

Bugges naiva tro på lagerstupningen såsom en pålitlig grund för bestämmandet af lagrens åldersföljd förefaller den, som har någon erfarenhet om fjällgeologiens svårigheter, ej så litet komisk, men i det hela gör det dock ett sorgligt intryck att se, hurusom ett så intressant område som bl Rennebus blifvit behandladt på ett så högst otillfredsställande sätt. Om behandlingssättet af områdets nordvästra del torde ofvan hafva blifvit nog ordadt. Områdets återstående $^2/_3$ upptages nästan uteslutande af skiffrar, s. k. Gula-skiffer. Denna benämning gaf Kjerulf provisoriskt åt ett stort men ännu outredt skifferfält, rörande hvilket han genom K. Hauans profiler mycket väl visste, att det innehåller många olika skifferformer, såsom grå fyllit, sandiga skiffrar, kvartsitskiffrar, alunskifferartade skiffrar, glimmerskiffrar af flera slag m. m. På sin tid, då godt geografiskt underlag ännu saknades, kunde Kjerulf dock ej åstadkomma någon utredning af detta invecklade skifferkomplex, utan han måste tills vidare taga dess »vidtlöftige rækker»[1] i klump. Men när nu en förnyad kartläggning på nytt geografiskt underlag i skalan 1 : 100 000 företagits, kunde man väntat, att något försök blifvit gjordt att utskilja Gula-fältets olika leder. Särskildt hade de alunskifferartade lagren, som bilda så utmärkta och skarpt markerade ledlager, förtjänat att blifva ordentligt kartlagda. Hade så skett, då hade en säker basis erhållits för uppfattningen af fältets tektonik. En närmare granskning af dessa mörka skiffrar kunde för öfrigt hafva lönat sig

[1] Kjerulf, »Udsigten», s. 180.

äfven i ett annat hänseende, då möjligheten af att i dem finna graptoliter ej torde vara utesluten. Men en sådan verkligt geologisk undersökning var för hr Bugge naturligtvis ett »for vidtlöftigt» arbete, hvars betydelse han för öfrigt ej torde hafva insett. Med en anstrykning af ogillande omnämner han också (s. 10) mitt försök att utskilja olika afdelningar inom Gula skiffrarna och inskränker sig för egen del till att i hufvudsak troget följa Kjerulfs öfversiktskarta af år 1877. Endast i fråga om eruptiven hafva en del kompletteringar införts. Hela det omkr. 10 kv.-mil stora Gulaskiffer-området får sålunda på kartan blott *en* beteckning, och i texten affärdas det på *knappt två* sidor. Detta må nu tillfredsställa Bugges små geologiska anspråk, men förundra sig måste man däröfver, att Norges Geologiske Undersökelse är lika anspråkslös och ansett sig kunna godkänna ett dylikt opus såsom värdigt att ingå bland dess publikationer.

Graptolitologiska bidrag.

Af

SV. LEONH. TÖRNQUIST.

(Härtill Tafl. 62.)

1.

Två Cyrtograptus-arter från Thüringen.

Cyrtograptus radians TÖRNQUIST.

Tafl. 62, fig. 1—4.

1887. *Cyrtograptus radians* TÖRNQUIST, Anteckn. om de äldre paleozoiska leden i Ostthüringen o. Voigtland, Appendix. Geol. Fören:s i Stockh. Förh., Bd IX, sid. 491, fig. 2.

1890. *Cyrtograptus radians* GEINITZ, Die Graptolithen des K. Mineralog. Museums in Dresden. Mittheil. aus dem königl. Mineral.-Geologischen und prähist. Museum in Dresden, S. 23, Taf. A, Fig. 36.

Arten har redan en gång af mig på anförda ställe beskrifvits och afbildats, men det där gifna träsnittet lämnar åtskilligt öfrigt att önska, och äfven beskrifningen kräfver fullständigande. Endast ett exemplar lämpligt för undersökning föreligger. Fig. 1 återgifver detta fullständigast; fig. 2 visar endast ett fragment däraf, synligt på ytan af den klufna skifferstuffens motstycke, men formen på grenarnas tekor framstår där tydligare. I min tidigare afbildning synas ett par friliggande grenstycken efter de sju första grenarna, men då deras samhörighet med den öfriga delen af exemplaret är osäker, hafva de i fig. 1 utelämnats.

Rhabdosomets initialdel bildar en sluten, nästan cirkelformig krets, hvars diameter inom virgulan håller omkring 3 *mm*; det fortsätter därefter i ett svagare böjdt parti, hvars längd på grund af exemplarets ofullständighet ej kan uppgifvas. Emedan själfva den proximala spetsen täckes af hufvudaxeln, har ej heller sikulan kunnat iakttagas. Den primära stammen har en vidd af 0.6 till 0.9 *mm* öfver tekornas bredaste del och omkring 0.2 *mm* vid deras ursprung. Dess tekor, af hvilka 10 rymmas på 1 *cm*, äro fria, triangulära och utåt slutande med en liten bakåtriktad lob. Deras proximala vägg bildar med virgulan en vinkel af 35° till 40°, och distalväggens motsvarande vinkel är något mindre än en rät. Vid hvar och en af de 8 tekor, som på det föreliggande exemplaret följa efter den fjärde, utskjuter en gren; endast en liten teka, belägen mellan den 6:te och 7:de grenen, gör härifrån undantag. Grenarna utgå, skenbart från tekalspetsarna, i radierande riktning och äro obetydligt böjda eller nästan räta. Alla äro afbrutna, hvarför deras längd är okänd; bredden når knappt 1 *mm*. På en längd af 1 *cm* räknas äfven här 10 tekor. Dessa äro prismatiska med vidvuxen distalvägg och bilda tänder, hvilkas ytterkanter med dorsalranden göra en vinkel af 35°—40°; mynningsranden är i det närmaste vinkelrät mot virgulan. De öfvergripa hvarandra något, men öfvergreppets storlek har ej kunnat bestämmas. Virgulan är såväl i hufvudaxeln som i grenarna mindre starkt framträdande än vanligen är fallet hos *Cyrtograpti*.

Från samsläktade arter med spiralformig proximaldel åtskiljes denna lätt genom hela sin habitus, sin ringa storlek och i synnerhet genom sina tätt ställda, nästan räta grenar. Geinitz' antydan (l. c.), att *Cyrtograptus radians* skulle kunna uppfattas som en ungdomsform af *Cyrtograptus Murchisoni* Carr., sammanhänger med denne författares åsikt, att graptoliter under en längre tid af sin tillväxt kunnat tilltaga i vidd och därunder äfven i viss mån ändra form.

I Skånes Graptoliter, II (1883), yttrar TULLBERG, sid. 31, om släktet *Cyrtograptus:* »Grenarna synas alltid vara ställda i ett plan, som är vinkelrätt mot hufvudaxelns plan.» Meningen med detta något tvetydiga uttryck är naturligtvis, att grenarnas symmetriplan synes stå vinkelrätt mot hufvudaxelns, eller, med andra ord, att grenarnas tekor utväxa i ett plan, som är vinkelrätt mot det plan, hvari den primära axelns tekor utväxa. Sådant tror jag mig äfven hafva funnit i allmänhet vara förhållandet hos de *Cyrtograptus*-arter, jag haft tillfälle undersöka. Det är då anmärkningsvärdt, att alla de synliga grenarna hos det beskrifna exemplaret, i likhet med den primära stammen, visa tekorna i profil.

Förekomst. *Cyrtograptus radians* fanns af mig 1887 vid Wetterahammer i furstendömet Reuss-Gera. Någon tydlig profil var vid mitt besök där ej att se; skiffrarna gingo i dagen i ett landsvägsdike och tillhörde dels zonen med *Monograptus testis*, dels zonen med *Monograptus colonus*. I hvilken af dem arten förekom, kunde icke stratigrafiskt afgöras; men då ingen *Cyrtograptus*-art, så vidt jag känner, blifvit funnen tillsammans med *Monograptus colonus* BARR., skulle man vara snarast böjd att förlägga dess fyndnivå till *testis*-zonen. Jag tror mig också hafva sett *Monograptus Flemingii* SALT. i dess sällskap. Härmed stämmer äfven R. HUNDTS uppgift om artens förekomst i »Beitrag zur Graptolithenfauna des Mittel- und Obersilurs des reussischen Oberlandes und einiger angrenzenden Gebiete».[1] Den af honom, sid. 9, anförda lokalen »Heinrichstaler Hammer bei Gräfenwarth» är antagligen identisk med den ofvanför nämnda.

[1] 51. u. 52. Jahresberichte der Gesellschaft von Freunden der Naturwissenschaften in Gera, Reuss.

Cyrtograptus multiramis n. sp.

Tafl. 62, fig. 5, 6.

Äfven af denna art har endast ett exemplar erhållits. Den skifferstuff, på hvars yta det befinner sig, var redan vid fyndtillfället genom en remna delad i två stycken, hvilka dock passade så fullkomligt till hvarandra, att deras samhörighet icke kan betviflas.

Från en föga böjd initialdel af omkring 8 *mm* längd öfvergår den primära axeln i en spiral af mer än ett och ett halft hvarf och antager därvid så småningom den svaga bågform, som utmärker dess distalparti. Hufvudstammens fulla längd är okänd, men i det afbildade exemplaret har den en längd af 9.5 *cm*; dess bredd öfverstiger knappt 1 *mm*. De äldsta tekorna äro fria, båglikt triangulära med nedböjd spets och påminna rätt mycket om motsvarande tekor hos *Cyrtograptus Lundgreni* Tullb., sådana de afbildats i Skånes Graptoliter II, Tafl. III, fig. 18. På grund af fossilets bevaringstillstånd, och delvis äfven i följd af axelns vridning, äro de distalare tekorna knappt urskiljbara. Förgreningen börjar tidigt i den spiralformiga delen, och grenarna följa efter hvarandra med mellanrum af till en början 3—6 *mm* och sist 10—12 *mm*. Det beskrifna exemplaret har sålunda åtminstone 16 grenar. Dessa äro skärformiga med konkaviteten vänd mot rhabdosomets distala del och hafva en bredd af högst 1.7 *mm*. I följd af sitt läge vid inbäddningen tyckas dock de flesta vara betydligt smalare, och af samma orsak äro tekorna hos flertalet af dem otydliga eller dolda i skiffern. På några grenar, särskildt på den 8:e, 9:e och 15:e, låta de dock någorlunda iakttaga sig. På en längd af 1 *cm* räknas 9—10 tekor. De äro prismatiska, nästan räta och göra med grenens dorsala rand en vinkel af omkring 35°. Enhvar af dem öfvergriper nästföljande teka med mer än hälften af sin längd. Virgulan framträder synnerligen starkt såväl i hufvudaxeln som i grenarna, och vid den 8:e grenen kan man tydligt se, huru dess virgula utgrenar sig från den primära virgulan. Vid den 11:e förgreningspunkten märkes ett egendomligt förhållande, i det att från denna två väl markerade virgulor synas utgå. Att ingen af dem utgör fortsättning af den 2:a grenens virgula, hvilken nästan i samma punkt skär hufvudaxeln, är tydligt däraf, att dess virgula kan följas ett litet stycke divergerande från de båda andra. Visserligen framträder någon gång inom en gren jämte den egentliga virgulan ännu en upphöjd linje, stundom jämnlöpande med denna, stundom förenad med henne, men i intetdera fallet skiljer sig en sådan gren till utseendet från de öfriga; däremot har det grenfält, som omgifver de båda virgulalika linjer, hvilka utgå från den 11:e förgreningspunkten, ett ganska afvikande utseende och särskildt större bredd än den normala grenvidden. Man har svårt att afvisa den föreställningen, att antingen två grenar verkligen utsändts från samma punkt på hufvudaxeln eller att en gren omedelbart vid sitt ursprung åter förgrenats. Då emellertid inga tekor här kunna urskiljas, kan intet härom afgöras, och orsaken till denna egendomliga tvillingbildning måste lämnas oförklarad. Vid angifvandet af grenarnas antal har jag emellertid endast räknat den primära stammens förgreningspunkter.

Den vridning af hufvudaxeln, på hvilken TULLBERG fäst uppmärksamhet som karakteristisk för hela släktet *Cyrtograptus* (l. c., sid. 31), är också här ganska märkbar; men då denna vridning, enligt samme författare, »hos alla de kända arterna är iakttagen på gränsen mellan den primordiala och grenbärande delen af hydrosomet», försiggår den hos *Cyrtograptus multiramis* först mellan den 8:e och 12:e grenen.

En dunkel fråga beträffande rhabdosomets byggnad hos *Cyrtograptus* är den om grenarnas förhållande till primäraxelns tekor. TULLBERG yttrar sig härom sålunda: »Grenarna utväxa alltid från den ventrala sidan, och det har iakttagits, att de alltid utväxa just där, hvarest en teka är placerad, icke i mellanrummet mellan tvenne tekor; huru grenen förhåller sig till tekan, om den genombryter densamma eller växer ut från dess sida, är icke bekant.» Att grenarna utgå från platsen för en teka och icke mellan tvenne sådana, har jag också alltid funnit bekräftadt. Finge man döma af det skenbara förhållandet hos *Cyrtograptus radians* och en del andra arter, skulle man vara böjd att tro, att grenarna utväxa från tekornas yttre hörn eller lober (jämf. Tafl. 62, fig. 1 och 4); men vid betraktandet af en del andra arter, t. ex. *Cyrtograptus Lundgreni* Tullb. och ännu mer *C. multiramis*, möter ett sådant antagande svårigheter. Det är nämligen icke så, att grenarna alltid utgå från hufvudaxelns ventrala sida; så vidt jag funnit, utsändas de konstant från denna axels konvexa sida. Men efter en half omvridning blir denna sida dorsal, och tekorna befinna sig i dess konkava parti; tekor och grenar utväxa sålunda i motsatta riktningar. Att uppvisa, i hvilket förhållande dessa delar af rhabdosomet stå till hvarandra, är ännu ett spörsmål, hvars besvarande är förbehållet framtida undersökningar.

Cyrtograptus multiramis påminner till sin allmänna form något om *Cyrtograptus Lundgreni* Tullb., men skiljer sig dock från denna vid första ögonkastet genom hufvudaxelns längre upprepade förgrening och i följd däraf genom ett större antal grenar. Tullberg har (l. c., Tafl. III, fig. 18) afbildat ett exemplar af *C. Lundgreni* med 3 grenar, och själf har jag hos denna art sett högst 4; hvaremot det afbildade exemplaret af *C. multiramis* företer ej mindre än 16 grenar. Den senare behåller också vid primäraxelns tillväxt längre spiralformen. Med ingen annan art röjer den närmare öfverensstämmelse.

Förekomst. Den beskrifna arten fanns vid Wetterahammer vid samma tillfälle som *Cyrtograptus radians* och under liknande geologiska förhållanden. — Obestämbara fragment af ännu en tredje *Cyrtograptus*-art tror jag mig hafva sett på samma lokal.

2.

Strödda anteckningar om släktena inom Monograptidæ.

I en uppsats »Observations on the genus Rastrites and some allied species of Monograptus»[1] har jag uttalat mig därhän, att de båda nämnda släktena tangerade hvarandra så att säga i en punkt genom arterna *Monograptus triangulatus* Harkn. och *Rastrites peregrinus* Barr. Otvifvelaktigt är ock, att den senare arten följes af en serie former, som alltmer afvika från de typiska *Monograpti*. Tvekan kunde dock uppstå, huruvida icke *Rastrites approximatus* Pern. och dess formkrets närmast slöte sig till *Monograptus convolutus* His. eller någon närstående art. Möjligen är det så; men å andra sidan är den sistnämnda arten yngre än den förra, och det är tänkbart, att likheten mellan dem beror på en analogi i utvecklingen, så att *Rastrites approximatus* förhåller sig till *R. peregrinus* som *Monograptus convolutus* till *M. triangulatus*.

Tydligare kan man iakttaga, huru olika arter af *Cyrtograptus* förbindas med skilda grupper af *Monograptus*. Hvad Tullberg i Skånes Graptoliter II (sid. 32) yttrar, att deras »stamformer äro troligen att söka inom gruppen *Helicopodes*», gäller helt visst om åtskilliga arter, och om ett ännu större antal, då man i likhet med Tullberg till släktet *Cyrtograptus* äfven hänförde *Monograptus spiralis* Gein. och *M. subconicus* Tqt; men andra arter af *Cyrtograptus* gifvas, hvilka icke kunna ställas i sådant förhållande till de helicoida *Monograpti*. Som exempel härpå må anföras *Cyrtograptus flaccidus* Tbg, *C. pulchellus* Tbg och *C. Grayæ* Lapw. Den sistnämnda tyckes mera närma sig *Monograptus sartorius* Tqt eller *M. dextrorsus* Linrs. Långsökt förekommer Frechs åsikt,[2] att *Cyrtograptus*, särskildt såvida den typiska formen *C. Murchi-*

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[1] Lunds Univ:s Årsskrift, N. F., Bd 3; K. Fysiografiska Sällsk:s Handl., N. F., Bd 18, 1907.

[2] Lethæa geognostica, 1. Theil, 1. Band, S. 650.

soni CARR. tages i betraktande, mest öfverensstämmer med den grupp af *Monograptus*, för hvilken han ställer *M. Becki* BARR. såsom typ. I hvarje händelse utgöra icke *Cyrtograptus*-arterna en fullt sluten enhet; det vill synas, som om under en viss tid, kort efter *Rastrites*-ålderns afslutning, en tendens till gren bildning uppstått inom olika grupper af *Monograptus*.

I framträdandet af de hvarandra successivt följande arterna å ena sidan af *Rastrites* och å den andra af *Cyrtograptus* spåras en märkbar analogi, som icke saknar sitt intresse. Liksom det förra släktet vid slutet af den tidsålder, som bär dess namn, och kort före sitt utdöende, uppträder med former sådana som *Rastrites Linnæi* BARR. och *R. maximus* CARR., i hvilka den på tekornas beskaffenhet grundade genuskaraktären företer en särdeles extrem utbildning, så når hos det yngre släktet *Cyrtograptus* hufvudaxelns karakteristiska grenbildningskapacitet sin kulmination i de representanter, som omedelbart föregå dess utslocknande. De båda i föregående afdelning beskrifna arterna lämna intyg därom.

Önskvärdheten af en fördelning af det artrika och mångformiga släktet *Monograptus* på underordnade grupper, undersläkten eller nya släkten har tid efter annan framhållits, och förslag i sådant syfte föreligga äfven.

År 1883 gaf TULLBERG i sitt bekanta arbete »Skånes Graptoliter» II, sid. 16, förslag till en sådan indelning. Han ansåg arterna af *Monograptus* efter affiniteter kunna ordnas på sex grupper. Såsom redan de gifna namnen antyda, karakteriseras dessa i främsta rummet efter de former, rhabdosomet i följd af olika tillväxtriktningar kunnat antaga. Visserligen nämnas äfven tekornas former i diagnoserna öfver de olika grupperna, men vid betraktande af arternas inordnande i dessa finner man, att jämförelsevis ringa vikt fästats vid dem. TULLBERGS afhandling är rik på nya och noggranna iakttagelser öfver de beskrifna arternas karaktärer och vertikala distribution, och dess betydelse för den äldre paleozoiska paleontologien och stratigrafien har allmänt blifvit erkänd. Men här är nu endast fråga om den systematiska gruppering af *Monograptus*-arterna, som han i det nämnda arbetet ställt framför species-beskrifningarna, och om denna kan, enligt min uppfattning, sägas, att den snarare är en öfversiktlig logisk division än en naturlig anordning efter arternas inbördes frändskap. Såsom nämnts, fördelas där *Monograpti* i sex grupper. Redan i den första af dem, *Leptopodes*, träffas *M. cyphus* Lapw. tillsammans med *M. Nilssoni* Barr. och *M. Sandersoni* Lapw., en sammanställning hvars berättigande synes mycket tvifvelaktigt. Men ännu mer olikartade former möta i den andra gruppen, *Orthopodes*, där *M. Hisingeri* Carr. sidoställes med *M. Linnarssoni* Tbg och *M. spinulosus* Tbg, oaktadt de båda senare i sin tekalbyggnad så mycket afvika från den första, att de t. o. m. enligt Jækels och Frechs genus-bestämningar, såsom i det följande visas, skulle föras till annat släkte. Den tredje gruppen åter, *Helicopodes*, bör helt visst betecknas som fullt naturlig och omfattar en samling arter, som tydligen stå hvarandra ganska nära. Vidkommande den fjärde gruppen, *Opisopodes*, har dess diagnos, att rhabdosomets proximala del är »tydligt tillbakaböjd», tolkats på ett nog godtyckligt sätt, och kan, om *M. lobiferus* M'Coy skall anses som typisk art, endast genom hårdragning af uttrycket tillämpas på *M. nodifer* Tqt och *M. speciosus* Tbg. Också har Tullberg vid den följande artbeskrifningen fört den sist anförda arten till *Orthopodes*, med hvilka den lika litet röjer förvandtskap. Fäster man sig vidare vid tekorna hos de inom denna grupp sammanförda arterna, så tillhöra dessa hos *M. priodon* Bronn, *M. sartorius* Tqt och *M. nodifer* Tqt skilda typer. Ej mindre olikheter i detta hänseende erbjuda de till sjätte gruppen, *Prosopodes*, hänförda arterna *M. dubius* Suess och *M. cultellus* Tqt.

Tullbergs grupp-uppställning har accepterats af Perner i hans tyvärr alltjämt oafslutade arbete »Étude sur les Graptolites de Bohême» (III:ième Partie, section a, 1897, och section b, 1899).

En från Tullbergs mycket afvikande fördelning af *Monograptus*-arterna möter oss i Jækels afhandling »Über das Alter des sogen. Graptolithen-Gesteins mit sonderbarer Berücksichtigung der in demselben enthaltenen Graptolithen».[1] Om Tullberg vid sin uppställning lagt ensidig vikt på rhabdosomens allmänna form, så har Jækel slagit in på en motsatt väg, i det han efter olikheter i tekornas utbildning klyft det gamla släktet *Monograptus* i två nya släkten, *Pristiograptus* och *Pomatograptus*. Det förra af dem utmärkes af prismatiska tekor, hvilkas distalväggar äro fullständigt vidvuxna närmast följande tekors proximala väggar; såsom kännetecken på *Pomatograptus* uppgifves, att hvarje tekas distalvägg är utåt fri och böjer sig läppformigt öfver den därunder befintliga mynningen. Onekligt är, att Jækel här fäst uppmärksamheten på karaktärer af vikt. Uppgiften däremot, att de båda uppställda släktena äfven skilja sig från hvarandra genom olika böjning af rhabdosomet, om böjning äger rum, grundar sig på spekulation och ofullständigt undersökningsmaterial samt motsäges af verkligheten.

Men den ifrågavarande klassifikationen lider af en vida större betänklighet. Oaktadt monograptidernas utveckling från sikulastadiet hade år 1889 länge varit bekant genom beskrifningar och afbildningar, allra först lämnade af Lapworth och senare af Tullberg och andra författare, förmenar dock Jækel, att man om deras initialparti intet vet; och han antager såsom otvifvelaktigt, att alla under namnet *Monograptus* såsom enkla former beskrifna graptoliter endast äro afbrutna stycken af förgrenade arter. Därmed har det väsentligaste kännetecknet på släktet *Monograptus*, och naturligtvis också på de släkten, som genom dess delning uppställts, blifvit förkastadt. Och af hela det resonemang, genom hvilket Jækel ansluter sig till James Halls uppfattning af *Monograpti*, framgår vidare, att han föreställt sig dessa som grenar af dichograptider och icke af *Cyrtograpti*, hvilket ju kunde

[1] Zeitschrift d. deutschen Geolog. Gesellschaft, 1889.

hafva ägt någon grad af rimlighet. Den enda karaktären, hvarigenom *Pristiograptus*, hvars tekor likna dem hos *Dichograptidæ*, skulle kunna skiljas från denna familj, vore då den mycket oväsentliga, att dess proximalände vore okänd, och att *Pristiograptus*-arterna på grund däraf icke kunde hänföras till *något* bestämdt släkte. Visserligen omnämnes i artbeskrifningarna en axel eller virgula, men tydligen har JÆKEL ej gifvit akt därpå, att detta organ under sådan form saknas hos *Dichograptidæ*.

Hvad *Pomatograptus* beträffar, äger ett något annat förhållande rum. JÆKEL tillkommer förtjänsten att hafva iakttagit tekalmynningens verkliga form hos *Monograptus priodon* BRONN,[1] men då han uppställer denna form såsom karakteristisk för hela släktet *Pomatograptus*, så har dettas omfång, som också FRECH senare anmärkt, kommit att inskränkas till ett litet antal *M. priodon* närstående arter. Tydligen har diagnosen i följd af en mindre noggrann formulering blifvit trängre än författaren åsyftat. Lägger man åter, som väl afsikten varit, hufvudvikten därpå, att tekornas distala väggar, i motsats mot hvad händelsen är hos författarens släkte *Pristiograptus*, till större eller mindre del äro fria, så skulle, på grund af JÆKELS åsikt om *Monograpti* såsom förgrenade former, släktet *Pomatograptus* äfven omfatta en stor del *Cyrtograptus*-arter.

Det af JÆKEL gifna uppslaget har, dock med högst väsentliga modifikationer, upptagits af F. FRECH i »Lethæa geognostica, Teil I, Bd 1» (1880) 1897. I den omsorgsfullt utarbetade del af detta storslagna, först af F. RÖMER planlagda och påbörjade verk, hvilken behandlar graptoliterna, finner man ej blott en allmän öfversikt öfver denna djurgrupps organisation, så vidt den vid tiden för arbetets utgifning var bekant, utan ock korta, koncisa beskrifningar af kända arter, hvartill

[1] En liknande form på tekalmynningen hade förut af TULLBERG iakttagits hos *Monograptus cultellus* TQT, men han ansåg likheten mellan dennas tekor och dem hos *M. priodon* endast vara skenbar.

författaren ej sällan fogat anmärkningar och egna iakttagelser af intresse. Den originella grupperingen af graptoliternas ordningar, familjer och släkten, som FRECH framlagt, erbjuder äfven för den, som i åtskilligt hyser afvikande åsikter från de där genomförda, synpunkter som måste beaktas. Hvad det gamla släktet *Monograptus* angår, styckar FRECH detta i fyra nya släkten, uteslutande skiljda från hvarandra genom tekornas olika beskaffenhet. Lika litet som i JÆKELS system finnes här någon plats för sådana *Monograpti*, hvilkas tekor i olika delar af rhabdosomet tillhöra olika typer. Redan tillvaron af sådana graptolitformer antyder emellertid, att naturen icke så strängt skiljt mellan de olika tekaltyperna, som man annars skulle vara benägen att antaga.

FRECH godkänner och behåller JÆKELS släktnamn *Pristiograptus*, dock med den betydande inskränkning i användningen, att *Dichograptidæ* redan genom graptolit-familjernas systematiska anordning ställes långt aflägsnad från *Pristiograptus*. Om under sådana förhållanden den använda namnbeteckningen anses korrekt, hade åtminstone varit nödvändigt, att ett »emend.» tillfogats efter auktorsnamnet.

Från de återstående *Monograpti* afskiljer sedan FRECH under namnet *Monoclimacis* de arter, hvilka i likhet med *M. crenulatus* TQT hafva tekor af den form, som äfven träffas hos det diprionidiska släktet *Climacograptus;* och han har därjämte flyttat det nya släktet öfver från *Monograptidi* till den af honom nyuppställda familjen *Climacograptidi.*[1] Att de på detta sätt sammanförda arterna bilda en naturlig grupp, är otvifvelaktigt, men å andra sidan är deras samhörighet med *Monograptidæ* så påtaglig, att deras förflyttning till en annan familj synes mig sakna berättigande. Enligt min uppfattning beror likheten mellan de båda till en familj af FRECH sammanförda släktena snarare på analogi i tekornas utbildning än på verklig affinitet mellan själfva släktena. Denna åsikt styrkes däraf, att den första tekan hos *Monoclimacis* utgår

[1] FRECH låter graptolit-familjernas namn ändas på *-idi.*

från sikulan på samma sätt som i allmänhet hos *Monograptus*, och ej såsom hos *Climacograptus* genom en trång förbindelsekanal är förenad med sikulans hålighet. Om dessutom *Monoclimacis* på uppgifna skäl sammanföres i en familj med *Climacograptus*, tyckes också konsekvensen fordra, att *Pristiograptus* lika nära förbindes med *Diplograptus*.

Om ett tredje utbrutet släkte *Linograptus*, i främsta rummet representeradt af *L. Nilssoni* Barr., tvekar jag att uttala någon mening, då jag möjligen i någon punkt kan hafva missförstått författaren, hvarför jag inskränker mig till angifvande af fakta, såsom jag uppfattat dem. Släktet säges karakteriseras däraf, att både sikula och tekor öppna sig »distalt», alltså i samma riktning. Enligt denna diagnos och med antagande af den betydelse, Frech fäster vid uttrycket distal, skulle *Linograptus* snarast öfverensstämma med den vid tiden för dess uppträdande längesedan utdöda familjen *Dichograptidæ*, om icke rhabdosomet uppgifvits äga en tydlig dorsal virgula.[1] Å andra sidan äro de till det nya släktet hänförda arterna väl kända, hafva af flera iakttagare funnits i sin initiala utbildning förhålla sig alldeles lika som öfriga *Monograpti* och kunna svårligen skiljas från *Pristiograptus* Jækel em. Frech. Härtill kommer nu, att Frech under namnet *Linograptus Nilssoni* Barr. afbildat två graptolit-exemplar (fig. 218 c, sid. 663 och Tafl. A, fig. 7), hvilka äro så egendomliga, att jag icke vågar mig på någon tydning af dem.

För de arter, som efter frånskiljandet af de tre nu anförda släktena kvarstå inom det gamla släktet *Monograptus*, behåller Frech detta namn.[2] Inom *Pristiograptus* och *Monograptus* urskiljas underordnade grupper, vid hvilkas karakteristik äfven andra delar af rhabdosomet än tekorna tagas i betraktande. Att bland dessa grupper träffas verkligt natur-

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[1] Olikheten mellan *Linograptus* och *Dichograptidæ* påpekas också af förf. själf (l. c., sid. 662).

[2] I Lethæa geognostica, sid. 638, betecknas släktet: »*Monograptus* Gein. em. Jækel et Frech». Hvarför Jækel, som förkastat namnet *Monograptus*, här anföres som emendator, är svårt att förstå.

liga enheter, är oomtvistligt, om också ej kan nekas, att stundom rätt heterogena former blifvit sammanställda. Så föres *Monograptus discus* TQT till den grupp, som blifvit nämnd efter *Pristiograptus testis* BARR., oaktadt dess tekalform ej ens medgifver dess hänförande till släktet *Pristiograptus*, sådant detta i diagnosen blifvit definieradt.

Före någon af de i det föregående nämnda författarne, och redan så tidigt som 1876, hade LAPWORTH i sin för hela graptolit-kännedomen ytterst viktiga uppsats »On Scottish Monograptidæ» [1] ordnat de däruti beskrifna arterna kring ett antal typer uti grupper, hvilka karakteriserades af fossilens hela byggnadsplan.

Öfvertygad därom, att den princip, som i detta förfarande fått uttryck, är den enda riktiga för en naturenlig klassifikation, har jag, så vidt det varit mig möjligt, sökt tillämpa densamma i två af mig publicerade monografiska afhandlingar: »Undersökningar öfver Siljansområdets graptoliter II» (1892) [2] och »Researches into the Monograptidæ of the Scanian Rastrites Beds» (1899). [3] I båda har framför artbeskrifningarna ställts en klav för anordningen af dessa. Som ofta är fallet med dylika öfversikter, har materialet först fördelats på större afdelningar och sedan inom dessa på underordnade sådana. Uppställningarna bära så till vida likhet med JÆKELS och FRECHS genus-schemata, att olikheter i tekornas utbildning lagts till grund för hufvudindelningen; men jag har också reserverat mig mot den föreställningen, att jag ansåge mig därmed hafva framlagt en fullt naturlig gruppering af *Monograptus*-arterna. I den äldre monografien säges uttryckligen, att hufvudafdelningarna äro i viss mån att anse som artificiella grupper, hvarmed jag velat säga, att karaktärer hämtade från tekorna, huru betydelsefulla de än i systematiskt afseende äro, dock ej ensamma räcka till för att konstituera väl

[1] Geological Magazine, Dec. II, Vol. III, 1876.
[2] Lunds Univ:s Årsskrift, Bd 28; K. Fysiogr. Sällsk:s Handl., Bd 3, 1892.
[3] Lunds Univ:s Årsskrift, Bd 35; K. Fysiogr. Sällsk:s Handl., Bd 10, 1899.

begränsade naturliga formkretsar. Däremot har jag både 1892 och 1899 uttalat den tanken, att sådana torde vara att finna bland de underordnade afdelningarna, vid hvilkas karakteristik hänsyn därjämte tagits till andra egenskaper i de behandlade arternas byggnad. Dels emedan det inskränkta material, som så vid det ena som vid det andra tillfället förelåg till behandling, icke medgaf en genomförd klassifikation af de till *Monograptus* hörande arterna, dels ock af andra orsaker, har jag icke föreslagit någon delning af detta släkte i namngifna enheter, vare sig af högre eller lägre ordning. Det är icke heller nu min afsikt att framställa något förslag i sådant syfte, utan endast att påvisa några synpunkter, som vid en naturlig gruppering af ifrågavarando arter förtjäna att beaktas.

Hvad först angår frågan, huruvida *Monograptus*-arterna böra fördelas på ett större eller mindre antal nya släkten eller endast på undersläkten, så kunna skäl anföras för hvartdera alternativet. Emellertid äro samtliga hithörande former sinsemellan så nära förbundna med hvarandra, att deras fördelning på subgenera under det gamla kollektiva genus-namnet åtminstone för det närvarande väl må kunna försvaras.

Granskar man närmare tekorna hos de hittills kända arterna, finner man, att i verkligheten ett större antal typer kunna urskiljas än man vanligen antagit, särskildt bland de tekor, som hafva den distala väggen till större eller mindre del fri. Af sålunda skilda tekaltyper skulle jag vilja anföra dem, som förekomma hos *Monograptus crenulatus* Tqt, *M. spinulosus* Tullb., *M. priodon* Bronn, (*? M. clingani* Carr.), *M. spiralis* Gein., *M. dextrorsus* Linrs. och *M. exiguus* Lapw. Det må vara, att dessa tekalformer tyckas öfvergå i hvarandra, men det befinnes ock, att kring hvar och en af de anförda *Monograpti* ordnar sig ett större eller mindre antal arter, och att de som tillhöra samma grupp förete en påfallande öfverensstämmelse i rhabdosomets hela byggnad. Också hafva de anförda tekaltyperna blifvit valda just med hänsyn till deras egenskap att förekomma i samband med bestämda rhabdosom-former. Så utmärker sig *crenulatus*-gruppen (*Monoclimacis* Frech) genom styft, rakt eller föga böjdt rhabdosom; *dextrorsus*-gruppen åter genom dettas smalhet och böjlighet; *spiralis*-gruppen genom rhabdosomets tendens till spiralvridning o. s. v. Mera isolerade stå, som det f. n. tyckes, *M. runcinatus* Lapw. och *M. singularis* Tqt; möjligen också *M. Sedgwicki* Portl. och *M. discus* Tqt. Mindre omväxling erbjuda de tekor, hvilkas distalvägg är fullständigt vidvuxen. Oftast hafva dessa mynningsranden hel, men äfven i detta fall torde de med sådana tekor försedda arterna kunna ordnas i naturliga grupper, representerade t. ex. af *M. jaculum* Lapw., *M. bohemicus* Barr. och *M. Nilssoni* Barr. De med taggar vid mynningen ornerade arterna synas bilda en grupp för sig. Svår att inordna bland de öfriga är *M. testis* Barr. Med de arter, som kännetecknas af difform tekalutbildning, äger det förhållandet rum, att de i öfrigt röja ringa förvandtskap med hvarandra. Man jämföre *M. difformis* Tqt, *M. revolutus* Kurck och *M. colonus* Barr. Den sistnämnda har för stor likhet med *M. dubius* Suess för att ställas på större afstånd från denna. Att icke allt för stor vikt får läggas på den omständigheten, att tekorna under rhabdosomets tillväxt öfvergå ifrån en form till en annan, inses af förhållandet hos *Monograptus convolutus* His, hvilken börjar som en *Rastrites*, men under sin fortväxt antager de närstående spiralformiga *Monograptus*-arternas utseende.

Förklaring till figurerna.

Cyrtograptus radians TÖRNQUIST.

Fig. 1—4.

Fig. 1. Exemplar i naturlig storlek.
» 2. De fyra yngsta grenarna af samma exemplar, sedda i skifferstuffens motstycke; naturlig storlek.
» 3. Stycke af den yngsta grenen förstoradt.
» 4. Stycke af hufvudaxeln med baser af de tre första grenarna förstoradt.

Cyrtograptus multiramis n. sp.

Fig. 5. 6.

Fig. 5. Exemplar i naturlig storlek.
» 6. Stycke af den 8:e grenen förstoradt.

Pris-lista

å

Geologiska Föreningens

Förhandlingar, Lösa häften och Generalregister samt å Separat af uppsatser, tryckta såsom kongress-guider i Band 31—32 (1909—1910).

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Band:

Band	**1**	kr. 6.—		**9—30**	kr.	10.—
	2—5	» 10.—		**31**	»	15.—
	6—7	» 15.—		**32**	»	30.—
	8	» 7.50				

Generalregister:

Band	**1—5**	kr.	1.50
»	**6—10**	»	2.—
»	**11—21**	»	3.—
»	**21—31**[2]	»	3.—

Häften:

Bd 1:			**Bd 2:**			11	(25)	kr. 1.50	6	(34)	kr. 1.50
H. 1	(N:r 1)	kr. 1.—	H. 1	(N:r 15)	kr. 1.—	12	(26)	» 2.—	7	(35)	» 1.—
2—6	(2—6)	» —[1]	2	(16)	» 1.—	13	(27)	» 0.50	8	(36)	» 0.50
7	(7)	» 1.50	3	(17)	» 1.—	14	(28)	» 1.50	9	(37)	» 1.—
8	(8)	» 2.—	4	(18)	» 2.—				10	(38)	» 1.—
9	(9)	» 1.—	5	(19)	» 1.—	**Bd 3:**			11	(39)	» 1.—
10	(10)	» 1.—	6	(20)	» 1.—	H. 1	(N:r 29)	kr. 2.—	12	(40)	» 1.50
11	(11)	» 1.—	7	(21)	» 1.50	2	(30)	» 1.50	13	(41)	» 1.—
12	(12)	» 1.50	8	(22)	» 1.50	3	(31)	» 1.—	14	(42)	» 1.—
13	(13)	» 1.50	9	(23)	» 2.—	4	(32)	» 1.50			
14	(14)	» 1.—	10	(24)	» 2.—	5	(33)	» 1.—			

[1] — betyder *slutsålda* häften.
[2] — under tryckning.

100170

Bd 4:

H. 1	(N:r 43)	kr. 1.50
2	(44)	» 1.50
3	(45)	» 1.—
4	(46)	» 1.—
5	(47)	» 1.50
6	(48)	» 0.50
7	(49)	» 1.50
8	(50)	» 1.50
9	(51)	» 1.50
10	(52)	» 0.50
11	(53)	» 1.—
12	(54)	» 1.—
13	(55)	» 1.50
14	(56)	» 2.—

Bd 5:

H. 1	(N:r 57)	kr. —
2	(58)	» 1.—
3	(59)	» —
4	(60)	» —
5	(61)	» 1.50
6	(62)	» 0.50
7	(63)	» 1.—
8	(64)	» —
9	(65)	» —
10	(66)	» —
11	(67)	» —
12	(68)	» —
13	(69)	» —
14	(70)	» —

Bd 6:

H. 1	(N:r 71)	kr 1.—
2	(72)	» —
3	(73)	» 0.75
4	(74)	» 1.—
5	(75)	» 1.—
6	(76)	» 1.—
7	(77)	kr. —
8	(78)	» —
9	(79)	» 1.—
10	(80)	» —
11	(81)	» —
12	(82)	» 2.—
13	(83)	» —
14	(84)	» —

Bd 7:

H. 1	(N:r 85)	kr. 1.50
2	(86)	» 1.50
3	(87)	» —
4	(88)	» —
5	(89)	» —
6	(90)	» 1.50
7	(91)	» —
7	(92)	» 1.—
9	(93)	» 1.50
10	(94)	» 1.50
11	(95)	» 1.50
12	(96)	» 1.50
13	(97)	» 1.—
14	(98)	» 2.—

Bd 8:

H. 1	(N:r 99)	kr. 1.50
2	(100)	» 2.—
3	(101)	» 1.50
4	(102)	» 2.50
5	(103)	» 1.50
6	(104)	» 1.—
7	(106)	» 1.—

Bd 9:

H. 1	(N:r 106)	kr. 1.—
2	(107)	» 2.—
3	(108)	» 1.50
4	(109)	» 1.50
5	(110)	» 2.—
6	(111)	kr. 1.50
7	(112)	» 1.50

Bd 10:

H. 1	(N:r 113)	kr. 1.—
2	(114)	» 1.50
3	(115)	» 2.—
4	(116)	» 1.50
5	(117)	» 2.—
6	(118)	» 1.—
7	(119)	» 1.—

Bd 11:

H. 1	(N:r 120)	kr. 1.—
2	(121)	» 1.50
3	(122)	» 1.50
4	(123)	» 1.50
5	(124)	» 1.50
6	(125)	» 2.—
7	(126)	» 1.—

Bd 12:

H. 1	(N:r 127)	kr. 1.—
2	(128)	» 1.50
3	(129)	» 1.50
4	(130)	» 1.50
5	(131)	» 1.50
6	(132)	» 1.50
7	(133)	» 1.50

Bd 13:

H. 1	(N:r 134)	kr. 1.50
2	(135)	» 1.50
3	(136)	» 2.—
4	(137)	» 2.50
5	(138)	» 1.50
6	(139)	» 1.—
7	(140)	» 2.—

Bd 14:

H. 1	(N:r 141)	kr. 1.50
2	(142)	kr 2.—
3	(143)	» 1.50
4	(144)	» 1.50
5	(145)	» 2.—
6	(146)	» 1.50
7	(147)	» 1.50

Bd 15:

H. 1	(N:r 148)	kr. 1.—
2	(149)	» 1.50
3	(150)	» 2.—
4	(151)	» 2.—
5	(152)	» 1.—
6	(153)	» 1.50
7	(154)	» 2.50

Bd 16:

H. 1	(N:r 155)	kr. 1.—
2	(156)	» 1.50
3	(157)	» 1.—
4	(158)	» 2.—
5	(159)	» 1.50
6	(160)	» 2.50
7	(161)	» 1.50

Bd 17:

H. 1	(N:r 162)	kr. 1.50
2	(163)	» 2.50
3	(164)	» 2.50
4	(165)	» 2.—
5	(166)	» 1.—
6	(167)	» 1.50
7	(168)	» 1.—

Bd 18:

H. 1	(N:r 169)	kr. 1.—
2	(170)	» 1.—
3	(171)	» 1.—
4	(172)	» 1.50
5	(173)	» 5.—

6	(174)	kr. 1.50
7	(175)	» 1.—

Bd 19:

H. 1	(N:r 176)	kr. 1.—
2	(177)	» 1.—
3	(178)	» 1.50
4	(179)	» 3.—
5	(180)	» 1.50
6	(181)	» 2.—
7	(182)	» 1.—

Bd 20:

H. 1	(N:r 183)	kr. 1.—
2	(184)	» 1.—
3	(185)	» 1.50
4	(186)	» 2.—
5	(187)	» 3.—
6	(188)	» 1.50
7	(189)	» 1.50

Bd 21:

H. 1	(N:r 190)	kr. 2.50
2	(191)	» 1.50
3	(192)	» 1.—
4	(193)	» 3.—
5	(194)	» 2.—
6	(195)	» 1.50
7	(196)	» 1.50

Bd 22:

H. 1	(N:r 197)	kr. 1.50
2	(198)	kr. 1.50
3	(199)	» 1.50
4	(200)	» 2.—
5	(201)	» 3.—
6	(202)	» 1.—
7	(203)	» 1.—

Bd 23:

H. 1	(N:r 204)	kr. 1.50
2	(205)	» 1.50
3	(206)	» 1.50
4	(207)	» 2.50
5	(208)	» 2.50
6	(209)	» 1.—
7	(210)	» 1.—

Bd 24:

H. 1	(N:r 211)	kr. 1.50
2	(212)	» 1.50
3	(213)	» 1.50
4	(214)	» 2.—
5	(215)	» 1.50
6	(216)	» 1.50
7	(217)	» 1.50

Bd 25:

H. 1	(N:r 218)	kr. 1.50
2	(219)	» 1.50
3	(220)	» 1.50
4	(221)	» 1.50
5	(222)	» 2.—
6	(223)	kr. 2.—
7	(224)	» 1.50

Bd 26:

H. 1	(N:r 225)	kr. 1.50
2	(226)	» 1.50
3	(227)	» 1.—
4	(228)	» 2.50
5	(229)	» 2.—
6	(230)	» 1.50
7	(231)	» 1.50

Bd 27:

H. 1	(N:r 232)	kr. 2.—
2	(233)	» 1.50
3	(234)	» 1.50
4	(235)	» 1.50
5	(236)	» 1.50
6	(237)	» 2.—
7	(238)	» 1.50

Bd 28:

H. 1	(N:r 229)	kr. 1.50
2	(240)	» 2.—
3	(241)	» 1.50
4	(242)	» 2.—
5	(243)	» 1.50
6	(244)	» 1.50
7	(245)	» 1.50

Bd 29:

H. 1	(N:r 246)	kr. 1.50
2	(247)	» 1.50
3	(248)	kr. 1.50
4	(249)	» 1.—
5	(250)	» 2.—
6	(251)	» 2.—
7	(252)	» 1.50

Bd 30:

H. 1	(N:r 253)	kr. 2.—
2	(254)	» 1.50
3	(255)	» 1.50
4	(256)	» 1.50
5	(257)	» 2.—
6	(258)	» 1.50
7	(259)	» 1.50

Bd 31:

H. 1	(N:r 260)	kr. 1.50
2	(261)	» 1.
3	(262)	» 2.—
4	(263)	» 2.—
5	(264)	» 3.—
6	(265)	» 2.—
7	(266)	» 5.—

Bd 32:

H. 1	(N:r 267)	kr. 3.—
2	(268)	» 5.—
3	(269)	» 4.—
4	(270)	» 10.—
5	(271)	» 10.—
6	(272)	» 1.—
7	(273)	» 1.50

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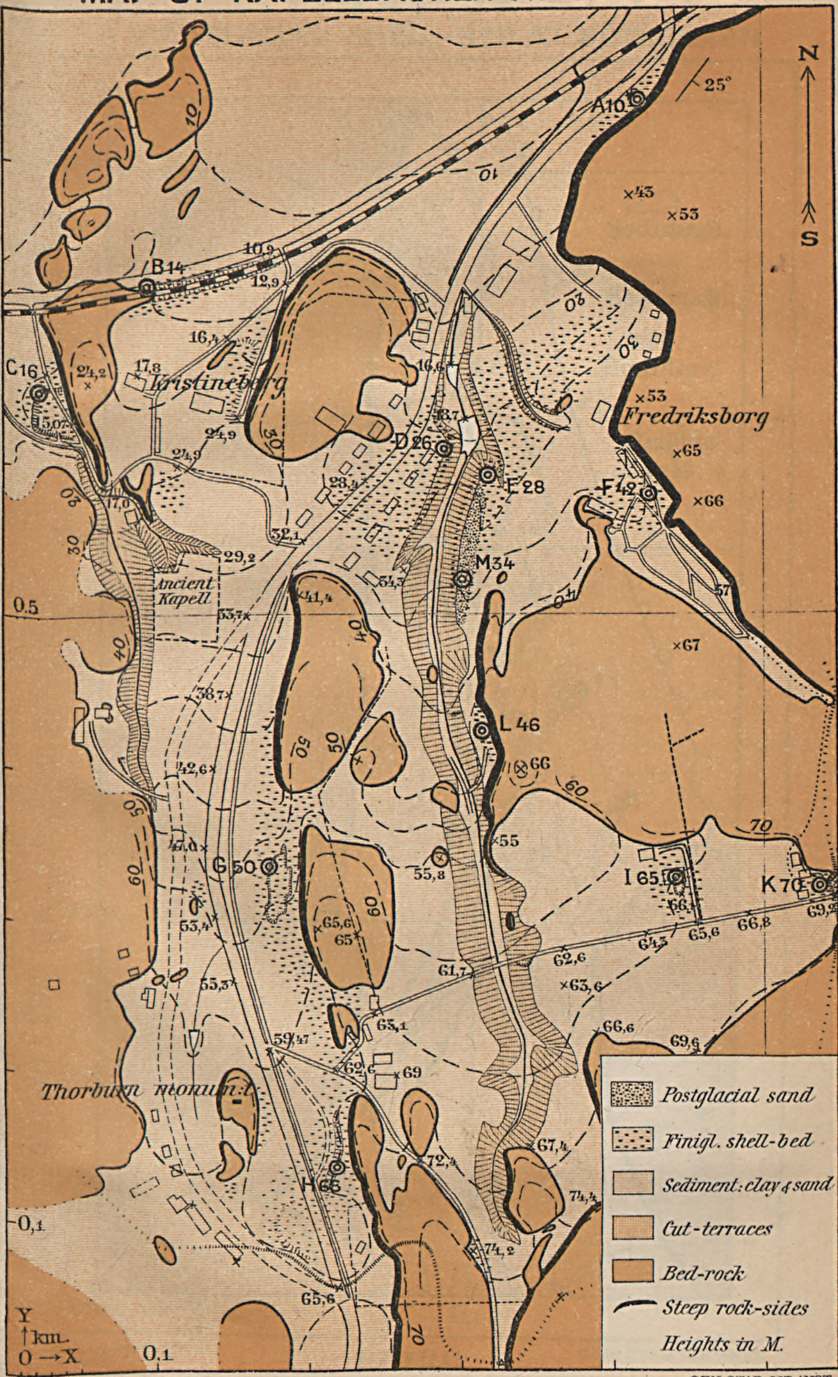
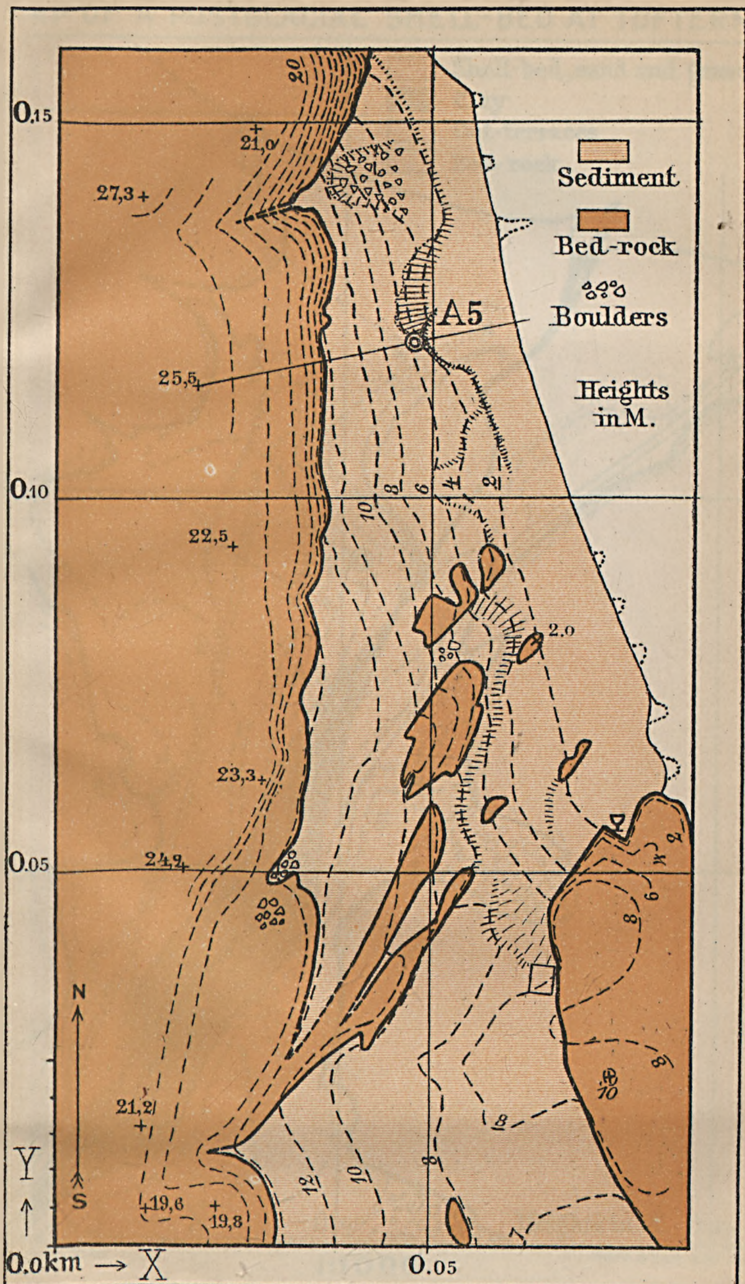


G. DE GEER 1910 1:5000 GEN. STAB. LIT. ANST.

MAP OF A POSTGLACIAL SHELL-BED AT NÖTHOLMEN



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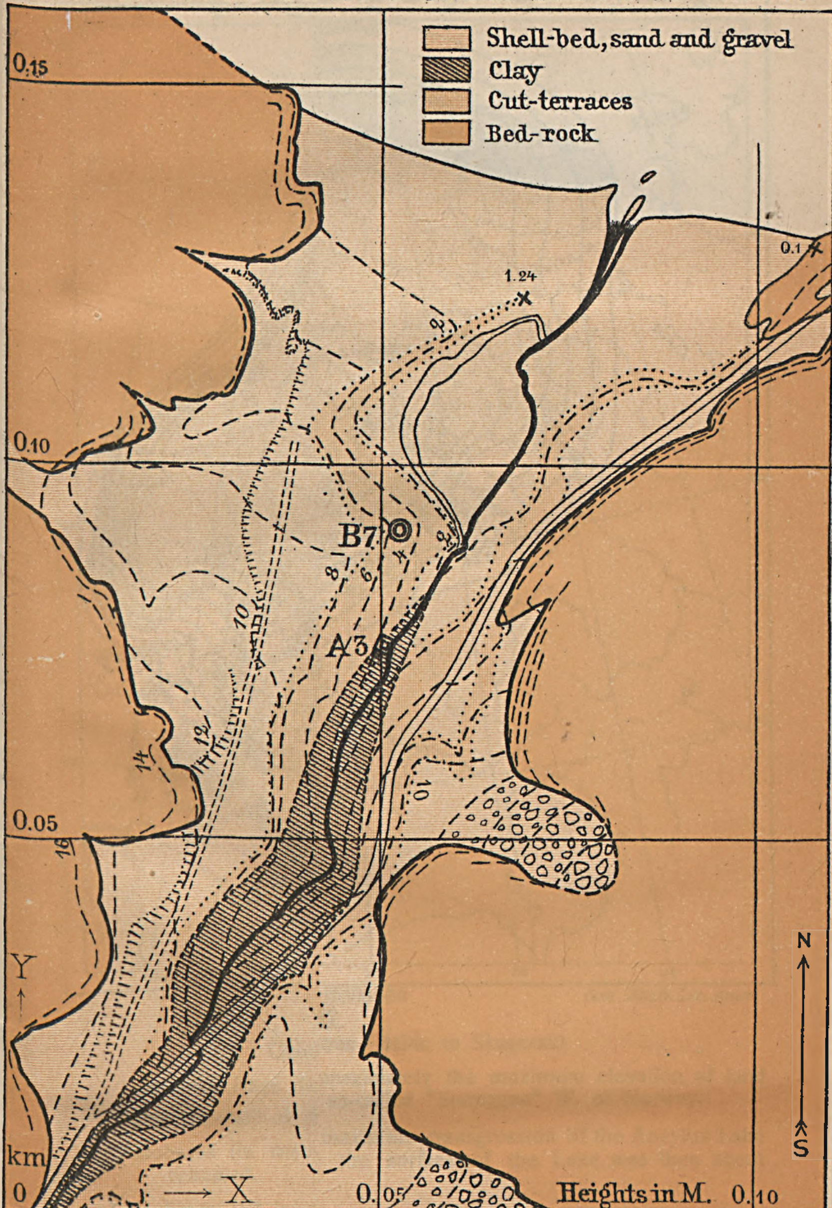
MAP OF A POSTGLACIAL SHELL-BED AT TOFTERNA



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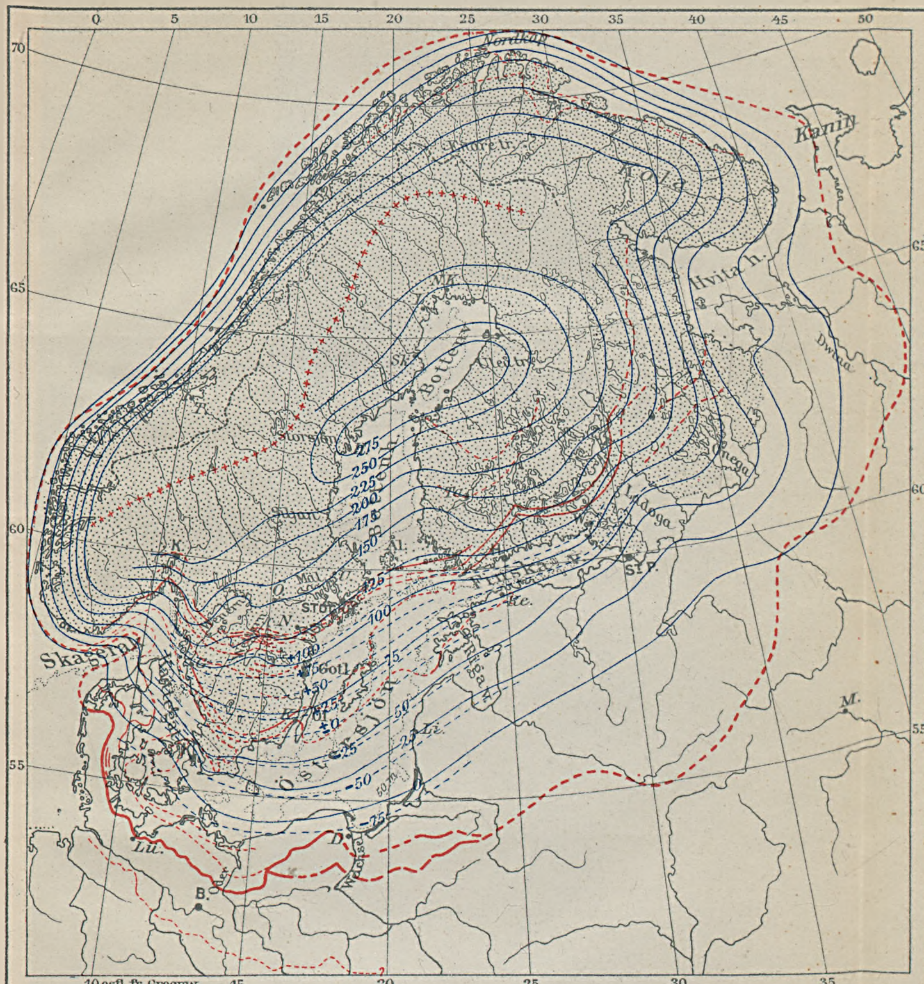
SOME FEATURES IN THE LATE-QUATERNARY DEVELOPMENT OF FENNO-SCANDIA AND ADJACENT DISTRICTS.



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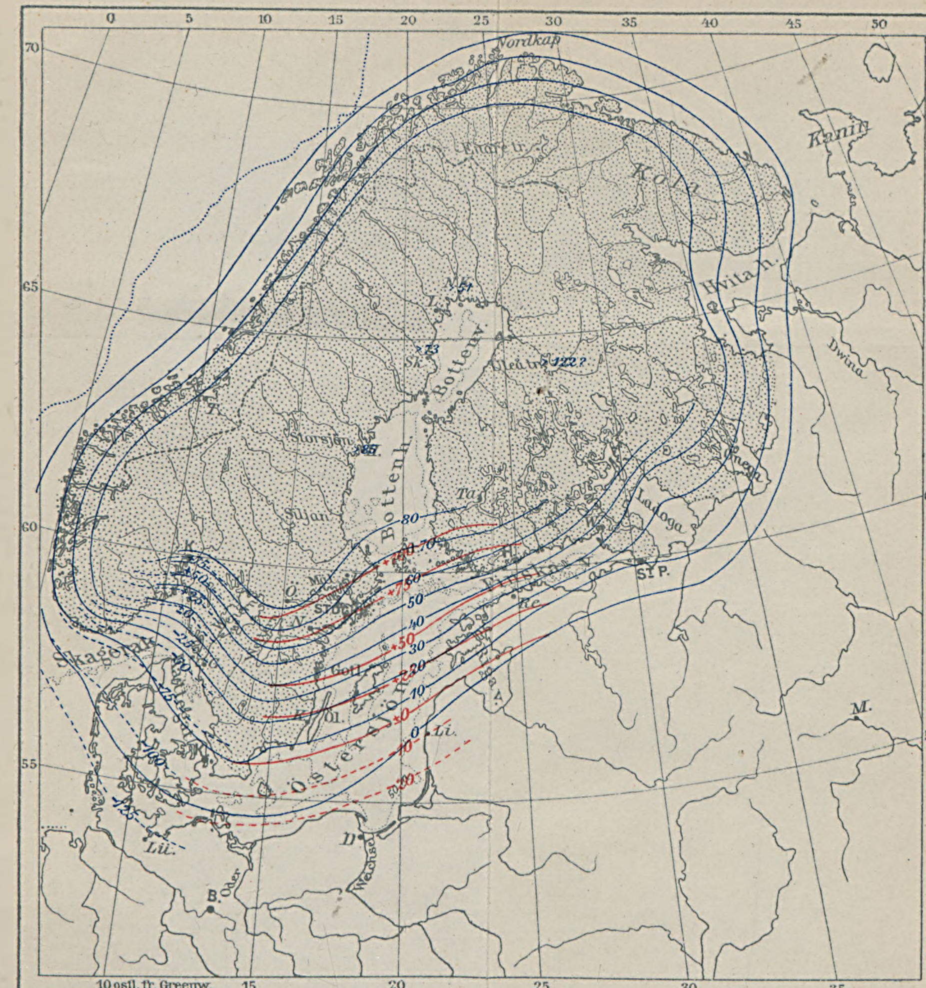
A.



Scale 1:12000000. *Gen. Stab. Lit. Anst.*

B.

Chiefly pre-Cambrian rocks (Fenno-Scandia). The water-shed of W. Scandinavia. The isobath of 50 metres (Baltic to Skagerak).

Terminal lines illustrating pauses in the retreat of the ice-border of the latest glaciation.

The ice-shed of W. Scandinavia.

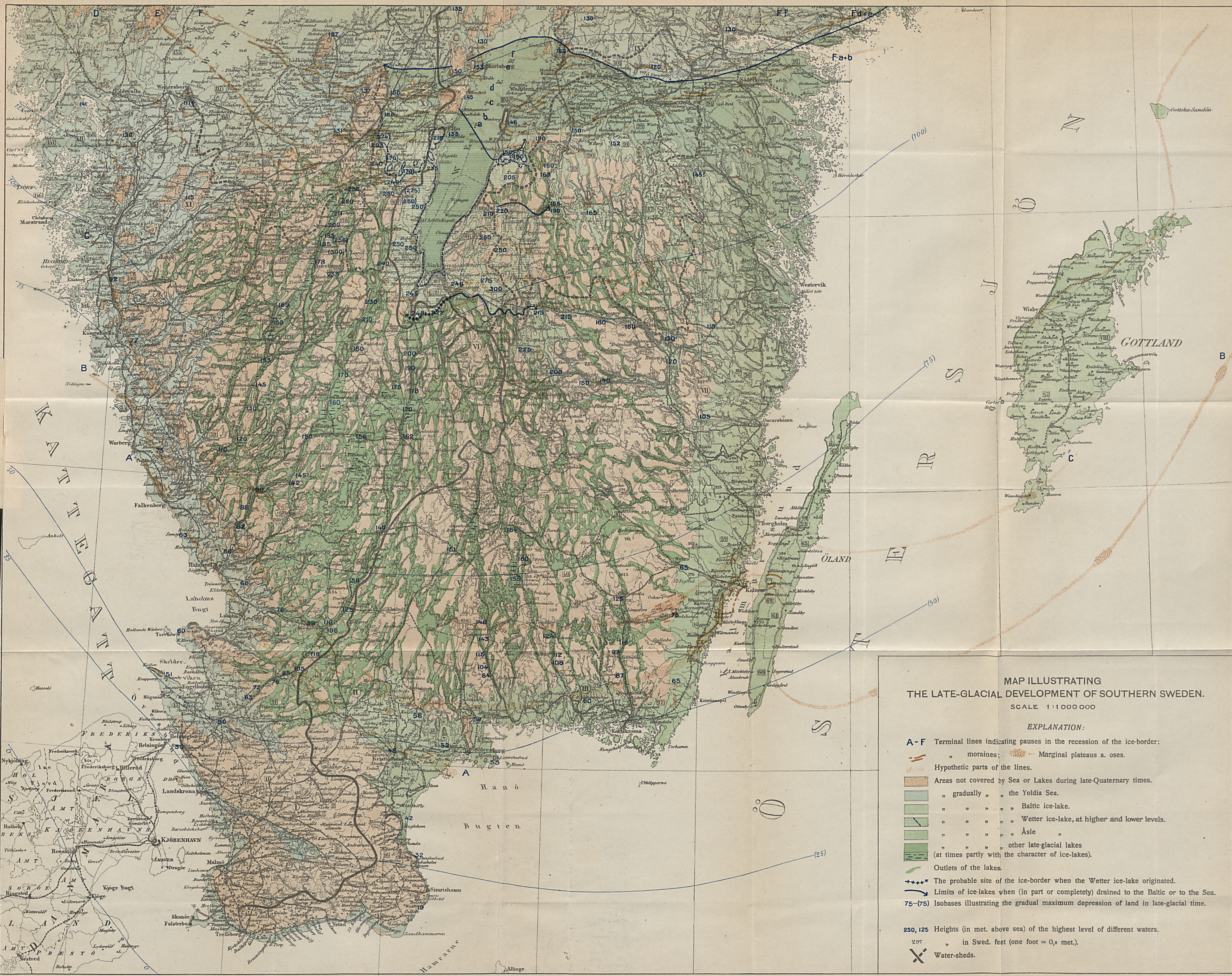
Isobases (in metres) illustrating the maximum land depression when the ice-border retreated.

Isobases and isocatabases partly illustrating the centripetal migration of the 0-isobase etc.

Isobases and isocatabases illustrating approximately the maximum elevation of land during the Ancylus time. The so-called "Storeggen" W. of Norway.

Isobases and isocatabases illustrating the maximum transgression of the Ancylus Lake within the Östersjö region. Probably the surface of the Lake was then about 50 metres above sea-level.

Isobases illustrating the amount of land-elevation after the maximum subsidence of land in postglacial time (= maximum extent of the Tapes-Litorina Seas).


MAP ILLUSTRATING
THE LATE-GLACIAL DEVELOPMENT OF SOUTHERN SWEDEN.
SCALE 1:1 000 000
EXPLANATION:
A-F Terminal lines indicating pauses in the recession of the ice-border:
„ moraines; Marginal plateaus a. oses.
Hypothetic parts of the lines.
Areas not covered by Sea or Lakes during late-Quaternary times.
„ gradually „ „ the Yoldia Sea.
„ „ „ „ „ Baltic ice-lake.
„ „ „ „ „ Wetter ice-lake, at higher and lower levels.
„ „ „ „ „ Åsle „
„ „ „ „ other late-glacial lakes (at times partly with the character of ice-lakes).
Outlets of the lakes.
The probable site of the ice-border when the Wetter ice-lake originated.
Limits of ice-lakes when (in part or completely) drained to the Baltic or to the Sea.
75–(75) Isobases illustrating the gradual maximum depression of land in late-glacial time.
250, 125 Heights (in met. above sea) of the highest level of different waters.
297 „ in Swed. feet (one foot = 0,3 met.).
Water-sheds.
KATTEGATT
ÖSTERSJÖN
GOTTLAND
ÖLAND
Hanö Bugten
Laholms Bugt

MAP ILLUSTRATING THE LATE-GLACIAL DEVELOPMENT OF FALBYGDEN.

MAP ILLUSTRATING THE DISCHARGING PHENOMENA OF THE WETTER ICE-LAKE WITHIN THE DALA DISTRICT.

H. Munthe 1910.

SCALE 1:30000

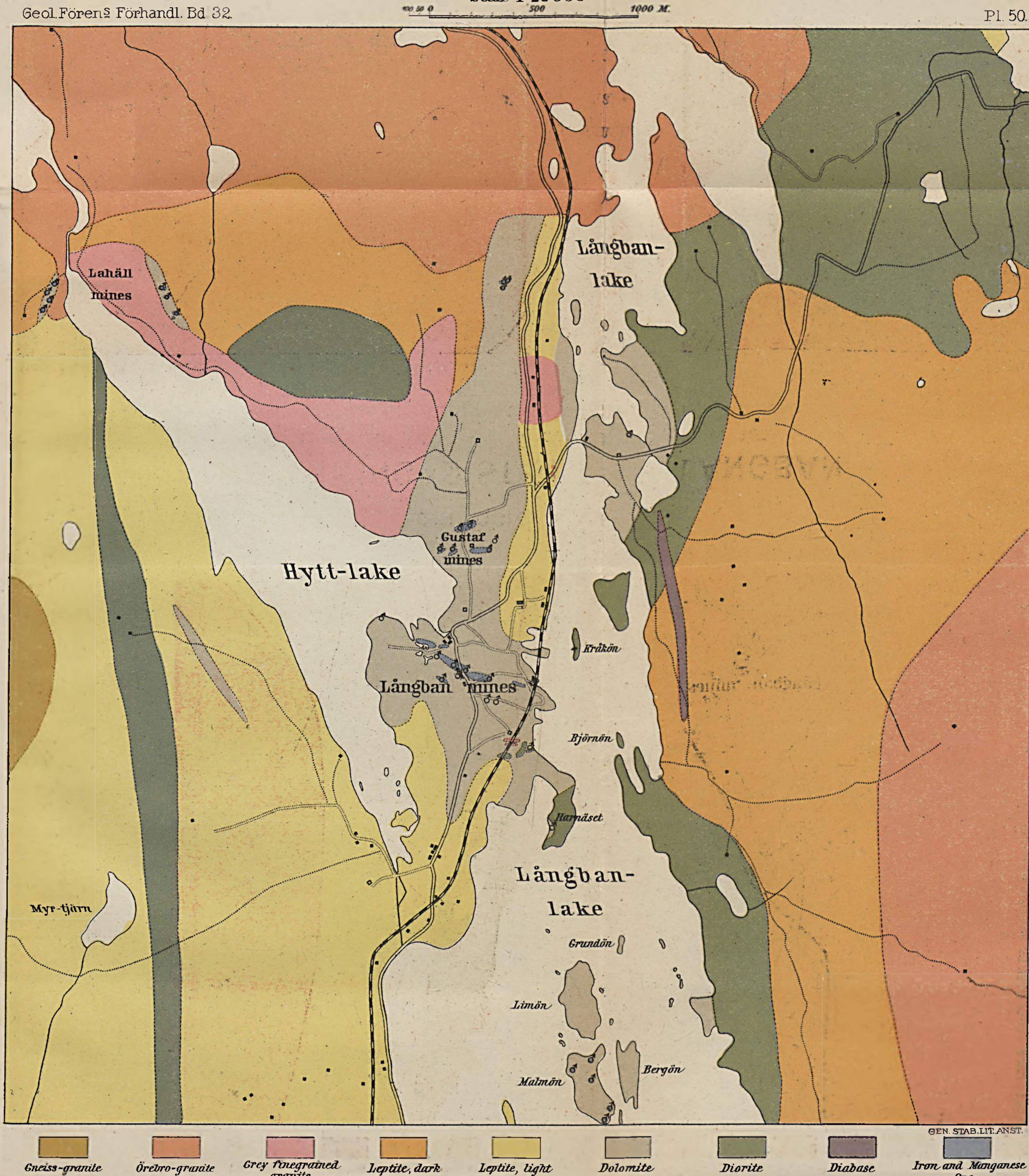
100 0 1000 2000 M.

Fotolit. Gen. Stab. Lit. Anst. Stockh.

1—8. Pauses of the ice-border represented by Terminal moraines. Hypothetic. — Areas not covered by late-glacial lakes. — Wetter ice-lake at its Higher a. Lowest stages. — Oulets of ice-lakes. Rapids (Bare-washed limestone). Rivers. — Erosion phenomena represented by Ravines. Steeps of water falls. Terraces. Planes. Isolated blocks (resid. of moraine). — Areas at times under water. — Heights (in met. ab. sea-level) of Ice-lakes. 200 Passes. 203 — Heights (in met. ab. sea). Sure 197.6 Approxim. c.198 — Isohypses. 200

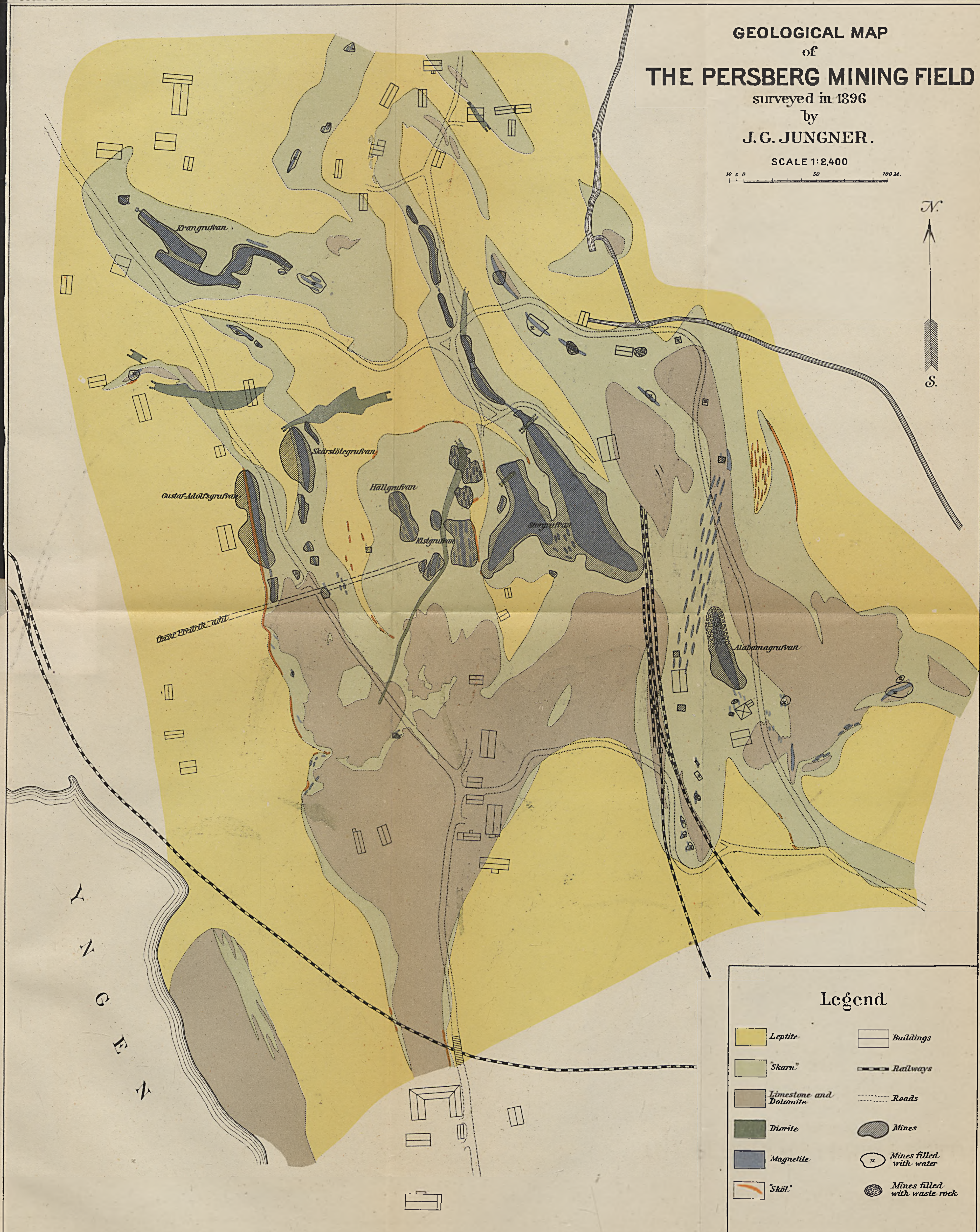
GEOLOGICAL MAP
of
THE MINING DISTRICT OF LÅNGBAN
on the basis of A. E. TÖRNEBOHM'S map of 1874
completed by B. G. G. TIBERG 1901

Scale 1:25 000



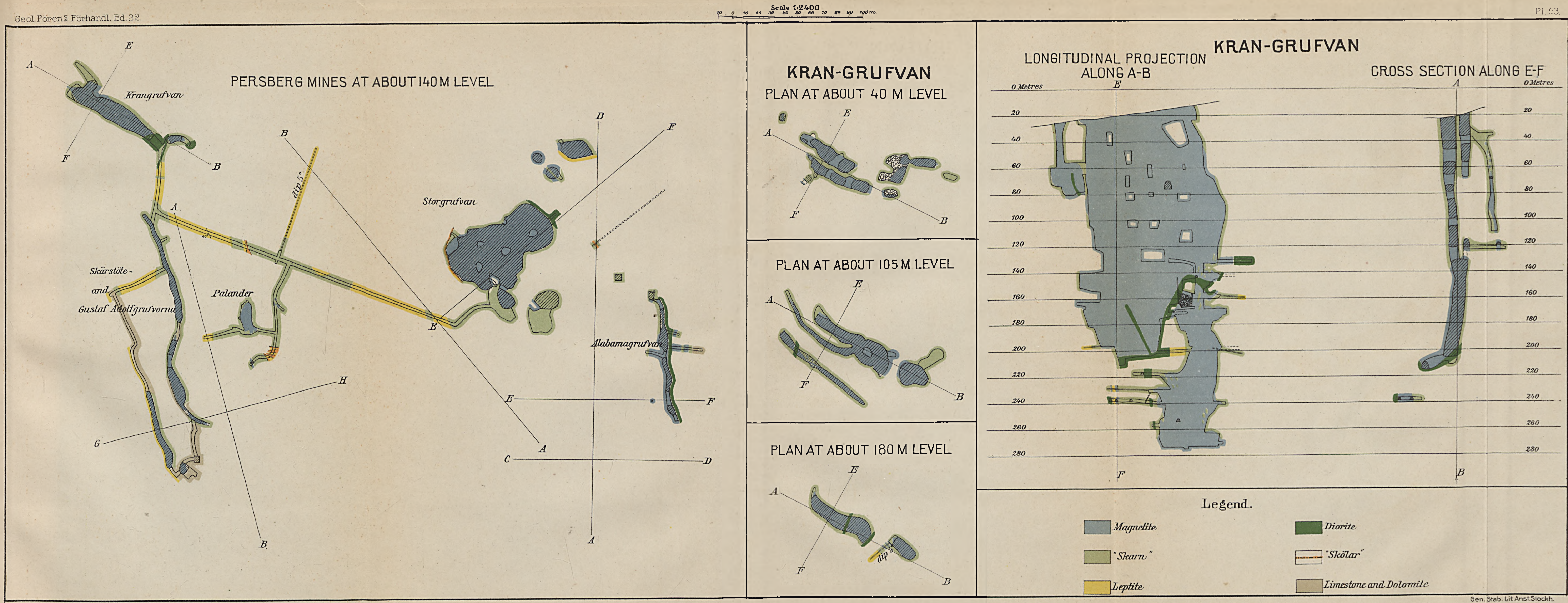
LÅNGBAN MINES

Gen. Stab. Lit. Anst. Stockh.



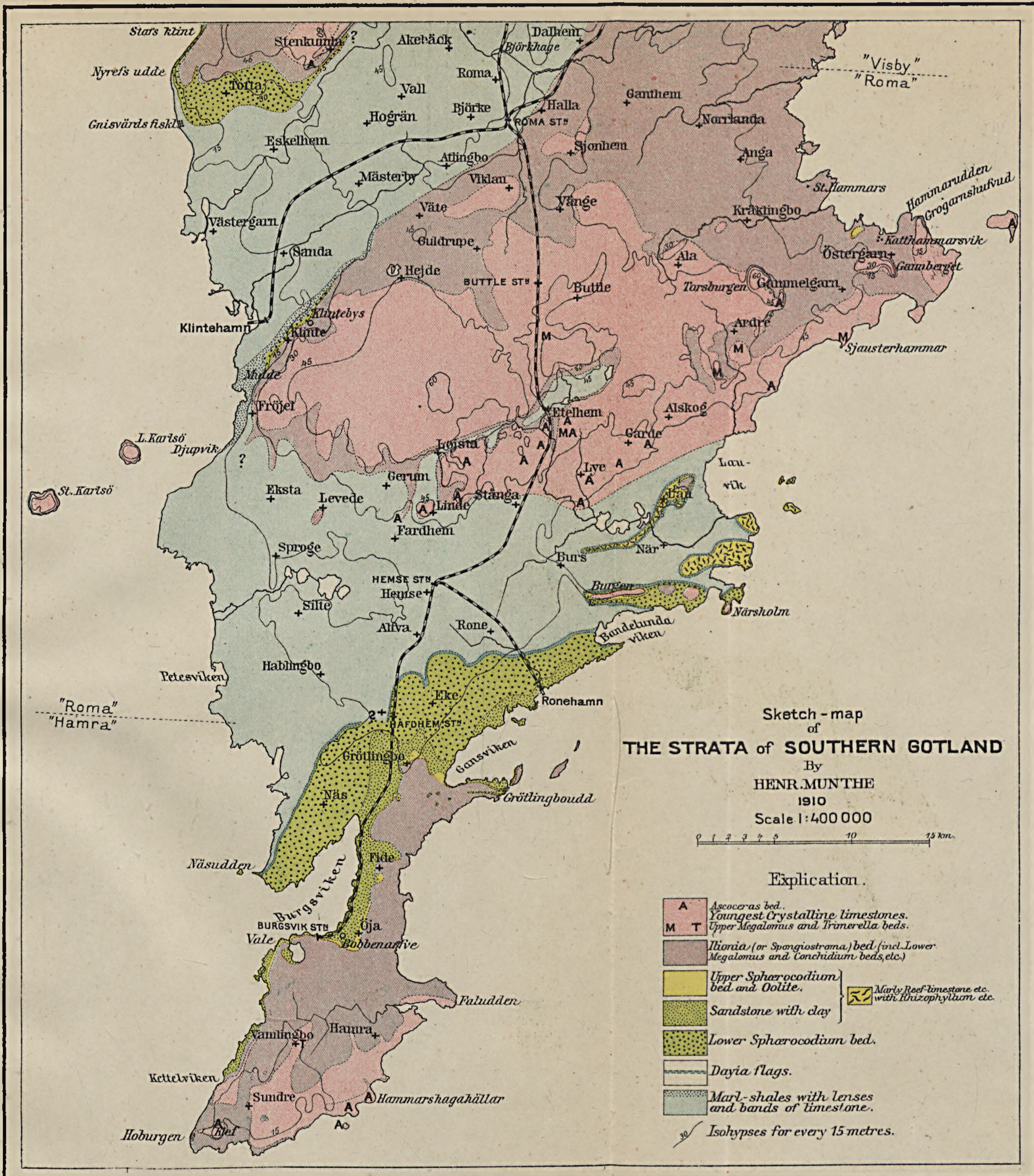
Gen. Stab. Lit. Anst. Stockh.

PERSBERG MINES

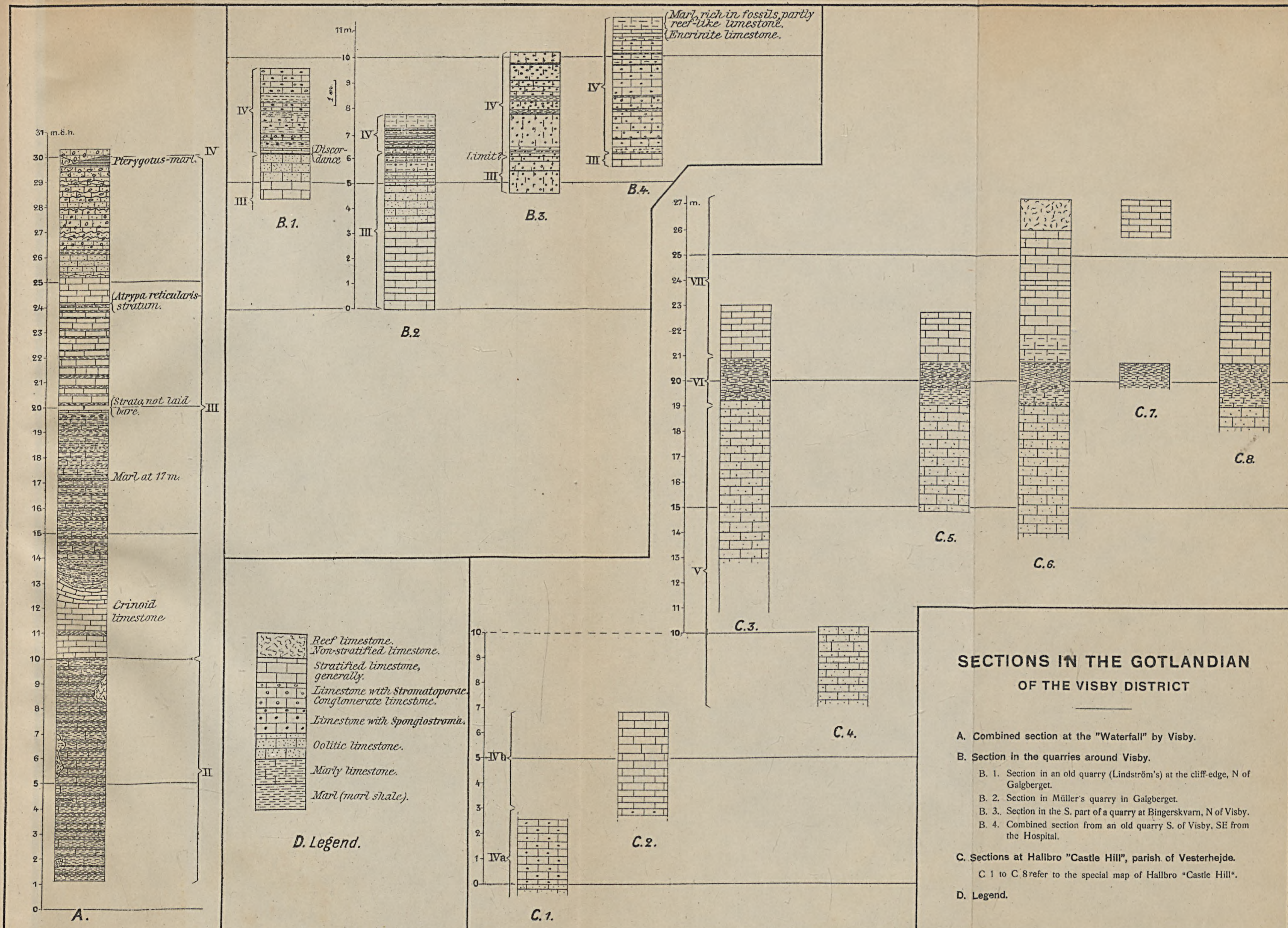


Gen. Stab. Lit Anst. Stockh.


SALA MINES
Scale 1:2400
PLAN AT ABOUT 190 M LEVEL
LONGITUDINAL PROJECTION ALONG A-B
CROSS SECTIONS ALONG
N-O
P-Q
0 Metres
A Torg shaft
B Trapprymning drift
C Sandrymning
D Queen Cristine shaft
E King Gustaf III do
F Do Carl XI do
G Fjärdedel drift
H N.Halfväg do
I Första Botten
K Spiran
L Svart drift
M Tredje Botten
N Schultzenheim
O King Carl XIV Johan shaft
A Makalös shaft
B Tandsköl-drifts
C Wallberg pit
D Smedje-drift
E Queen Cristine shaft
F W. Halfväg-drift
G N. do
H NW. do
I Ribbing-drift
K Första Botten
L Flint-drift
M Hans Pers mine
Legend.
Limestone
Lead, zink and silver ore
Diabase
"Skölar"



Generalstabens Litografiska Anstalt 1910



SECTIONS IN THE GOTLANDIAN
OF THE VISBY DISTRICT

A. Combined section at the "Waterfall" by Visby.

B. Section in the quarries around Visby.

- B. 1. Section in an old quarry (Lindström's) at the cliff-edge, N of Galgberget.
- B. 2. Section in Müller's quarry in Galgberget.
- B. 3. Section in the S. part of a quarry at Bingerskvarn, N of Visby.
- B. 4. Combined section from an old quarry S. of Visby, SE from the Hospital.

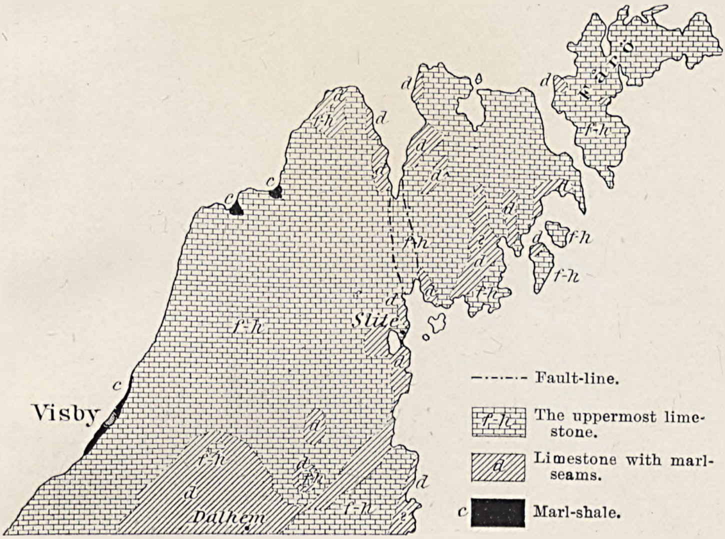
C. Sections at Hallbro "Castle Hill", parish of Vesterhejde.

C 1 to C 8 refer to the special map of Hallbro "Castle Hill".

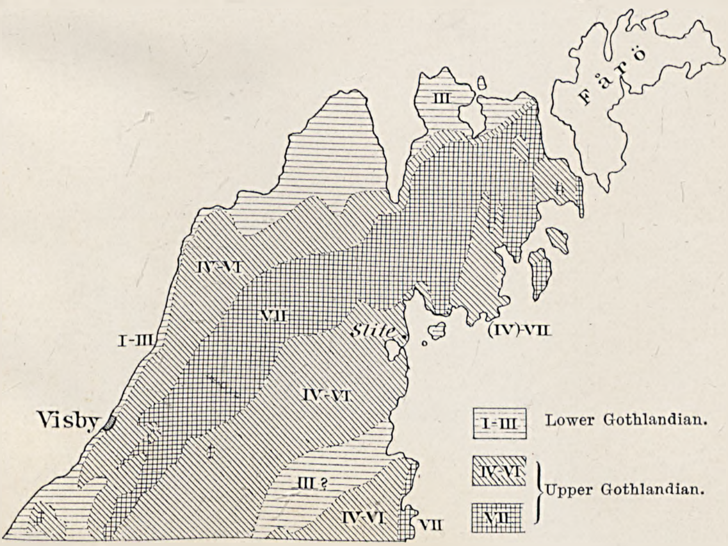
D. Legend.

Generalstabens Litografiska Anstalt, 1910.

Geological Map of northern Gothland.
According to G. Lindström 1888.



Geological Map of northern Gothland.
According to H. Hedström 1910.



100170.

58 a. The *Korpklint Reef* north of Visby. Photo G. Holm.

The reef limestone resting upon banks of Crinoid limestone which belongs to the border-layers between II and III (lower and upper cliff horizons). Below the last mentioned marl-schist belonging to the lower cliff horizon (II).

58 b. The Ners south of *Snäckgärdsviken.* Photo by the author.

Typical shore from north of Visby. To left there are in the surf lying some boulders washed out from the boulder clay, in the middle at the foot of the shore terrace the *Stricklandinia* marl is exposed, to the right some beaches and boulders thrown up upon parts of the moraine that were left and upon the underlying *Stricklandinia* marl.

100170.

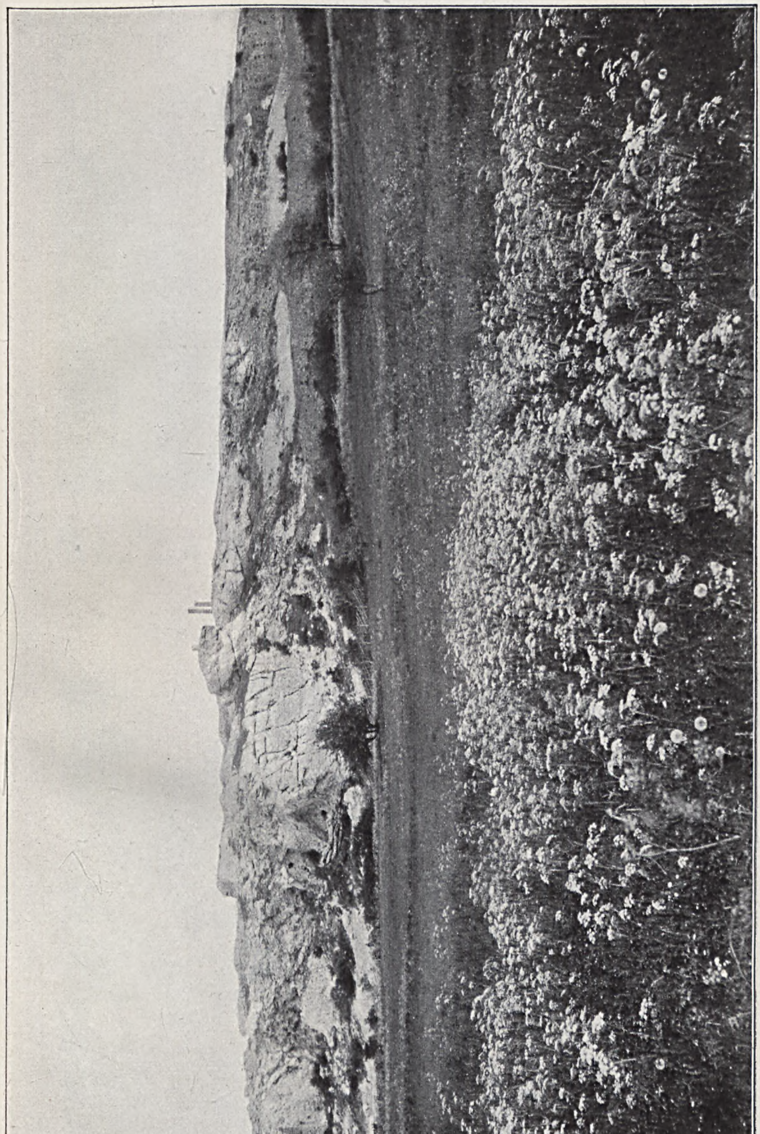


Photo G. Holm.

The reef of *Galgberget* (Gallows Hill) to the north of Visby.

Photo by the author.

60 a. The »*Waterfall*». The third fall from below. Lower marl-schist division of the upper cliff horizon, The marl stratum at 17 m. is marked as a weathering ledge.

Photo G. Holm.

60 b. The »*Waterfall*». The second fall from below. Reef-limestones in the upper part of the lower cliff horizon (II), higher up covered by Crinoid limestone banks belonging to the lower part of the upper cliff horizon (III). The reef-limestone is seen in the middle ot the photo.

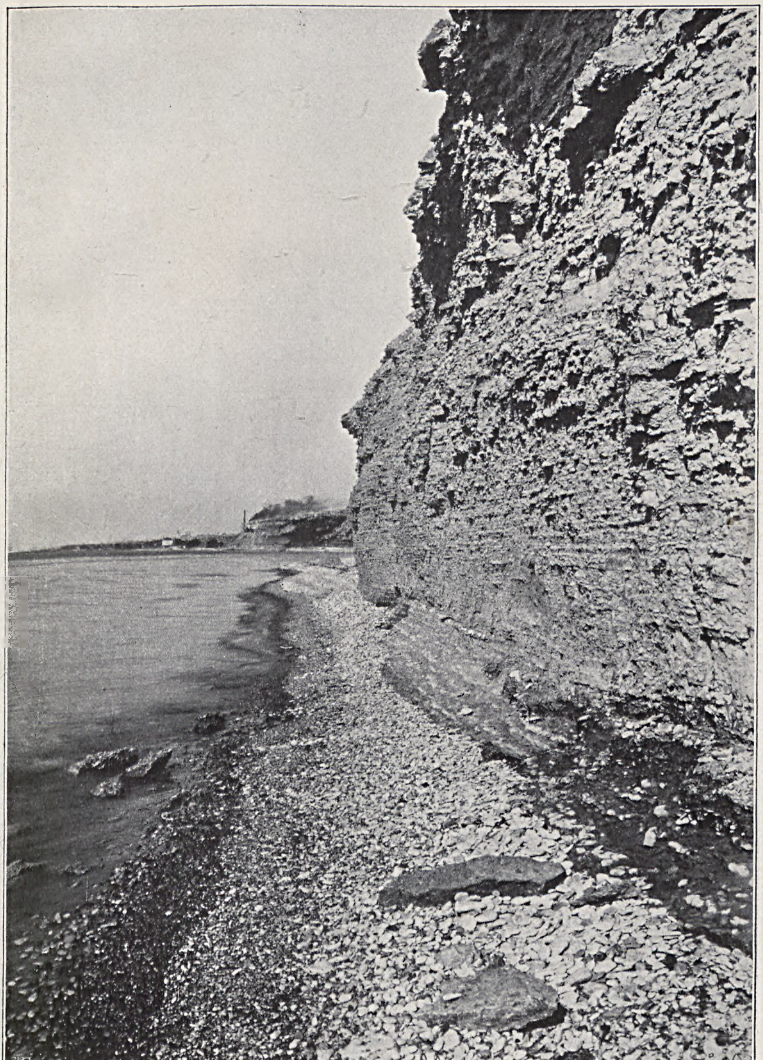


Photo G. Holm.

Pl. 61. Shore precipice in the lower cliff horizon (II) south of *Kopparsvik*.

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1

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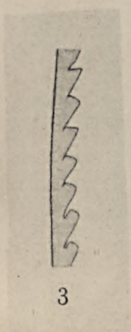

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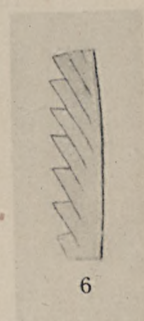

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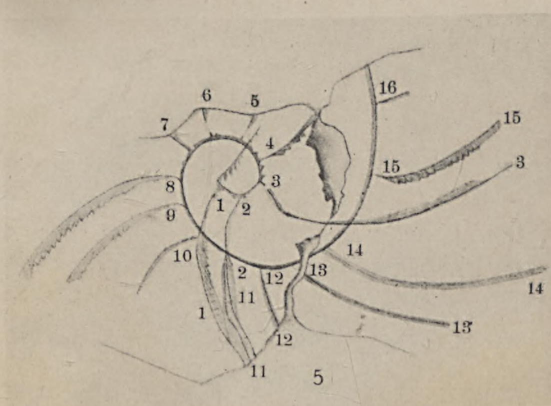

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Cederquists Graf. A.-B., Sthlm.

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GEOLOGISKA FÖRENINGENS

I

STOCKHOLM

FÖRHANDLINGAR

BAND 32

HÄFTE 5.

Innehåll:

Författarna äro ensamma ansvariga för sina uppsatsers innehåll.

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279

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Föreningens ***ordinarie möten*** *äga rum* ***första helgfria tors[-] dag*** *i månaderna februari, mars, april, maj, november oc[h] december. Dagen för januarimötet bestämmes å dec.-samman[-] komsten.*

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N:o 273 1910 December

GEOLOGISKA FÖRENINGENS

I

STOCKHOLM

FÖRHANDLINGAR

BAND 32

HÄFTE 7.

Innehåll:

Författarna äro ensamma ansvariga för sina uppsatsers innehåll.

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»	8 » » » »	....	à 7,50
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»	31 » » » »	....	à 15
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