DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 733

GEOLOGY OF THE YORK TIN DEPOSITS ALASKA

BY

EDWARD STEIDTMANN AND S. H. CATHCART

WASHINGTON
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GEOLOGY OF THE YORK TIN DEPOSITS, ALASKA.

By Edward Steidtmann and S. H. Cathcart.

INTRODUCTION.

SCOPE OF REPORT.

Tin is one of the few metals of which the United States needs more than can be furnished by its domestic supplies. This country is the world's leading consumer of tin but yields less than one-half of 1 per cent of the world's production. Our normal needs for tin are increasing, and the price has been going up during the last 10 years. Our normal deficiency in this metal was accentuated by the abnormal requirements of the World War.

This report discusses the York tin region of Alaska, the source of nearly all our domestic output of tin. It aims to present the facts known regarding the location, character, and history of the tin deposits of this region and the rocks associated with them. Emphasis is laid on the study of the origin of the lode deposits, with the view of formulating suggestions which may be helpful in the future search for tin in this region. Having had the results of Brooks, Collier, Hess, and Knopf to build on, the writers hope that they have succeeded in making some advances in the study of the structural relations of the tin deposits and of the rocks of the region. They have also revised some of the earlier reconnaissance mapping.

ACKNOWLEDGMENTS.

The acknowledgments of the writers are due first to the earlier students of this area, especially Messrs. Brooks, Collier, Hess, and Knopf, whose publications are listed in this report.

Of the people actively engaged in exploring and operating in the York tin region, Mr. J. F. Halpin, of New York City, has been especially helpful in extending courtesies. Others associated with Mr. Halpin, to whom acknowledgments are due, include Messrs. F. C. Fearing, mining engineer, of Philadelphia; W. B. O'Brien, of Seattle; and Alex McIntosh, of New York City. Courtesies and valuable information regarding the Potato Mountain country were

received from Messrs. A. S. Graham, George Mahla, and Tom Petersen.

Acknowledgments are also due to Messrs. G. C. Martin, Edwin Kirk, and E. S. Larsen, of the United States Geological Survey.

GEOGRAPHY.

LOCATION AND AREA.

The York tin region is the most westerly portion of the North American continent, extending within 60 miles of the coast of Asia. (See fig. 1.) It lies about 40 miles south of the Arctic circle. The

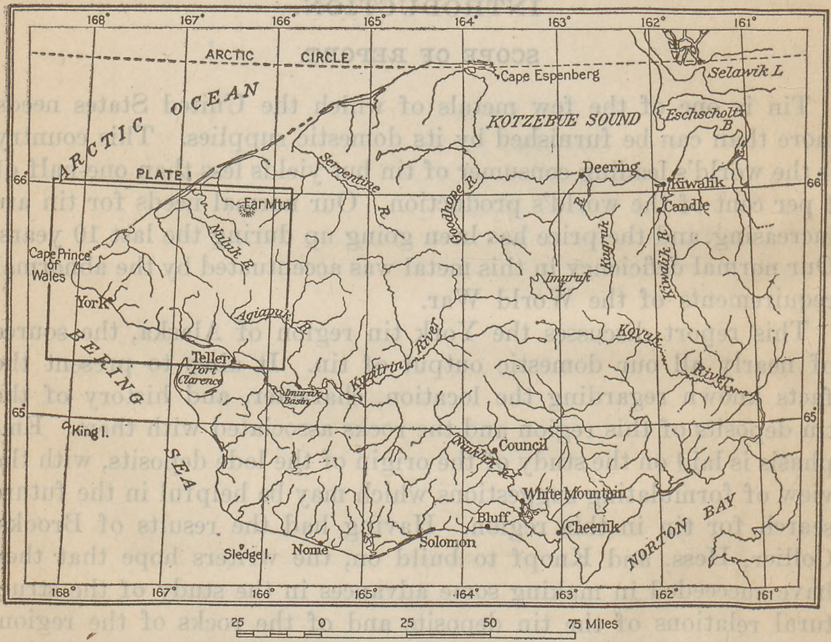


FIGURE 1.—Outline map of Seward Peninsula showing location of York region.

Arctic Ocean bounds it on the north, Bering Sea on the south, and Bering Strait on the west. This region is a part of Seward Peninsula, the westerly projection of Alaska.

The area has the form of a triangle whose base extends from Teller northward to Ear Mountain and whose apex is formed by Cape Prince of Wales. It includes about 600 square miles lying about 100 miles northwest of Nome, the largest town and distributing point for all of Seward Peninsula.

TOPOGRAPHY.

Three topographic types predominate—the mountain type, represented by York, Cape, and Ear mountains; the plateau type, represented by the slate area between the York and Cape mountains and by a sea terrace fronting Bering Sea between Kanauguk and Don rivers; and the coastal-plain type, represented on the Arctic coast and on the Bering coast north of Port Clarence. In addition to these may be considered the present beaches. (See Pl. I.)

The York Mountains constitute the greatest upland area of the region. They are steep and rugged and rise from the coast to general altitudes of 2,000 to 2,500 feet. The altitude of Brooks Mountain, the highest of the group, is 2,900 feet. The trend of the range is east-northeast. On the north the mountains slope gradually seaward and are represented in the broad tundra plain of the Arctic coast by rounded hills a few hundred feet above the sea. On the south, where they abut upon the Bering coast, they terminate in a sea cliff 400 to 600 feet high, capped by a terrace 1 to 4 miles in width. To the east the mountains recede from the coast, and cliffs and terrace are lost in the valleys of Don and California rivers, which, for 6 miles above their mouths, flow across a tundra plain. Northeast and east of California River the rugged, sharp-crested ridges of the main mountain mass gradually give way to more rounded hills that have an altitude slightly more than 1,000 feet.

On the west the York Mountains give way abruptly to the York Plateau. The plateau area is a rolling tundra-covered plain with an average relief of 200 to 600 feet. Potato Mountain, at its northern extremity, is the only notable prominence and has an altitude of 1,400 feet.

The western extremity of the area is marked by the isolated mass of Cape Mountain, which rises abruptly from the water's edge to an altitude of 2,250 feet.

Ear Mountain is an isolated butte in the northeast corner of the area, separated from the outlying ridges of the York Mountains by 20 miles of tundra-covered plain.

The coastal marsh and tundra plain bordering the Arctic coast ranges from 2 to 10 miles in width, and the tundra extends up some of the larger stream valleys 20 miles or more. The marsh is characterized by sluggish meandering streams and numerous lakes. On Bering Sea the coastal marsh occurs only within the shelter of Port Clarence, where it covers a triangular area of about 70 square miles. It is bordered by a shallow lagoon impounded by a barrier beach, which extends for 12 miles along the Bering coast.[1] (See fig. 2.)

DRAINAGE.

Probably two-thirds of the area is drained northward into Lopp Lagoon. The streams are numerous and of no great size. The

[1] Collier, A. J., The tin deposits of the York region, Alaska: U. S. Geol. Survey Bull. 229, pl. 2, 1904.

largest streams are easily forded, even at their mouths, and the many tributaries that dissect the mountains, plateaus, and terraces are but a few feet in width and in depth.

In the higher hills of the York Mountains the streams flow through V-shaped valleys. The smaller stream valleys are almost without bottom lands, and the walls are steep talus slopes, which give to the valleys canyon-like characteristics. The larger streams, such as Lost River, have developed valley bottoms half a mile or more in width, and their confining hills are less precipitous and are interrupted at short intervals by well-developed tributary valleys.

In the York Plateau, in the lower hills that extend northward and eastward from the main mass of the York Mountains, and in isolated slate areas throughout the region, the streams flow through valleys of mild relief and in general have well-developed lowlands.

Where the streams enter the coastal-plain area and flow through tundra marsh, their currents are sluggish and their course meandering.

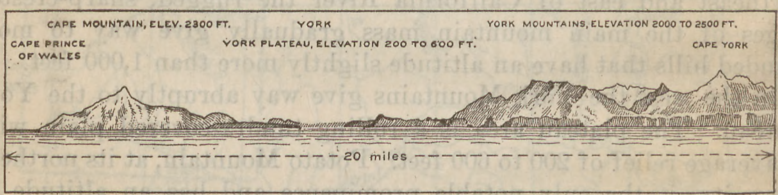


FIGURE 2.—Sketch of the coast from Cape York to Cape Prince of Wales, Alaska.

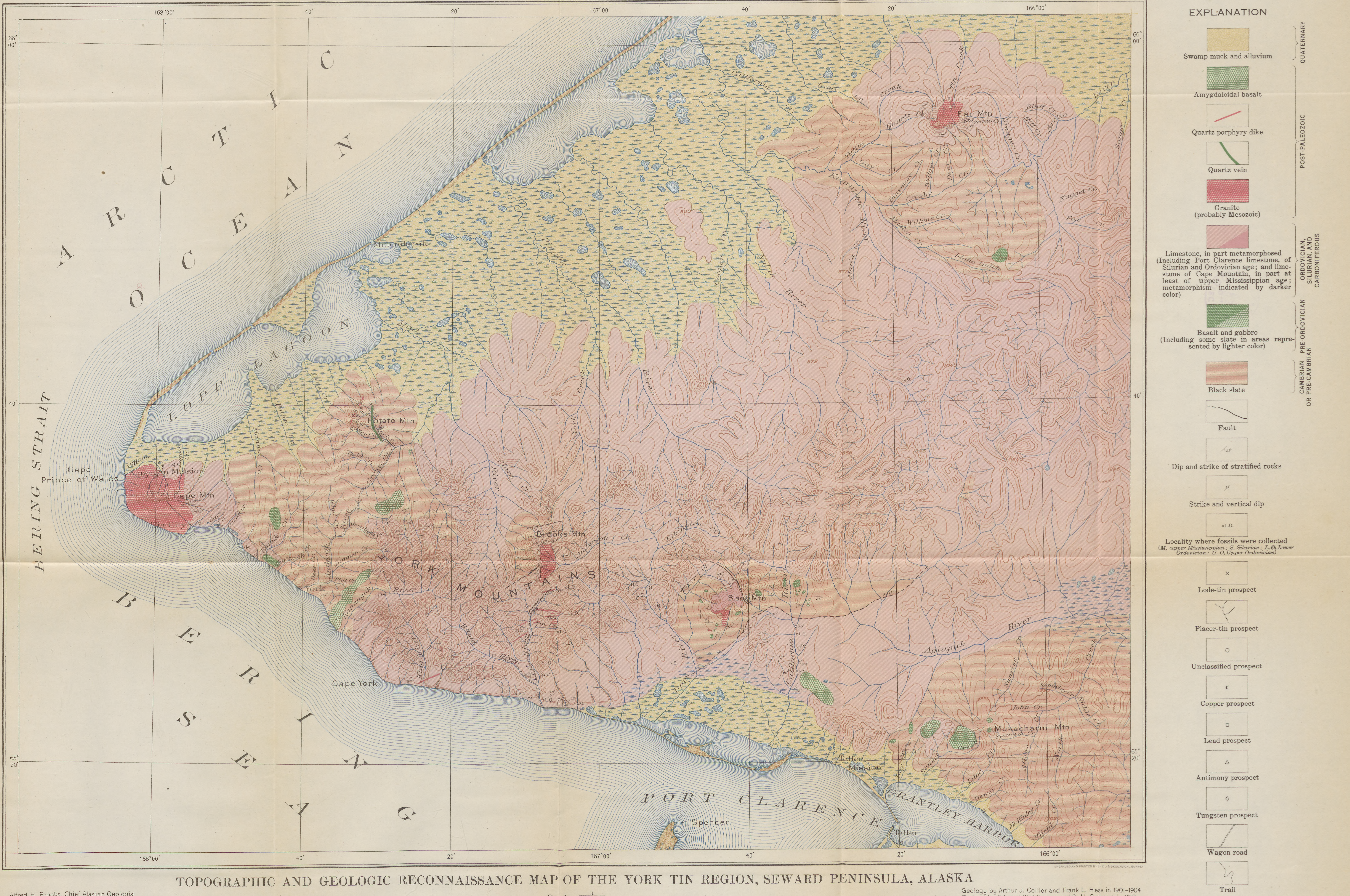
In the areas not covered by tundra most of the rainfall disappears immediately as run-off, owing to the steep slopes, the frozen condition of the ground at no great depth, and the total absence of vegetation. In the areas covered by tundra the run-off is retarded, as if held by a sponge, and supplied gradually to the streams.

Gullies and ravines are the sites for the accumulation of ice and of much of the winter's snowfall, which is swept from the lowlands and ridges by the high winds that prevail throughout the region. In the spring most of the snow and ice disappears from the lowlands and exposed ridges and supplies water for the usual spring run-off, to which the placer miner looks forward.

Isolated masses of ice and snow persist in the sheltered ravines into and even throughout the summer. They furnish a constant source of supply to the streams, but in dry seasons the miner often finds them insufficient.

CLIMATE.

The climate of the region is arctic and is controlled largely by the Arctic Ocean and Bering Sea. High winds from the north or south are the rule, and fog and rain prevail in the summer. The precipita-



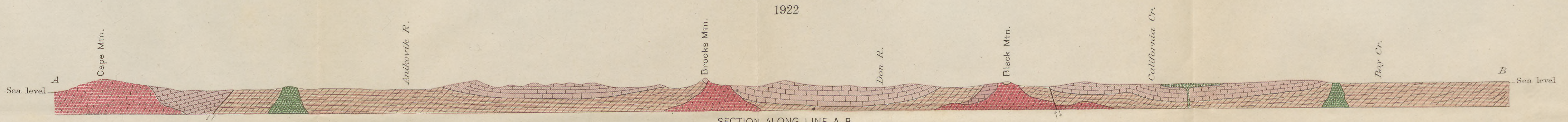
TOPOGRAPHIC AND GEOLOGIC RECONNAISSANCE MAP OF THE YORK TIN REGION, SEWARD PENINSULA, ALASKA

Alfred H. Brooks, Chief Alaskan Geologist
Topography by T. G. Gerdine, D. C. Witherspoon and A. H. Brooks.
Surveyed in 1900 and 1901

Geology by Arthur J. Collier and Frank L. Hess in 1901-1904
Revised by Edward Steidtmann and S. H. Cathcart in 1918

Scale $\frac{1}{250000}$

Contour interval 200 feet
Datum is mean sea level
1922



SECTION ALONG LINE A-B

tion is probably not great. St. Michael, at the mouth of the Yukon, the nearest recording station, has an annual precipitation of 18 inches and a season of 125 days during which rain falls. The precipitation of the York region is probably a little more and the season shorter—24 inches and 100 days might more nearly express it.

The winters are severe and snows often heavy. Temperatures of —50° F. are frequently recorded.

Bering Sea is frozen from November to June, when the ice pack drifts northward through the straits and navigation opens. Inclosed waters, creeks, and ditches may be expected to freeze up in October and to open in May.

The summers are short. Freezing temperatures are prevalent at some hour of the day except for three or four weeks in July and August. The days from July to mid-September are not uncomfortably cold to one dressed in woolens. During July and August the temperature is above freezing sufficiently to give the creek and pond waters a temperature of 40°–50° F.

Snow caps the higher hills until late in July, and many of the gullies are never free from snow and ice the year around.

The unconsolidated materials (muck, gravel, etc.) underlying the tundra are frozen solid the year around and must be thawed before they can be mined. Such frozen masses may include 50 feet or more of material, as on the Nome flats, in the southern part of the peninsula. Again, a tundra-covered surface 50 feet from the bedrock may be underlain by 40 feet or more of ice with only a few feet of earth. Peat is a common constituent of such a section and as a rule immediately underlies the tundra for a thickness of 1 to 3 feet. The stream gravels are frozen to a depth of several feet in winter, but are thawed by circulating waters in the open season.

ROCK WEATHERING.

Rock weathering in the York region is caused chiefly by solution and frost action, of which the latter is by far the more effective. In so cold a climate solution is much less vigorous than in warm, moist regions. It is checked directly by the low temperatures and to a greater extent indirectly by the limitation which the low temperatures in turn place upon the duration and depth of the underground water circulation. Low temperature does not decrease the solubility of certain substances in water. Calcium carbonate, for example, is more soluble in cold carbon dioxide bearing waters than in warm. That solution has taken place in this region is evinced by gossans, the occurrence of hard stream waters in the limestone areas, the development of residual clays on limestones, and the occasional deposition of limonite in tundra pools.

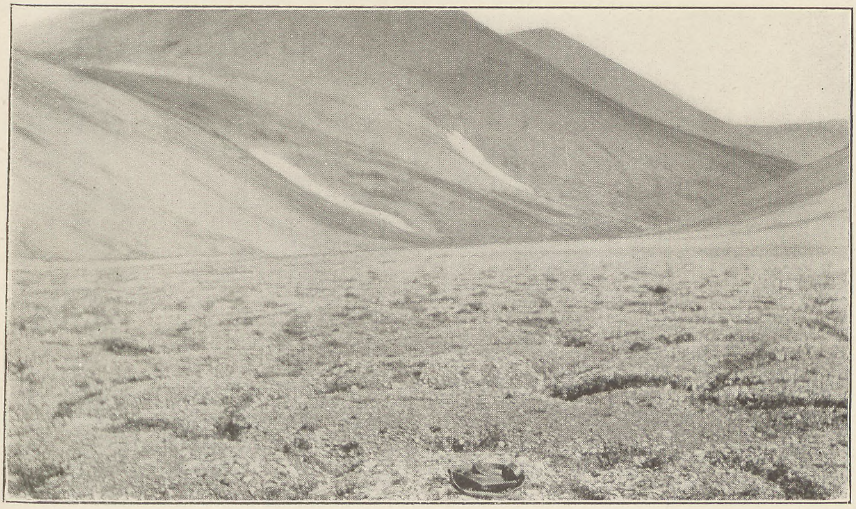
The checking of the underground water flow is most pronounced under low tundra-covered areas. In the rugged portions of the slate and limestone areas underground circulation penetrates to considerable depth, causing the perennial flow of springs and streams and the development of gossans 85 feet or more deep. It is more vigorous in limestone areas than in those underlain by slates. Slate areas are sufficiently impervious to make the transmission of water in open ditches along hillsides a success, but similar undertakings in the limestone areas of the York region failed because of the permeability of the rock.

But even the rugged areas probably have some deep, frozen ground that retards circulation. The formation of ice in summer at the end of adit No. 3 on Cassiterite Creek at a depth of 260 feet below the surface and 61 feet above the creek indicates that the temperature underground in this hilly limestone area is low enough to cause the formation of ice wherever the circulation is not sufficiently vigorous to cause thawing. That vigor of circulation is a vital factor in thawing is shown by the practical success of a method of thawing placer ground by forcing cold water into it. The existence of deep frozen ground in the limestone area may also be a cause for the rapid swelling of the streams in response to even light showers. A very high percentage of run-off is also characteristic of the tundra-covered slate country, but here it is to be expected because of the saturation of the surface materials. On the other hand, the quick response of streams of the limestone area is surprising in view of the porous character of the surface deposits.

The underground waters in the slate areas are probably more active chemically because of the peat and tundra through which they pass, but the waters of the limestone areas accomplish more solution because of their more vigorous circulation and the greater solubility of the limestone. Stream waters of the limestone areas are hard; those of the slate areas are generally soft.

Frost action consists mainly in the expansion of freezing water held in the pores and cracks of rocks. This expansion tends to reduce all outcrops to a mass of broken rock of all sizes down to minute grains. Outcrops are therefore rare except where the removal of the broken rock is more rapid than its formation, as along cliffs and stream channels. The expansion of ice when the temperature rises also contributes to the breaking up of rocks, but a rise of 1° in the temperature of ice causes an expansion only about 0.006 per cent of that due to the change from water to ice.

The conditions most favorable for frost action are southerly exposures, barren surfaces, and a highly fractured rock. It is most effective in spring and autumn, because these seasons have the greatest frequency of alternate freezing and thawing. Limestone surfaces are

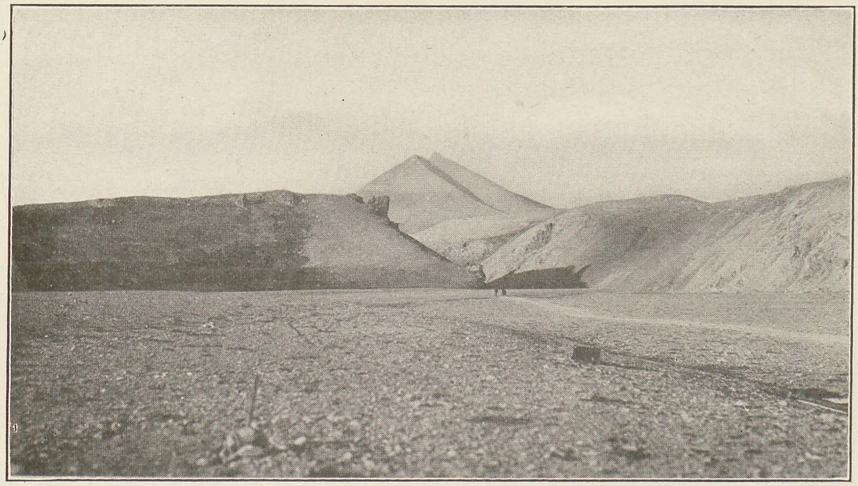


A.

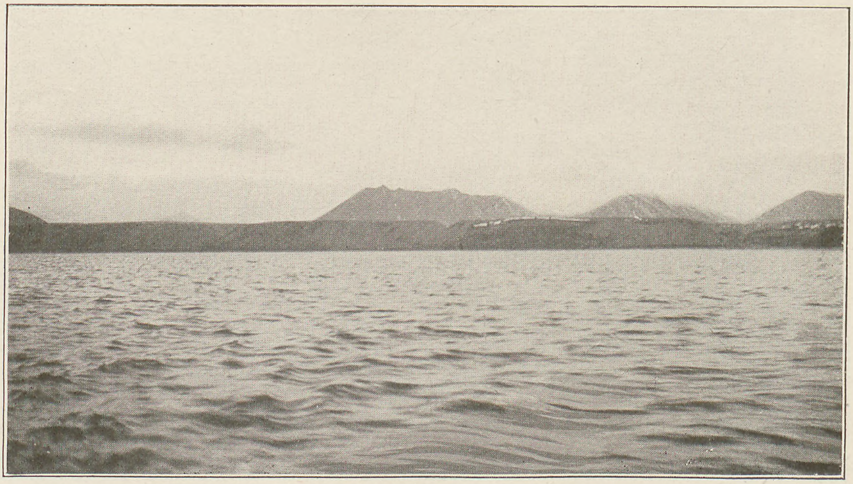
B.

FROST CRACKS IN SLOPE WASH EAST OF LOST RIVER.

A, In foreground polygonal gaping cracks; *B*, cracks filled with coarse rubble, chiefly limestone.



A. CANYON NEAR THE MOUTH OF LOST RIVER.



B. THE SEA TERRACE NEAR LOST RIVER.

York Mountains in the background.

SURFACE FEATURES NEAR THE MOUTH OF LOST RIVER.

more barren than slates, but slates, because of their cleavage, are more subject to frost action, and hence disintegrate more rapidly than limestone.

The reason for the slate being covered by tundra whereas the limestones are nearly all bare is an interesting problem in itself. The poorer drainage of the slates is probably a contributing factor, but that it is not the only one is shown by the limestones being generally bare, even on low ground. In marked contrast to this the surface of decayed dikes cutting limestones are commonly covered with moss. The barreness of the limestone seems to be tied to the composition of the limestone and not to any condition of slope or altitude. The plants that constitute the tundra, being distinctly of the "acid soil" type, thrive best where there are no neutralizers of acids. The limestones have a strong destructive action on these acids and therefore do not offer a favorable environment for these plants. The slates, on the other hand, having in themselves neither pronounced acid nor acid-destroying properties and being poorly drained, offer favorable conditions for the accumulation of the acidity which these plants require for their existence.

ROCK TRANSPORTATION.

The products of weathering in this climate are chiefly broken, chemically unaltered rock materials and only to a very minor degree leached soil. They are transported by stream action, soil creep or flow, landslides, peat and mud flows, and other agencies. The slow, unnoticed creep or flow of surface materials down slopes appears to be very common in arctic regions and is an inviting subject of study. The saturation of the thawed surface materials in the summer and their consequent mobility is an important factor in this downward movement, particularly in tundra-covered areas. More spectacular flows occur when lakes on hillsides or hilltops which are held by the growth of tundra burst through their organically deposited barriers and send a flood of water, mud, and peat upon the slopes below.

An interesting result of combined frost action and the transportation of surface materials is the frost-crack pattern (Pl. II). In the York region this pattern was studied only on barren, clay-covered areas of the limestone country. Leffingwell[2] describes a more gigantic frost-crack pattern developed in the peat bogs bordering the Artic Ocean.

The frost-crack pattern studied in the York region was commonly developed on gentle clay-covered slopes. It consists of a network of wedge-shaped cracks, at least 3 feet deep in many places and about 1 foot wide at the top. Cross sections were not seen. Commonly

[2] Leffingwell, E. de K., Ground-ice wedges: Jour. Geology, vol. 23, pp. 635–654, 1915.

large cracks unite into a roughly hexagonal pattern. The blocks between the cracks are usually five, four, or three sided or even circular. Not uncommonly they are perfectly hexagonal. The diameter of the large blocks averages about 6 to 8 feet and rarely exceeds 10 feet (fig. 3). Commonly a miniature frost-crack pattern is shown on the blocks between the large cracks. The width of the blocks in this minor network is commonly from 4 to 6 inches.

The large pattern presents two extreme phases. In one the cracks are empty or nearly empty and gaping. In the other the cracks are filled with angular and rounded rocks 1 foot or less in diameter, which rise as ridges above the adjacent blocks, in some places to a height of 2 feet. The cracks are thus marked by ridges of loose rock. The rocks in many of the cracks are not all limestones but include granites, porphyries—in fact all the rocks transported over the surface on which they occur.

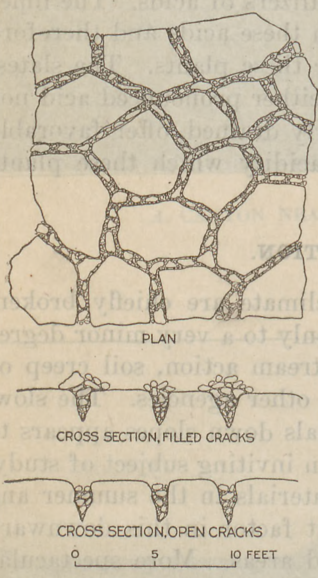


FIGURE 3.—Frost-crack pattern.

The history of the frost-crack pattern is interpreted as follows: The wet clays freeze, and as the temperature falls linear contraction of the ice tends to take place at the rate of about 1/36,000 for each degree Fahrenheit. A bar of ice 8 feet long, for example, would tend to contract about 0.2 inch if its temperature was reduced from 32° F. to —50°. If the ice is not free to move, tensile stresses are set up which, when they exceed the tensile strength, cause cracks. An interesting unsolved secondary problem is why two frost-crack patterns are developed, the large and the small. The gaping, wedge-shaped form of the cracks may be due to the fact that the clays suffer less reduction in temperature at depth and hence contract less, and also to the fact that the surface materials have a lower tensile strength. It is probable, too, that the wedge shape is accentuated by a later freezing of water in the cracks.

When the spring thaws begin water fills some of the cracks and, on freezing, expands and tends to widen and preserve the cracks. This is also liable to happen in autumn. Season after season this process is repeated and tends to preserve and increase the size of the openings.

Over nearly all surfaces of this region rock débris is moving downhill. The occasional vigorous rains may cause some of this movement, but the large size of some of the particles of the débris suggests that slow forms of creep are more important. Rains adequate to move materials of the size seen on some of these gentle slopes did not fall in 1918. A slow motion of boulders may perhaps result from the change in their center of gravity produced by the upward heave of freezing water under them, which may cause them to move slightly downhill. Boulders in their transit over the surface fall into the frost cracks and fill them. The suggestion that the boulders may get into the cracks in other ways, such as by frost heaving them up from ledges or boulder beds below, will not serve as a complete explanation, for they occur in places where underlying boulder beds are nonexistent or highly improbable. The material that fills some cracks, comprising several kinds of limestone, granite, and porphyry, could not have come from underlying ledges.

The upheaval of the boulders lying in the frost cracks into ridges that rise above the adjacent surface is believed to be due to the upward shove of ice that formed in the cracks. Ice expands as rapidly when the temperature rises as it contracts when the temperature falls. Such expansion would be relieved chiefly by upward movement, for the opportunity for lateral relief would be very slight, and resistance from below would prevent expansion downward.

VEGETATION AND ANIMALS.

The only timber available for construction in this region is driftwood deposited on the beach in time of storm. Locally, in some of the stream valleys, a scanty growth of scrub willows, ordinarily but a few feet high, is available for use as fuel. It is an uncertain and unsatisfactory fuel at best and to be recommended only as a last resort.

Most of the larger stream valleys and the coastal plains afford grass which is suitable for grazing during the short summer season of July and August. The great fields of tundra furnish an abundant supply of moss that is well adapted to the needs of reindeer, but of little value to other stock.

The higher hills of the York, Ear, Potato, and Cape mountains are almost barren of vegetable growth, affording neither timber for fuel nor grass for grazing. In general, the York Mountains proper and the lower limestone hills extending eastward from them are the most destitute of willows and grass. The slate areas usually afford a considerable supply of both.

Land animals were once plentiful in the area, ptarmigan, snipe, plover, curlew, rabbits, and a few bear furnishing prospectors with an abundance of meat, but within recent years their numbers have been greatly reduced. Rabbits have practically disappeared, and a few small flocks of ptarmigan, with an occasional fox or bear, alone remain. Sea fowl, including geese, ducks, sandhill cranes, and swans, are plentiful, especially along the coast.

The streams, with the exception of some of those flowing through the heart of the York Mountains, which contain scarcely any vegetable life, are fairly well stocked with grayling and trout.

Geological Survey parties working in the region have found it necessary to carry horse feed and advisable to carry oil for fuel.

ACCESSIBILITY.

During the open season, from June to November, one steamship line maintains a rather erratic schedule between Seattle and the ports of Seward Peninsula. Nome is as far north as the passenger service extends, but between July 1 and September 30 freighters are occasionally sent through the straits to Arctic ports. The freighters touch at Teller and also discharge cargo at points on the south coast of the York district, the freight being transferred from the boats to shore on lighters sent out from Teller. Except for these freighters, communication between Nome and the York region is maintained by small coastwise gas schooners of 20 to 50 tons burden. This navigation opens about the middle of June and continues until late in October. One schooner licensed to carry mail maintains a two-week schedule, as nearly as the weather conditions permit, between Nome and Arctic points, carrying passengers and freight and stopping at several coast points on signal if the winds and fog are favorable. Other schooners also carry freight and passengers but make no pretense at maintaining a schedule.

Points on the Arctic coast of the York district are not easily accessible by boat owing to the shallow lagoons impounded behind barrier beaches which extend along the shore and which are in turn bordered by extensive tundra marshes. Freight landed at such points as Shishmaref Inlet must be lightered in shallow-draft boats from the coastwise schooners to the shore and up the tortuous stream channels of the tundra flats to solid ground, where it can be picked up by teams.

HARBOR.

Port Clarence, about 40 miles east of Cape Prince of Wales, is the only harbor that affords adequate protection to coastwise schooners plying between Nome and the cape. From Port Clarence westward the coast is treacherous and subject to frequent storms. Landings are not attempted except in favorable weather. Much loss of time, hardship, and uncertainty of coast boat service are occasioned by the inadequate harbor facilities. The Arctic coast of the area has no harbors.

TRAILS.

During the winter communication between Nome and Teller is effected by the overland route by means of dog and sledge. A 10-day mail service is maintained. The overland trail used in the open season follows the coast from Nome westward to Tisuk River, up the Tisuk and across the divide to Bluestone River, down the Bluestone to Right Fork, and thence by a direct course over tundra-covered hills to Teller. The trails are everywhere passable to horse and wagon, although they do not afford an easy haul. Pack trains experience no serious difficulty. Sinuk River is crossed on a Government ferry; all other streams are fordable. There are roadhouses affording accommodations on the trail at Sinuk and Gold Run. A shelter cabin has been constructed by the road commission at the mouth of the Tisuk. The journey of about 85 miles is readily made in four days' travel.

From the sand spit north of the entrance to Grantley Harbor all the known mineral deposits of the region can be reached by light teams. Where the trails cross the tundra, however, travel is difficult in the most favorable seasons and almost impossible during wet seasons. Pack trains have been found by Geological Survey parties to furnish the best means of transportation if it is desired to reach all points under adverse climatic conditions.

A trail leads westward along the beach past Teller Mission to the mouth of Lost River, a distance of about 27 miles. Don and California Rivers, which are crossed on the way, are easily forded, and the trail as a whole is adapted to a team and light loads. Continuing up Lost River for 7 miles is a good wagon road leading to the Cassiterite Creek tin mine. A trail leads from the mouth of Cassiterite Creek across the Lost and Mint rivers divide into the Brooks Mountain country, a distance of 7 miles. Teams can cross by this route to reach Potato Mountain from Brooks Mountain, a distance of 28 miles. An easy trail leads from the Mint River valley into the valley of Skookum Creek, down Skookum Creek to Grouse Creek, and thence up Grouse Creek to Buck Creek and up Buck Creek to Potato Mountain. A good wagon road runs from Buck Creek to York, a distance of 17 miles. York may be reached from the mouth of Lost River by way of a trail up Rapid River, across the divide to the Kanauguk, down the Kanauguk to the point where it turns abruptly south, thence along the telephone line across the tundra westward into the Anikovik Valley, and down the Anikovik to York, a distance of 22 miles. This trail is poor most of the way and adapted only to very light loads. Cape Mountain is easily reached from York by a trail, which follows the beach the entire distance of 12 miles. In general, the valleys of the southward-flowing streams—Don and California rivers, Tozer Creek, Lost and Rapid rivers, Cassiterite Creek, Kanauguk and Anikovik rivers—are readily traversed. So also are the upper reaches of the northward-flowing streams, but as they leave the mountains they flow through wide valleys and over flat tundra plains and coastal marshes, which offer serious impediments to travel.

Ear Mountain, an isolated mass in the northeastern part of the area, is about 50 miles from Teller. It is reached by trail from Teller leading up Bay Creek, across the divide into the Agiapuk basin, across the Agiapuk and northward into its upper valley, up its headwaters to the Nuluk divide, down the Nuluk to East Branch, up East Branch to its head, thence on to a tundra plain which extends to the base of Ear Mountain, 20 miles distant. The last 20 miles of this trail offers some difficulties in wet seasons but has been traveled with a light wagon.

HABITATION.

Tin City, at the base of Cape Mountain, and York, at the mouth of Anikovik River, have been centers of population in this region. Tin City is now deserted, and its revival is dependent upon the renewal of work on the Cape Mountain lode prospects. York, once a flourishing tent town, now consists of half a dozen cabins and is permanently inhabited by one family of three persons. A representative of the Bureau of Education at the Cape Mission and a missionary family at Teller Mission are the only other permanent white inhabitants of the region. Winter prospecting is carried on from year to year and engages possibly an additional 15 white men. During the summer mining season probably 50 or 60 men are employed in the placer and lode mines. The Eskimo population, which centers at Cape Prince of Wales and Teller missions, numbers probably 500.

Teller, on the south shore of Grantley Harbor, on the sand pit separating Grantley Harbor from Port Clarence, is the local post office and supply center for the York district. It contains two general stores and road houses and has a population of about 30 whites. A lighterage company which transfers freight to points along the Bering coast and to points along the inland waters of Grantley Harbor, Tuksuk Channel, and Imuruk Basin as far east as Davidson's landing, maintains a freight and passenger ferry across Grantley Harbor.

A telephone line, which for a time connected Tin City with Nome by way of York and Teller, was put out of commission by storms in 1913. Restoration of the line would be a comparatively simple matter, as many of the poles and much of the wire are still available.

INDUSTRIES.

Mining, reindeer herding, and fishing are the principal industries of the area.

Gold is mined by placer methods in the creeks that flow into Grantley Harbor just east of the area and was formerly mined in the vicinity of York. The tin placers of Buck Creek are the most productive mines of the region. Work is in progress on the lode-tin deposit at Cassiterite Creek and promises future production.

Several thousand reindeer, some of which are owned by natives, but most of which are controlled by outside interests, are grazed throughout the region.

In the summer some fishing is done along the coast for salmon and white whale and in the inland waters for herring.

Walrus, seal, and polar bear are hunted by the natives during the winter. Some trapping is done. The total returns from fishing, hunting, and trapping are small compared with those obtained in other parts of the peninsula.

The fuel problem of the area is a serious one. For generating power crude oil, distillate, and gasoline are in general use. Coal is used for heating, but the consumption is limited by the cost. Coal delivered at many localities in this area in 1918 cost $50 or more a ton. All fuel is imported, chiefly from Seattle.

PREVIOUS EXPLORATION.

Prior to the discovery of gold at Cape Nome very little was known of the York region. A mission had been established for a number of years at Cape Nome, where one of the Government reindeer herds was maintained. After the first rush to Nome, prospectors rapidly extended their search to all parts of the peninsula, and as early as the fall of 1899 some placer gold had been found in the Anikovik basin.[3]

In September, 1900, A. H. Brooks, during his investigation of the southern part of Seward Peninsula, spent 10 days in the York region and made the first topographic and geologic map of it.[4] At this time there was little gold placer mining in the York region. The miners were much disturbed by some heavy minerals which clogged the sluice boxes. A part of this heavy concentrate, from Anikovik River and Buhner Creek, one of its tributaries, proved to be stream tin. Upon his return, Brooks published a brief note[5] calling attention

[3] Brooks, A. H., and Schrader, F. C., Preliminary report on the Cape Nome gold region, Alaska, with maps and illustrations: U. S. Geol. Survey Spec. Pub., pp. 25–26, 1900.

[4] Idem.

[5] Science, new ser., vol. 13, p. 593, 1901.

to this new locality for stream tin. Copies of this note were mailed to all the prospectors in the district, so that they might have early knowledge of the discovery. The discovery was also given considerable publicity by the daily press, and the first steamers going north in the summer of 1901 carried a number of men who were bound for York to search for tin.

In 1901 A. J. Collier undertook the geologic mapping of the northwestern part of Seward Peninsula. He accompanied T. G. Gerdine, in charge of party, who was engaged in making a topographic survey of the same area. Collier[6] made some examinations of the occurrence of tin. His geologic map covered the essential features of the region, and has been but little modified by later work. In the later part of the season a great many prospectors searched the York region for tin, and before winter they had located promising deposits of stream tin on Buck Creek, a tributary of Mint River, about 20 miles north of York.[7]

In 1902 the search was continued and the first real attempt to mine tin-bearing gravels was made. The nature of this occurrence and the mining conditions which existed there at that time have been described by Rickard.[8]

In 1903 Collier and Hess were engaged in a study of the geology and mineral resources of the southern part of Seward Peninsula.[9] In the course of this work they reached Teller, on Port Clarence, and here met Crum, Randt, and O'Brien, three prospectors who had been searching for tin. They had about a bushel of samples of supposed tin ore. This material was examined by Collier, who found only one piece of rock that looked as if it might contain cassiterite. With an improvised blow pipe and candle Collier determined the mineral as cassiterite. It came from an angular fragment of float rock. Collier decided that the occurrence was important enough to warrant a special examination of the locality. He therefore accompanied the three prospectors to Lost River, where they pointed out the locality from which the specimen had been derived. Collier discovered the tin-bearing ledge, which the three prospectors staked under the name Cassiterite Lode. Collier was therefore the discoverer of lode tin in the York district, though prior to this time some alleged tin ore had been found at Cape Mountain, most of which on test proved to be a tourmaline granite. Later some lode tin was found at Cape Mountain.

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[6] Collier, A. J., Reconnaissance of the northwestern portion of Seward Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 2, 1902.

[7] Collier, A. J., Tin deposits of the York region, Alaska: U. S. Geol. Survey Bull 229, p. 11, 1904.

[8] Rickard, Edgar, Tin deposits of the York region, Alaska: Eng. and Min. Jour., vol. 75, pp. 30–31, 1903.

[9] Collier, A. J., Recent developments of Alaska tin deposits: U. S. Geol. Survey Bull. 259, 1905.

In 1904 Collier, on returning from the Cape Lisburne coal fields, spent a few days noting the progress of development in opening the tin deposits.[10] Hess [11] fully described the later developments in 1905. No member of the Geological Survey visited the region in 1906, but in 1907 Knopf spent an entire season in examining in detail the tin deposits and general geology of the region. All the localities where prospecting was in progress, including Ear Mountain, were visited, and the mineralogy and petrology of the region thoroughly investigated.[12]

In 1910 Kindle [13] studied the stratigraphy of the region and collected fossils from numerous localities.

In 1913 Chapin [14] reported on the development of the region.

Eakin [15] visited the region in 1914 and summarized the recent developments and the occurrences of tin.

In 1916 Mertie[16] and in 1917 Harrington[17] made reports on development.

GENERAL GEOLOGY.

SUMMARY OF GEOLOGIC HISTORY.

The principal known events of the geologic history of the York tin-bearing region, in the order of their occurence, may be summarized as follows:

1. Deposition in Cambrian or pre-Cambrian time of black muds, now represented by black slates.

2. Intrusion (in pre-Ordovician time) of sills, dikes, and stock-like masses of basalt and gabbro into the slates.

3. Probably warping and erosion of the slates. Deposition on the slates and greenstones of limestone beds 2,000 feet or more thick, ranging in age from Lower Ordovician to upper Mississippian—the Port Clarence limestone (Ordovician and Silurian) and the limestones of Cape Mountain (in part at least of Missippian age).

4. Compression of the limestone and slate beds into a broad, shallow north-south basin with steep sides on the east and west, the whole basin tilted 15°–40° N. Minor folds trending roughly north and east were superimposed upon the major basin.

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[10] Collier, A. J., Recent developments of Alaska tin deposits: U. S. Geol. Survey Bull. 259, pp. 120–127, 1905.

[11] Hess, F. L., The York tin region: U. S. Geol. Survey Bull. 284, pp. 145–157, 1906.

[12] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 359, 1908.

[13] Kindle, E. M., The formal succession in the Port Clarence limestone, Alaska: Am. Jour. Sci., 4th ser., vol. 32, pp. 335–349, 1911.

[14] Chapin, Theodore, Mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 592, pp. 385–397, 1913.

[15] Eakin, H. M., Tin mining in Alaska: U. S. Geol. Survey Bull. 622, pp. 81–94, 1915.

[16] Mertie, J. B., jr., Lode and placer mining on Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 662, pp. 425–451, 1917.

[17] Harrington, G. L., Mineral resources of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 692, pp. 353–400, 1919.

5. Normal faulting of the limestone beds along zones striking generally N. 20° W. and N. 70° E. Some reversed faults striking N. 70° W. may belong to this period.

6. Injection of quartz porphyry dikes into the N. 70° E. fault zones and to a minor extent along those striking N. 20° W. Intrusion (probably in Mesozoic time) of granitic stocks without visibly disturbing the structure of the limestones and slate beds.

7. Release of tin-bearing fluorine and boron solutions from the deep-seated granitic masses, forming tin-bearing veins and replacement deposits in the marginal portions of the granite and in portions of the dikes and limestones.

8. Erosion of the region accompanied by several changes of level:

(*a*) Beveling of the Port Clarence limestone to a nearly plane surface, the modified remnants of which are represented by the crests of the York Mountains, the so-called Nuluk Plateau.

(*b*) Elevation of the region and cutting of a marine plain of erosion along Bering Sea—the York Plateau—about 1,600 feet lower in elevation than the Nuluk Plateau.

(*c*) Uplift and warping of the region. The marine plain is raised 400 to 600 feet above Bering Sea, from Cape Mountain to Lost River. East of Lost River it was tilted toward the east, thus drowning Grantley Harbor and submerging the Tuksuk Channel and the Imuruk Basin.

(*d*) Cutting of the present Bering Sea cliff, averaging about 400 feet in height.

9. Extrusion of olivine basalt flows. Continued erosion and deposition of stream gravels, some of them tin-bearing. Minor modifications of the Bering Sea coast by processes of cut and fill.

SLATE OF THE YORK REGION.

GENERAL CHARACTERISTICS.

Erosion of the east and west ends of the structural basin of the York region has laid bare the slate areas northeast of Teller and west of the York Mountains. At Brooks Mountain the slate is exposed by the truncation of an upwarp of the slate and limestone beds, complicated by faulting. The slate of Black Mountain has been uncovered by the erosion of fault blocks. (See Pl. I.)

In general, the slates are dark-colored to glistening black graphitic sediments of exceedingly fine grain without prominent bedding. A slaty cleavage is well developed in the most graphitic beds. Alternation of minerals usually produces a faint banding.

The mineral composition and grain are remarkably uniform. Thin laminae of fine-grained quartz about one-twentieth of an inch in thickness alternate with laminae composed mainly of very thin, wavy scales of brown biotite standing obliquely to the banding. Here and there the quartzose bands show minute fragments of plagioclase feldspar. With the mica are commonly black streaks of amorphous, grainless carbon. Carbon also forms distinct bands or is uniformly distributed like a fog throughout the rock.

The slate area extending along the seacoast from a point 1½ miles east of York to the Kanauguk Valley is different from that described above. Here for a distance of 3 miles the slate beds strike N. 15° to 20° W. and stand on end or are overturned to the west. They are disturbed by several normal faults striking N. 20° W., with the downthrow on the west. The beds are also interrupted by intrusive greenstones.

The bedding of the slate in this area is distinct. Beds of dark-gray sandy slate from 3 to 8 inches thick alternate with beds of dark-green to black fine-grained slate of about the same thickness. The quartzose beds are distinctly cross-bedded, and cross beds indicate that the west side of the beds is the top of the formation.

CONTACT METAMORPHISM.

Near granite contacts the slate is changed to a dense, hard fine-grained brown rock resembling certain rhyolites. In other respects it is unchanged except that the carbonaceous matter has been aggregated into tiny brown jagged, rodlike forms.

A characteristic of the slate rarely seen in the limestone is an abundance of thin quartz stringers, generally parallel to the bedding. Pyrite cubes are also very abundant in the slate, probably because of its high carbonaceous content. Locally, as in the coast section between Kanauguk River and York, pyrite constitutes about 3 per cent of the volume of the slate. Here the pyrite is almost invariably embedded in a shell of white vein calcite. The pyrite in its growth did not deform the slate materials but has replaced them.

CONDITIONS OF DEPOSITION.

A hypothesis that would satisfactorily explain the conditions of deposition of the slate must take into account its uniformity, grain, mineral composition, bedding, lamination, areal extent, and thickness. Little is known regarding the last two points.

The grain and composition of the slate indicate that originally three-fourths of it was composed of grains less than 0.05 millimeter in diameter, of a dominantly sandy nature. The remainder was clayey and carbonaceous matter. The clayey portion has recrystallized into brown biotite. The sandy material is dominantly quartz, of irregular outline, with occasional unaltered plagioclase fragments.

It is evident that these materials represent the smallest particles of dissolved rock that can be transported by sluggish streams or currents. Winds did not carry them, else the quartz grains would have been rounded. The evenness of the lamination or bedding indicates conditions of quiet water, such as prevailed below the wave zone of large seas or lakes, or on the delta flood plains of large streams.

The materials were largely the fine-grained end products of rock decay, chiefly quartz and clay. The conversion of the clayey portion into brown biotite indicates that originally it had a considerable content of iron, magnesium, and potash, characteristic of clays leached under conditions of good drainage in climates humid and warm enough to permit chemical decomposition. The occasional presence of a fresh plagioclase feldspar grain, it is believed, does not exclude the probability that the clays came from regions where the rocks were decayed. Plagioclase often resists weathering very well, as is seen in some thin sections of partly weathered granite and is also shown by its presence in some limestones to the exclusion of orthoclase.

The carbon of the slate may represent organic, most probably vegetable matter, that grew in the waters in which these muds were laid down, or it may have been brought down with the streams that transported the muds. The carbonaceous matter is exceedingly fine grained and amorphous and belongs to an age when tree growths probably did not exist. Hence, even if the material was carried from the land, coarse fragments of organic matter could not be expected. Under present conditions the streams of the Arctic region have access to the largest contemporary surface deposits of organic matter known, the Arctic tundra, and organic material is present in both solid and insoluble forms in all the rivers except those of exceedingly barren areas. Available analyses show that streams draining tropical swamps have the highest content of dissolved organic matter, but analyses of Arctic streams are not included in the comparison. It appears that with the facts at hand the possibility can not be excluded that some or all of the organic material of the slate in the York region may have been carried with the silts.

The thin lamination of the slate caused by alternations of quartzose, micaceous, and organic material presents an interesting problem. It is difficult to believe that such an alternation of layers of almost microscopic thickness is due to a rain of fine particles from a succession of clouds of these different materials carried horizontally over the area of sedimentation. It is more likely that these alternating layers of sandy silt and black clay represent laminae once suspended as alternating strata in the waters from which they came.

Barus[18] found that fine tripoli suspended in pure water was stratified and that each stratum sank at a uniformly accelerated rate

[18] Barus, Carl, Subsidence of fine solid particles in liquids: U. S. Geol. Survey Bull. 36, 1886.

with respect to the one overlying. This experiment suggests that if two or more different fine-grained substances were in suspension each would stratify into discrete or possibly overlapping strata, thus forming alternating layers of different composition on reaching the bottom. The experimental facts would seem to indicate that the conditions most favorable to stratification in suspension are deep, quiet, fresh waters. In experiments the flocculating effect of salt water has prevented the stratification of suspended materials. It is suggested that the fine lamination of the slate in the York region may be due to the deposition of suspended strata. Furthermore, the possibility that certain finely laminated clays of fresh-water glacial lakes may be due to the deposition of suspended strata rather than the result of seasonal contributions, as is generally believed, seems worthy of consideration.

The suggestions made regarding the deposition of the slate from materials stratified in suspension does not apply to the slate area on the coast between Kanauguk River and York. Here the thickness of the alternating layers and more specifically the cross-bedding of the quartzose layers show that they were laid down from materials swept along by currents.

PRE-ORDOVICIAN BASALT AND GABBRO.

The pre-Ordovician basalt, gabbro, and olivine gabbro are fine to medium grained compact rocks which were intruded as dikes, sills, and stocks into the slate before the limestone was laid down. They were folded with the slate and limestone and in general show a marked schistosity due to the development of nearly parallel columns of secondary hornblende. Intrusions of this kind, rarely large, the stocks being as a rule less than half a mile in diameter, are very abundant throughout the slate area. They are remarkably alike in grain, color, composition, and alteration and undoubtedly came from one parent magma.

The topography of the slate area is strongly influenced by the intrusives. The sills of basalt and gabbro form hogback ridges whose gentle slopes are parallel to the dip of the sill. The stocks form cone-shaped hills resembling an array of low volcanoes. Through these forms the slate area acquires a distinctiveness which does not escape even the casual observer.

LIMESTONE.

The limestone underlies two distinct areas separated by slate—the York Mountains and, in the extreme western part of peninsula, Cape Mountain.

LIMESTONE OF THE YORK MOUNTAINS.

The character and succession of the limestone beds of the York Mountain area is poorly known. Numerous faults disturb the beds to an unknown degree; hence it is impossible to estimate their thickness. Studies of the limestone beds at the mouth of Lost River, in the canyon of California River, 6½ miles above the mouth of this stream, at the head of the Mint River valley west of Brooks Mountain, at the northern border of Black Mountain, and on the western flank of the York Mountains, show that they comprise at least three lithologic members. The lowest, about 100 feet thick, consists of thin laminae of black slate alternating with thin beds of gray calcitic limestone. The middle member, about 900 feet thick, consists of thin-bedded gray to chocolate-colored microgranular limestone with gray to brown shaly partings. The top member includes thick-bedded pure dark-gray to light-gray limestone in beds 1 to 3 feet thick and in places containing small irregular nodules of black chert. Between the middle and top members there is commonly a gradational phase. The thickness of the top member is uncertain, but is probably about 1,000 feet. This threefold classification of the limestone beds of the York Mountains is not extended to the entire area but only to the localities specified above.

The limestone of the York Mountains contains very little quartz. Some exceedingly fine-grained quartz occurs in the clay beds of the middle member. Nearly all the carbonate is calcite. Dolomite débris was found on a branch of Don River, about 400 paces south of the fossil locality indicated on Plate I. Knopf also found some dolomite at the head of Lost River. Considering the Ordovician age of at least a part of these rocks this scarcity of dolomite is notable in view of the emphasis which has sometimes been placed upon the supposed dominance of dolomite among the early Paleozoic and more ancient calcareous sediments.

LIMESTONE OF CAPE MOUNTAIN.

Limestone extends from Baituk Creek to Cape Mountain and is well exposed in cliffs 400 feet high along Bering Sea. The mapping of the limestone and slate contact in this area is by no means complete. A hurried survey up the Baituk showed that the border of the limestone area is not straight as mapped but that irregular patches of limestone occur in the slate. (See Pl. I.) Topographically the limestone area of Cape Mountain, in marked contrast with that of the York Mountains, is a feebly undulating plateau about 400 feet above sea level except in the vicinity of the mountain.

In composition the limestone beds of Cape Mountain are generally pure gray to white granular marbles. At Cape Mountain they are interstratified with white quartzite beds a few inches thick occurring at intervals of 10 feet or more. On top of Cape Mountain some sericite-quartz schists are associated with the limestone. The limestones are dominantly calcitic, but the original presence of some magnesium is suggested by the secondary development of phlogopite and tremolite.

Fossils found in the limestone beds north of Cape Mountain (see Pl. I) include doubtful forms resembling corals of the genera *Syringopora* and *Lithostrotion*, like those in the upper Mississippian rocks at Cape Lisburne, and probably of the same age. It is not proved that all the limestone beds of this area are upper Mississippian. At the head of Ocean Creek the limestones overlie an exposed section of black slate 100 feet thick, and both formations dip about 10° N. The lower 20 feet of the limestone is thin bedded and contains black graphitic partings. Above this is 50 feet of thick-bedded gray limestone. The position and character of these limestone beds is like that of the lowest beds of the limestone of the York Mountains, and they may be of the same age.

It is evident from this that some of the limestone beds of Cape Mountain overlie the slate, apparently with concordant bedding. Some of them, however, are in fault contact. Fault relations were found at the head of the first east branch of Baituk Creek going upstream from the sea. Here the limestone is faulted downward along an east-west vertical plane against the greenstone intruded into the slate.

The relation of the limestone of York Mountain to that of Cape Mountain is not clear. They are separated by about 16 miles of black slate, all of which appears to belong to the same formation. Both groups of limestone beds overlie the slate apparently with concordant bedding. The basal beds of both consist of alternating layers of black slate and limestone. Apparently the only marked differences known between the two areas are that the limestone of Cape Mountain has so far yielded only Mississippian fossils and contains thin beds of white sand. Sand beds of this kind have not been found in the limestone of the York Mountains. In the York Mountain area Lower and Upper Ordovician marine fossils have been found in a number of places, whereas Mississippian fossils have been reported only from a locality north of Brooks Mountain. It looks as if the basal beds in the Cape Mountain area are the same as those of the York Mountains, and future studies may prove that the two areas include the same group of limestone beds, their absence in the intervening area having been caused by erosion and structural disturbances.

STRUCTURAL RELATIONS OF THE SLATE AND LIMESTONE.

It has been pointed out that along the slate and limestone contact in both the York Mountain and the Cape Mountain areas beds of black slate dip under the limestone, with no apparent difference in inclination. Away from the contact the attitude of the slate beds is about the same as that of the limestone. The lowest beds of the limestone in both areas have the character of gradational beds from the slate to the limestone. These facts suggest that the deposition of the slate was followed by that of the limestone without an intervening period of erosion.

The conformity of the slate and limestone would appear to fit all the known facts except the nature of the basalt and gabbro intrusives. These rocks are very abundant in the slate within a few feet of the limestone beds, but none of them enter the limestone. Their schistosity and the crenulations of thin sills show that they were folded with the limestone and slate beds.

The relations of the slate and limestone may be interpreted in two ways. They may be conformable, and before they were folded, the basalts and gabbro may have been intruded and reached a level within a few feet of the limestones. This is improbable. Basic lavas are more mobile than acidic lavas, and acidic intrusions passed through the slate and into the limestone at a later time.

A better interpretation is to assume that the slate was intruded by the basic igneous rocks and then without having been folded to any marked degree was eroded to a nearly level surface, after which it was covered by limestone beds. On this interpretation the apparent gradational character of the basal limestone is a coincidence rather than a sequel. The deposition of limestone without a sandy or gravelly base unconformably on older surfaces has its counterpart in other parts of the world.

CONTACT METAMORPHISM.

Where affected by the granite intrusives the limestone shows changes of two kinds—(1) changes that can be attributed to the expulsion of the carbon dioxide by heat and the recrystallization of the remaining constituents into heavy, complex silicates including wollastonite, tremolite, grossularite, vesuvianite, hedenbergite or augite, and phlogopite; (2) changes resulting in the development of minerals all or most of whose constituents have been introduced, including cassiterite, wolframite, scheelite, paigeite, hulsite, tourmaline, danburite, topaz, humite, chondrodite, scapolite, fluorite, hornblende, green mica, zinnwaldite, muscovite, plagioclase, and the sulphides stannite, stibnite, molybdenite, arsenopyrite, galena, sphalerite, and chalcopyrite.

The changes of the first kind are regional, being in some areas noticeable for miles from the visible granite contact. The changes involving the introduction of materials are local and as a rule are pronounced only within 20 feet of the granite contact. To a marked degree they probably extend no farther than about 500 feet from the contact, as the limestone was very susceptible to reaction with the solutions that caused the changes.

FOSSILS AND AGE.

Fossils are rare in the limestone, but in a few localities certain species have been found in great abundance. The fossil localities found by the writers as well as those found by earlier explorers are all shown on Plate I (and the age of the strata is indicated). The collections of Carboniferous fossils were examined by George H. Girty, and those of early Paleozoic fossils by Edwin Kirk. In view of certain changes in paleontologic correlation, Mr. Kirk's classifications are slightly different from those of earlier workers. The fossil collections previously assigned to the Upper Cambrian he regards as Lower Ordovician, and in this determination C. D. Walcott and E. O. Ulrich concur. Most of the Silurian of earlier correlations he places in the Upper Ordovician, but he identifies one lot of fossils, from the Port Clarence limestone in the vicinity of Don River, as "Silurian, probably middle to Upper Silurian."

The location and character of the beds from which fossils were collected by the writers are set forth below.

Lot 3.—From dolomitic débris on west bank of Don River, elevation about 200 feet. Débris from outcrops of buff thin, even-bedded, fine-grained cherty dolomite, with fine calcite veinlets. Strike east; dip 35° W.

Lot 4.—From débris on north bank of tributary of Don River, elevation about 200 feet. Dense, compact, fine-grained rock with conchoidal fracture. Has many small, irregular calcite spots and small clayey lenses. Does not break parallel to the bedding. Slightly cherty and in spots has irregular chert masses about 6 inches across.

Lot 5.—From ledges on sea cliffs 2 miles west of the mouth of Lost River. Beds dip 30° N. and strike east. Fossils from beds 130 feet above sea. Fossiliferous beds about 15 feet thick, thin bedded. Full of small brachiopods.

Lot 6.—From talus on southeast slope of Brooks Mountain, elevation about 1,000 feet. Thin-bedded, flaggy Port Clarence limestone, showing fucoid markings. Collection made here because Triassic had been reported from this place.

Lot 7.—From Anigovik River, elevation about 300 feet. Limestone and slate débris. Slates show a few doubtful brachiopods; the limestones some fucoid markings.

Lot 8.—From limestone débris on Banner Creek.

Lot 9.—From dark-gray medium-grained limestone talus north of Cape Mountain, elevation about 300 feet.

Lot 10.—From chert débris from sea cliffs between Ocean Creek and Bailuk Creek, elevation 75 feet. Source uncertain but is near by.

Lot 11.—From débris from limestone cliff 2½ miles east of mouth of Lost River, elevation about 100 feet.

Lot 12.—From rock outcrops on east bank of California River, elevation about 175 feet. Grayish-blue fine-grained calcitic, dense limestone with uneven conchoidal fracture. Beds 6 inches to 6 feet thick. Difficult to split parallel to the bedding. Strike N. 60° W.; dip 30° N.

Lot 13.—From limestone outcrops on ridge extending westward toward the Lost River mine, from the highest peak between Tin and Cassiterite creeks, elevation about 1,800 feet. Strike of limestone N. 40° E., dip about 30° N. Thin, even-bedded limestone with shaly partings, weathering yellow. Contains numerous *Maclurea.*

Mr. Kirk's report on this collection, excluding lots 9 and 10, which are from the Carboniferous limestone of Cape Mountain, follows:

I have the honor to submit the following report on paleontologic collections made by Messrs. Steidtmann and Cathcart in the Seward Peninsula, Alaska, transmitted under date of December 12, 1918. Two lots of fossils from the area brought back by E. M. Kindle not previously reported on have been included. All previously collected material has been reexamined, and in various places in the present report comments will be made in regard to them.

LOWER ORDOVICIAN.

The upper Cambrian faunas as hitherto reported from the Seward Peninsula are referable to the Ordovician, as the line is now drawn in North America. It will be noted that the *Finkelnburgia* sp. determined by Ulrich was stated to be " indistinguishable from a species occurring in the Roubidoux formation of the Cambrian in Missouri." The Roubidoux is now referred to the Lower Ordovician (Beekmantown). The determination of the age of Kindle's collections 7 and 8 rests on brachiopods of a type common in both the Upper Cambrian and the Lower Ordovician. The shell structure of the Seward Peninsula brachiopods is fibrous, and this character is now held to be characteristic of Ordovician types and wanting in the Cambrian. The evidence, then, is for an assignment of the collections to the Ordovician.

Loc. 5. Sea cliffs 2 miles west of mouth of Lost River.

Eoorthis cf. E. wimani (Walcott).
Trilobite fragment.

This collection carries the same brachiopod as Kindle's loc. 9.

Loc. 12. East bank of California River:

Maclurea sp.
Hormotoma sp.
Endoceras sp.
Ptychopyge sp.
Asaphus sp.

Loc. 11. Cliff 2½ miles east of the mouth of Lost River:

Gastropod suggesting Ophileta.
Fucoids.

The following lot carries two poor gastropods. Their age is certainly Ordovician, and probably Beekmantown.

Loc. 13. Ridge extending easterly from Lost River mine:

Maclurea? sp.

UPPER ORDOVICIAN.

As reported by Ulrich in Kindle, two post-Beekmantown Ordovician faunas are indicated in the region, one of Black River or Trenton age and the other of Richmond age. Similar faunas are known throughout the Rocky Mountains as far south as El Paso, Tex., and a notable development of the beds occurs in Manitoba. Evidence accumulated in recent years throughout the Rocky Mountain area has tended to disprove the Black River or Trenton correlation of the beds formerly given this age assignment. Available evidence points to the Fernvale (Richmond) age of these beds, as typified by the lower massive Bighorn dolomite of Wyoming. It is conceivable, however, that the fauna can not accurately be correlated with Mississippi Valley formations and may represent a gap in the stratigraphic section as known east of the Rocky Mountains. It were best, therefore, to call this fauna Upper Ordovician, rather than Richmond.

I have recast the faunal lists as given by Kindle for his 13a and 13b. It will be noted that the changes are chiefly by way of making determinations less exact. Some forms have been dropped as irrelevant. In 13a *Maclurina manitobensis* Whiteaves has definitely been determined and is of high importance. It supersedes *Maclurea bigsbyi* Hall of Ulrich's list. A detailed study of the material has shown that the Seward Peninsula forms are not specifically identical with Middle Ordovician types and in most cases will probably prove new species or varieties.

So far as can be determined from the material on hand Kindle's 13a and 13b, as well as Steidtmann and Cathcart's lots 3 and 4, represent the same general faunal zone. As noted above, they should be listed as Upper Ordovician rather than Richmond.

Kindle's 13a:
- Streptelasma sp.
- Halysites cf. H. gracilis Hall, several varieties.
- Calapoecia cf. canticostiensis Billings.
- Columnaria alveolata Goldfuss, two varieties.
- Strophomena cf. Strilobata (Owen).
- Triplecia cf. T. extans Hall.
- Leptaena sp.
- Dinorthis sp.
- Hebertella sp.
- Rhynchotrema sp.
- Modiolopsis cf. M. faba Hall.
- Maclurina manitobensis (Whiteaves).
- Stenotheca? sp.
- Lophospira sp.
- Hormotoma cf. H. gracilis Hall.
- Hormotoma sp.
- Trochonema sp.
- Bumastus sp.

Kindle's 13b.
- Columnaria alveolata Goldfuss, 2 varieties.
- Calapoecia cf. C. anticostiensis Billings.
- Lichenaria sp.
- Halysites gracilis Hall var.
- Stromatocerium? sp.
- Nicholsonella? sp.
- Leptaena richmondensis Foerste.

Kindle's 13b—Continued.
- Hebertella sp.
- Rhynchotrema cf. R. capax Conrad.
- Ctenodonta cf. C. levata Hall.
- Cyrtodonta sp.
- Liospira sp.
- Lophospira sp.
- Trochonema cf. T. umbilicatum Hall.

Lot 3. West bank of Don River.
- Columnaria (Palaeophyllum) cf. C. stokesi Edwards and Haime.
- Halysites gracilis Hall var.
- Dystactospongia? sp.
- Hebertella sp.
- Maclurina manitobensis (Whiteaves).
- Hormotoma sp.
- Endoceras sp.

Lot 4. North bank of tributary of Don River.
- Halysites gracilis Hall.
- Streptelasma sp.
- Stromatocerium? sp.
- Calapoecia anticostiensis.
- Columnaria alveolata Goldfuss.
- Favosites sp.
- Dystactospongia? sp.
- Hormotoma sp.
- Trochonema sp.
- Maclurina sp.

SILURIAN.

As quoted by Kindle, Schuchert determined middle Silurian from the Seward Peninsula. The locality is given as "near the forks of Rock Creek, a northern tributary of Agiapuk River." The material was collected by Collier.

As redetermined this fauna is clearly of Upper Ordovician age and correlates exactly with the faunas on Don River.

INDETERMINABLE.

Lots 6, 7, and 8 carry nothing but fucoids or annelid trails. No age determinations are possible.

Two lots of fossils have been found in the Survey collections that have not hitherto been reported on. One is from the north slope of Brooks Mountain and the other from Kanauguk River. The latter was collected by Kindle and the other given him by a prospector.

Kanauguk River, near junction of south and middle forks:
- Orthoid brachiopods.
- Asaphus? sp., apparently same as loc. 12, California River, and of Canadian age.

A lot of fossils from Brooks Mountain not previously reported on has been found in the Survey collections. The locality is given as "north side of Brooks Mountain, Seward Peninsula." The collector was Philip Asth, as written on the label by Kindle. The label accompanying the Triassic fossils reported from the southeast side of Brooks Mountain gives the collector as Philip Ast, evidently the same man. Kindle in his paper on the Port Clarence limestone gives the collector's name as Peter Esch for the latter lot. The collection from the north side of the mountain consists of fragments of some branching cyathophylloid coral. The preservation is poor, but the fossils could not be older than late Paleozoic. Considering the Paleozoic section of this general area it would appear that this material could not well represent anything other than Mississippian. This would tend to strengthen the claim of Triassic rocks elsewhere on the mountain.

The collections of Mississippian fossils from the region were restudied by Mr. Girty, and the results are embodied in the following report:

I have reexamined the collections mentioned in your letter of March 11, 1919, and in searching for those collections I came upon several others made by Mr. Hess, apparently from the same area. All of these are covered in the following report.

Before giving a list of the faunas collected I must comment on the preservation of the fossils, which is such as to render any inference based upon them unusually precarious. The fossils are all corals, other types, if present, being entirely unrecognizable. The corals apparently are pseudomorphs or have been so completely altered as to resemble pseudomorphs of crystalline calcite. They stand out conspicuously in the black rock which incloses them, but when examined more closely they are found to have lost all trace of the structures upon which generic and specific distinctions are largely based. The only evidence of this sort still remaining is to be observed where the specimens show the contact of the matrix with the growing ends of the corals into whose calices the black mud had penetrated.

The specimens referred to *Syringopora* show the typical mode of growth of that genus, slender corallites connected by supporting stolons. In a few instances the generic reference suggested by this mode of growth is corroborated by traces of the funnel-shaped tabulae. The discrimination of the species adopted in my lists is based largely on the size of the corallites and partly on their mode of growth.

The fossils referred to *Zaphrentis* are few in number, and the generic reference as against related types, as for instance *Triplophyllum*, can not be insisted upon.

The forms referred to *Lithostrotion* exemplify both the bushy or branching mode of growth (species 1 and 2) and the massive (species 3). Some of them show the presence of numerous thin septa and of a central columella, such being the structures as exhibited in the calice. The species, as I have discriminated them in my lists, are distinguished largely on the size of the corallites instead of on the number of septa and other structural characters, the usual method being here impossible. Obviously nothing was to be gained by trying to identify species separated in this manner with described species, most of the criteria on which the described species were founded being unknown. Not all of the specimens referred to *Lithostrotion* show the septa and columella, the presence of which suggests the generic reference, and it is possible that quite diverse forms have been included in the same species. For instance, some of the large Syringoporas as identified in the collection may, in fact, be small Lithostrotions. This fact does not, however, vitiate the evidence of other specimens whose characters are less imperfectly shown.

Personally I have scarcely a doubt that these fossils represent the same coral fauna that occurs in the Lisburne limestone, upper Mississippian, as against the Devonian coral faunas or the very deceptive Triassic coral fauna found in this region. This belief, however, is not capable of scientific demonstration on the material at hand, and my statement must also be modified to this extent, that inasmuch as most of the specimens are from beach gravels and as many do not show even the significant structures observable in some of them, the collection may contain besides the Lisburne fauna stray specimens that had their origin in other horizons. The following lists will serve to show the composition of the several local faunas considered here.

Lot 2499. Beach near Cape Mountain, Seward Peninsula, Alaska:

Syringopora sp. 4.
Lithostrotion sp. 2.
Lithostrotion sp. 3.
Zaphrentis sp.

Lot 2500. Beach northwest of York. (Six specimens labeled "T. 5 A H 46 to 51"; one label reads "6 miles northwest of York.")

Syringopora sp 1.
Syringopora sp. 2.
Syringopora sp. 4.
Lithostrotion sp. 1.
Lithostrotion sp. 2.

Lot 2501. Beach east of Tin City, York tin region, Alaska. (Four specimens labeled "T. 5 A H 41 to 44"; one label reads "1 mile east of Tin City.")

Syringopora sp. 1.
Syringopora sp. 2.
Syringopora sp. 3.
Syringopora sp. 4.

Lot 2502. North side of valley north of North Star mine, Cape Mountain, York tin region, Alaska:

Syringopora sp. 4.

Lot 2503. North side of Brooks Mountain, Seward Peninsula, Alaska:

Lithostrotion sp. 1.

Lot 7139. Northeast of Kingegan Mission, Cape Prince of Wales, Alaska:

Syringopora sp. 1.
Syringopora sp. 3.
Zaphrentis sp.
Lithostrotion sp. 2.

Mr. Kirk kindly undertook a reclassification of the pre-Carboniferous fossils collected prior to 1918, and his results are given below. The notes regarding the location of the fossil beds were inserted by the writers and were compiled from the memoranda of the collectors. The localities from which the collections restudied by Messrs. Girty and Kirk were taken are shown on Plate I by their respective permanent collection numbers.

The following lots could not be found: Collier 1900, 3 AC 136, and Kindle lot 11. The two latter lots are both probably in Dr. Girty's collections. Lot 1 AC 77 as found consists merely of an indeterminable thin section on a glass slide, with which nothing can be done.

Collier 1900. Not found.

287. 1 AC 26. (2 miles southwest of forks of Don River.)

Favosites sp.
Pentameroid brachiopod.

Of Silurian age, probably middle to upper Silurian, in place of lower Silurian.

288. 1 AC 28. (Mountain 4 miles north of Rapid River.)
Badly silicified sponges. This type of sponge strongly suggests Lower Ordovician forms, and I think this age assignment would be warranted, in place of middle of lower Silurian.

289. 1 AC 45. (Don River 4 miles north of Tozer Creek.)
Maclurina manitobensis (Whiteaves).
Columnaria alveolata Goldfuss.
Stromatocerium? sp.
Halysites cf. H. gracilis Hall.
Upper Ordovician in place of middle of lower Silurian.

290. 1 AC 76. (Boulder from gravel, Nuluk River.)
Trilobite fragments.
Lower Ordovician, in place of middle of lower Silurian.

291. 1 AC 77. (Bluff above Nuluk River, latitude 65° 4′, longitude 166° 20′.)
Indeterminable thin section.

292. 1 AC 78. (Foot of talus slope, Nuluk River.)
Cephalopod siphuncle, probably referable to Endoceras.
Lower Ordovician, in place of middle of lower Silurian.

293. 1 AC 185. (Pebble from sand spit 1 mile north of Teller.)
Ecorthis wimani Walcott.
Lower Ordovician, in place of middle of lower Silurian.

3 AC 136. (1 mile east of Cape Prince of Wales.) Not found.

281. 3 AC 146. (Rock Creek, tributary to Agiapuk River.)
Upper Ordovician, in place of Niagaran or the middle third of the Silurian.

276. Washburne, 1904. 4 AW 55. (Merril Mountain, 3 miles north-northeast of mouth of Lost River.)
Lower Ordovician.

828. Knopf, 1907. (Head of Cassiterite Creek, Lost River.)
Indeterminable gastropods.
Lower Ordovician.

Lot 11, Kindle. (North side of Cape Mountain.) Not found.

876. Lot 6. (450 yards southeast of mouth of Lost River, near top of cliffs; 15 feet of dark-gray thin-bedded limestone.)

877. Lot 7. (Near head of south branch of Tin Creek at its junction with a ravine from the east. Hard blue-gray limestone stratum, a few inches in thickness, which lies just above beds with numerous fucoid-like markings.)

878. Lot 8. (A single thin band of limestone. Elevation 2,000 feet, at head of north fork of Tin Creek.)

879. Lot 9. (A single bed of limestone on Cape York.)

1365. Lot 12. Kindle.
The foregoing five lots (6, 7, 8, 9, 12) are lower Ordovician (Beekmantown). These are the lots formerly identified as Cambrian. Ulrich's generic and specific determinations stand.

235. Lot 13a, Kindle. (Don River, at side of short ravine heading on slope of a mountain marked 1242 and joining the Don 9 miles from the coast.)

236. Lot 13b, Kindle. (Immediately north of the mouth of the ravine from which 13a was taken.)
Lots 13a and 13b. Upper Ordovician.

CONDITIONS OF DEPOSITION.

The purity of most of the limestone beds, the presence of corals in some, and their local interstratification with thin beds of clean white quartz sand indicate that probably most of them were deposited in shallow, warm seas. That conditions in these seas were uniform for a long time is inferred from the great thickness of the beds. The abundance of black carbonaceous matter in the lowest limestone beds raises the same questions called forth by the black slates as to whether the carbon is detrital or whether it was organically precipitated in place and in either case what were the conditions of its deposition.

The thick-bedded purer limestone of the upper part of the Port Clarence formation indicates that the seas had become clearer and the conditions of deposition more uniform than they were when the underlying beds were deposited. The reason for this change is not clear. At least four conditions could have given rise to it; (1) the area of sedimentation may have become farther removed from land masses by a shift in the position of the strand line, (2) the surface of the lands from which the detritus came may have been lowered either by erosion or by earth movements so as to make stream and shore action less vigorous, (3) the streams may have carried less detritus because of a climatic change, (4) the ocean currents carrying detritus may have changed their direction.

GRANITE, ASSOCIATED DIKES, AND TIN ORES.

Small stocks of granite have intruded the limestone at five places in the region—Cape Mountain, Brooks Mountain, Tin Creek, Black Mountain, and Ear Mountain. The presence of one stock underneath the tin prospect on Cassiterite Creek and of another under Potato Mountain is inferred. These stocks, except the one at Cape Mountain, are associated with faults that are older than the granite. The invasion of the granite seems therefore to have been influenced by planes of weakness in the crust.

In form the stocks appear to be steep on all sides except one. The Tin Creek stock is not well enough exposed to give any suggestions as to its shape. None of them are deeply eroded—in fact, all have parts of the roof remaining.

The composition of all the stocks is that of a normal granite. Orthoclase is the chief constituent. The plagioclase feldspar is sodic, and the ferromagnesian mineral is biotite, except in a 3-foot border zone of the granite at Brooks Mountain which contains hornblende in place of biotite. Except at their borders the granites at both Brooks Mountain and Cape Mountain are porphyritic, the orthoclase forming prominent phenocrysts. Their border phases are even grained. The two granites can not be distinguished in hand specimens. The granites of Tin Creek, Black Mountain, and Ear Mountain are even grained and resemble one another closely.

The granites of Tin Creek and Black Mountain are closely associated in time and place with certain quartz porphyry dikes. Those of Brooks Mountain and Ear Mountain are similarly associated with dacite porphyry dikes containing limy plagioclase. The Dolcoath dike, between Brooks Mountain and Tin Creek, is also of the latter type. The granite of Cape Mountain is not accompanied by porphyry dikes but has even-grained granitoid offshoots which are like it in composition. It is also closely related in age to certain granite pegmatite dikes. A granite pegmatite dike was also found at Brooks Mountain.

After the injection of the granites of Cape Mountain, Ear Mountain, Brooks Mountain, and Tin Creek and some of the dikes associated with them, hot tin-bearing solutions containing boron, fluorine, and other elements invaded the border of the granite and the adjoining limestones and dikes. They gave rise to tin-bearing replacement and vein deposits in granites, dikes, and limestones. The only commercial tin mineral in these deposits is cassiterite, but paigeite, hulsite, and stannite have been found. Tin has not been found at Black Mountain. An area on Cassiterite Creek was invaded by tin-bearing solutions that formed deposits in the dikes and limestone. Tin-bearing solutions, which are inferred to have come from a granite intrusion below, invaded the slates of Potato Mountain.

The granites are believed to have come from a common deep-seated source, because of their similarity in chemical and mineral composition and their common association with nearly contemporaneous quartz-bearing dikes, including rhyolites and dacites, and because both granite and dikes, with the possible exception of those at Black Mountain, were followed by tin-bearing solutions. The strongest argument for their consanguinity seems to be their relation to the tin-bearing solutions.

AMYGDALOIDAL OLIVINE BASALT.

The amygdaloidal basalt comprises black fine-grained and glassy rocks with a scoriaceous structure. The only visible minerals which it contains are tiny green grains of olivine. The microscopic texture is diabasic to vitrophyric. The diabasic types contain labradorite and augite. The others have a glassy base containing microscopic rods of labradorite and perfect crystals of olivine.

These rocks occur as dikes at Cape Mountain and as flows at Black Mountain and east of California River. They are the youngest igneous rocks of the region. The flows at Black Mountain were formed when the topography was essentially the same as at present.

SEQUENCE OF IGNEOUS INTRUSIONS.

The York tin region has had three distinct periods of igneous activity. In the first period basalt and gabbro dikes, sills, and stocks were intruded into the slate before the limestone was deposited. The second period came after the deposition of the limestone and is divisible into three epochs, during which occurred (1) the intrusion of the granite stocks, (2) the injection of rhyolite and dacite dikes, (3) the expulsion of hot solutions containing tin, boron, and fluorine. In the third period dikes and flows of basic olivine basalt were formed, which in composition resemble the products of the first period. They are young, having solidified when the topography of the region was about the same as it is to-day.

STRUCTURE.

The structure of the region is that of a shallow north-south basin upturned at the east and west ends, and the whole tilted northward on the average about 20°. Superimposed on the major syncline are minor cross and longitudinal folds of varying magnitude. Two systems of normal faults disturb the beds of the region. In the main one system strikes roughly east, dips steeply to the south, and has the downthrow on the south; the other strikes roughly north, dips steeply to the west, and has the downthrow on the west. Evidence of overthrust faulting has also been found in the Lost River and Black Mountain areas. (See pp. 53, 112.)

In the central part of the area the underlying rocks are the beds of the Port Clarence limestone, which except in a few places dip 8°–45° N. The two systems of faulting alluded to have numerous representatives in the Lost River area. The truncation of a fault block has exposed the slate at Black Mountain and in the Agiapuk Valley, to the east. At Brooks Mountain slate is exposed by the erosion of a fold complicated with faulting. Details are given in the descriptions of these areas.

Along the western flank of the York Mountains the black slate beds dip to the east, under the limestone. Exposures of the contact were not seen. The dip of the slate seems to be conformable with that of the limestone. It averages about 30° and reaches a maximum of about 60° on Kanauguk River. Minor folds pitching eastward are superimposed on the general eastward monocline. Synclinal folds of this kind cause certain projections of limestone into the slate area, and the anticlines have produced certain embayments of slate extending into the limestone.

An exception to this close relation of folds to undulations in the limestone border is found in the upper part of the Skookum Creek valley. Here the slate forms a deep reentrant in the limestone. Along the northern border of the valley the slate dips northward at an angle of about 30° under the limestone, but along the southern border of the valley it dips eastward at a steep angle which should cause its rapid disappearance under the limestone. There is evidently a marked discordance in the dip of the slate beds that crop out along the two sides of the valley. The extent of the slate area is not related to the dip of the limestone and slate beds or to the topography. Faulting therefore appears to have disturbed the beds along a zone running about N. 70° W., parallel to the Skookum Creek valley. Inspection of Plate I shows that this suggested line of faulting is in alinement with a zone of faulting that runs nearly due east along the head of the Mint River valley and with another zone of faulting that marks the southern border of the slate area east of Black Mountain.

Evidence of faulting along a nearly north-south line was noted at one place on the western flank of the York Mountains between Kanauguk River and Skookum Creek. As shown on Plate I, this locality is marked by the close proximity of a basalt intrusive to the Port Clarence limestone. The proof of faulting lies in the vertical plane of contact between the slate beds and basalt intrusive and the limestone beds.

The slate beds in the area west of the York Mountains dip mainly to the east and northeast. Along Bering Sea between Kanauguk River and York the slate beds are vertical or dip to the east because of their having been overturned. In the western part of the slate area near the mouth of Baituk and Ocean creeks most of the slate beds dip gently to the north. A normal fault was observed near the head of the first east branch at the mouth of Baituk Creek. The fault has brought the basalt and slate into vertical contact with limestone beds. The trend of the fault appears to be east, and the displacement was relatively downward on the north side of the fault plane. Normal faults striking N. 20° W., with relative downward displacement on the west side, were also noted in the section between Kanauguk and York rivers.

The limestone beds near the slate contact in the vicinity of Baituk Creek show a variable dip, being very steep in some places and nearly horizontal in others. West of the mouth of Baituk Creek they dip steeply to the west. Some outcrops up Baituk Creek and Ocean Creek dip gently toward the north. Knopf speaks of friction breccias in the limestone of this vicinity and also alludes to the variable dip of the beds as evidence of faulting along a zone parallel to the border of the limestone and slate areas.

Along the seacoast, between Baituk Creek and Cape Mountain, the limestone beds generally dip about 45° E. and in places are vertical. Along the eastern border of the granite of Cape Mountain the limestone beds dip westward into the granite. North of the granite they dip northward, away from the granite.

East of Mountain Creek, to the north of Teller, the Port Clarence limestone is bordered by black micaceous schist which is intruded by schistose basic igneous rocks. As these intrusions are schistose and apparently do not invade the limestone, it is inferred that they are older than the limestone. The schistosity of the intrusives precludes the possibility that they may have come in after the schist was exposed by erosion.

The schist in the vicinity of Mountain and Bay creeks appears to belong to the same formation as the slate of the York region. This correlation, however, does not include all of the great schist area extending eastward from Teller. The proposed correlation of the schist east of Mountain Creek and the slate of the York region is based on the following grounds:

1. Both schist and slate are stratigraphically below the Port Clarence limestone.
2. They are similar lithologically, the only difference consisting in the more intense regional metamorphism of the schist.
3. Both are intruded by basic igneous rocks which show about the same degree of metamorphism, are similar lithologically, and bear the same relations to the limestone.

The hills west and north of Mountain Creek are barren, steep, and rugged, being underlain by the Port Clarence limestone, which in this locality is generally thin bedded, clayey, buff colored, and contorted. Outcrops are scarce. A few frost-shattered exposures indicate that the dip is northward. The high hills east of Mountain Creek are less rugged and are covered with tundra. Numerous outcrops along Bay Creek show that the inclination of the schist is to the north.

At the head of Mountain Creek the surface of the limestone area lies flush with the surface underlain by schist. It is evident from the exposures of schist and limestone in this vicinity that the schist if projected downward would meet the limestone beds along a vertical or nearly vertical plane, as the limestone beds dip in the same northerly direction as the schist. Mountain Creek therefore seems to mark the location of a zone of faulting. As the schist is stratigraphically below the limestone, the faulting is inferred to have depressed the limestone beds with respect to the schist.

TOPOGRAPHIC HISTORY.

At least three, and possibly four, epochs of erosion due to successive uplifts of the region are suggested by the Nuluk Plateau, the York Plateau, and the recently developed lowlands. The Kougarok Plateau is less clearly developed within this region, but is said to be well defined farther east.

The Nuluk Plateau[19] is indicated by the even crests of the York Mountain ridges, the tilted and faulted strata of which are beveled to a markedly uniform elevation of 2,000 to 2,500 feet. The flat tops of Cape Mountain and Ear Mountain, which have an elevation of 2,300 feet, would seem to be remnants of the same plain. This oldest plain of erosion of the region has been thoroughly dissected and has been deformed by later differential uplift. (See Pl. III.)

The York Plateau[20] is best developed in the slate area west of the York Mountains, at an elevation of about 600 feet. It is further shown in the terrace that caps the sea cliff fronting Bering Sea and extends eastward to Don River. The terrace is cut on the Port Clarence limestone, the highly tilted and faulted strata of which have been beveled with marked uniformity. It is from 1 to 4 miles wide and occurs at an elevation of 500 to 700 feet. On the north side of the York Mountains it is present as a system of benches which extend into the mountains along the stream channels. Between California and Agiapuk rivers it is marked by a plateau surface at an elevation of 500 feet. This plain extends up the Agiapuk and is correlated with the terrace of the upper Nuluk, which in turn is correlated with the terraces on the north side of the York Mountains. Evidence of the plain is found in the low hills surrounding Ear Mountain at an elevation of 500 feet.

Since its elevation the York Plateau has been well dissected. It has a mild relief of 200 to 600 feet, which is in marked contrast with the rugged limestone ridges of 2,000 to 2,500 feet forming the York Mountains.

At an elevation of about 1,000 feet there is evidence of an old erosion surface which was first named the Kugruk Plateau.[21] It is marked in this area by benches on Cape and Ear mountains and is said to be well developed in the region adjoining to the east. Collier[19] speaks of it as "a well-marked plateau surface extending * * * across the Kugruk [now Kougarok] River and continuing in a system of benches and table-topped hills to Cape Prince of Wales. * * * Its relation to the Nuluk Plateau is best seen a few miles east of the Nuluk River, where a prominent bench, at 1,000 feet elevation, extends for several miles and encircles one of the mountains on which the Nuluk plain is well marked at 1,600 feet."

The recent lowlands comprise valley and coastal plains. The valley plains are covered by unconsolidated Pleistocene deposits.

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[19] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska; U. S. Geol. Survey Prof. Paper 2, p. 35, 1902.

[20] Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900, p. 52, U. S. Geol. Survey Spec. Pub., 1901.

[21] Idem, p. 54.

The coastal plains are covered in part by Pleistocene and Recent deposits and in part consist of country rock.

Practically all the larger streams have, along their lower channels, well-developed gravel terraces, many of which extend well toward the headwaters. This feature is most marked on Agiapuk, Lost, Kanauguk, Anikovik, Nuluk, and Mint rivers and on Grouse Creek and its tributaries. Few of the streams, except the headwaters, flow on bedrock. The stream gravels range from a few feet to 20 feet or more in depth.

The coastal-plain areas north of Port Clarence and along the Arctic Ocean are partly constructional, as is shown by the barrier beach, lagoon, and lake features. A considerable part of the fill has been in the form of peat. Extending throughout the coastal-plain area are low mounds of bedrock which have been degraded almost to the plain level. South of Lopp Lagoon the York Plateau merges almost imperceptibly into the coastal plain, so that the two features are difficult to separate. Along Bering Sea, however, the coastal plain is sharply differentiated from the York Plateau and the sea terrace.

MINERALOGY.

The following is a list of minerals known to occur in the York region, with a brief outline of their chemical composition and of those physical properties which the prospector may use in their identification.

Amphibole.—A group of minerals, chiefly silicates of calcium, magnesium, and iron, which occur commonly as gangue minerals but which in themselves have no economic value. Tremolite, actinolite, and hornblende are members of the group observed in the rocks of this region. Tremolite is a colorless variety and occurs as glistening slender crystals in the limestone adjacent to the mineralized part of the cassiterite dike and as fine radial groups in the limestone of Cape Mountain. It is a calcium-magnesium silicate. Actinolite, an iron, magnesium, and calcium silicate, is green and occurs as fine, slender prisms forming veins in the slate of Potato Mountain. Hornblende is of more complex composition, is green to black, and is the most common variety of amphibole. It is found in limestone adjoining cassiterite veins and in places colors the limestone green. As a group, the amphibole minerals may be recognized by the angle which the prism faces make with each other—56° or 124°. Similar angles on pyroxenes, with which amphibole is easily confused, are 87° or 93°. Amphibole can not be scratched with a knife. Its color may vary from white through brown and green to black. Amphibole crystals are usually long and slender as compared with crystals of pyroxene, which tend to be short and stout prisms.

Apatite.—Essentially calcium phosphate. Widely distributed as a minor constituent of granite and some other rocks, but rarely in sufficient quantity to be of economic value as a source of phosphate. In this region it occurs as a microscopic constituent of the granite and is of no commercial value.

Arsenopyrite.—A compound of iron, arsenic, and sulphur. Silver-white, has a metallic luster, and can not be scratched with a knife. Thin splinters fuse slowly in a luminous flame, and the arsenic fumes liberated have the odor of garlic. The fused mass is magnetic. It is rather abundant in the Cassiterite Creek tin ore and also occurs at Brooks and Potato mountains. Its usual mineral associates are ores of silver, lead, and tin, also pyrite, chalcopyrite, and sphalerite.

Axinite.—Essentially a calcium, boron, and aluminum silicate. An uncommon mineral occurring with tourmaline at Ear Mountain. The crystals are ax-shaped, and its luster is highly glassy. The Ear Mountain material is brown, although the mineral may be blue, yellow, or greenish. It can not be scratched with a knife. The thinnest of edges fuse slowly in the lamp flame to a black mass and may give a greenish color to the flame.

Azurite.—Azure-blue copper carbonate. Can be scratched with a knife. In places occurs with the green copper carbonate malachite as an incrustation on rocks. When treated with nitric acid it effervesces (bubbles), and if to the nitric acid solution some ammonia is added a blue solution results. It is formed by the alteration of the sulphide ores of copper, and is commonly found on or near the surface. It occurs in the wolframite-topaz lode on Lost River, where it is probably derived from the alteration of stamnite in the ore.

Biotite.—A potassium, magnesium, iron, and aluminum silicate, commonly called black mica. Occurs in thin scales which can easily be picked apart with a knife point. The flakes are both flexible and elastic. It is a common minor constituent of many igneous rocks, in which it occurs as small lustrous flakes. Some biotite has been found in a prospect on Village Creek at Cape Mountain, where it occurs in a pegmatite vein, but this variety of mica is without economic value. Muscovite and phlogopite are white or light-colored micas which may be of value where found in pegmatite veins such as that on Village Creek. The value of such a deposit depends on the abundance and the quality of the mica, and commercial deposits are rare. Biotite occurs in the granite and schist and in pegmatite on Brooks Mountain, in plates as much as half an inch in size, and at Cape Mountain in plates measuring as much as several inches.

Calcite.—Calcium carbonate, the essential constituent of limestone. Locally occurs in veins and possibly mistaken for quartz, from which it is easily distinquishable by its softness. Can be scratched with a pin. Gives off gas bubbles when treated with cold dilute acid. Is widely distributed and of no commercial value in this region.

Cassiterite.—Tin oxide, the only commercial source of tin. The pure crystallized mineral contains 78.6 per cent of tin. It is best distinguished by its weight, having a specific gravity of 6.8 to 7.1. It can not be scratched by a knife. The color may vary from white through gray, yellow, and brown to black. The luster of a freshly broken surface is brilliant. It occurs in the York region in quartz veins, in marginal portions of granite, and in limestone and porphyry dikes near granite intrusions, but its best-known occurrence is that as stream tin on Buck Creek. When in placer form its weight serves well to identify it, but frequently it is confused with other materials, among which iron oxide is the most common. A simply performed and reliable test for cassiterite is as follows: Using preferably a shallow dish, cover a mineral particle one-quarter to one-half inch in size with dilute hydrochloric acid, and add a small quantity of granulated zinc. Reaction between the zinc and hydrochloric acid will be vigorous, and at the end of two or three minutes the mineral, if cassiterite, will be coated with a white incrustation of metallic tin, which may be polished by rubbing the particle on a dry cloth.

Cerusite.—Lead carbonate. White to gray. Easily scratched with knife. High specific gravity. Commonly occurs as groups or bundles of highly lustrous crystals. Effervesces with acid. Fuses easily in the lamp flame. It occurs in connection with other lead minerals and is formed from galena, the sulphide of lead. Found at the Yankee Girl prospect, southwest of the Tin Creek granite boss.

Chalcopyrite.—A copper-iron sulphide called copper pyrites. It is easily confused with pyrite, or "white iron," which it resembles in color. Pyrite is light brass-yellow; chalcopyrite is deep brass-yellow. Pyrite can not be scratched with a knife; chalcopyrite can. Pyrite may occur in cubes or octohedrons; the crystal form of chalcopyrite is seldom recognizable. Pyrrhotite, another mineral with which chalcopyrite may be confused, is bronze-yellow and is an iron sulphide, is slightly magnetic, and will not react for copper. Chalcopyrite was found on Brooks Mountain at Read's prospect. It dissolves in nitric acid, and if ammonia is added to the acid solution a blue solution results, indicating copper, while the iron forms a brownish precipitate in the solution. The mineral is important as an ore of copper where it occurs in sufficient quantities. It is known to occur in this region near the mouth of Tin Creek and in the contact limestone of Ear Mountain.

Chlorite.—Iron, magnesium, and aluminum silicates with water closely related to the micas in many respects; characterized by greenish color and a mica-like structure. The thin flakes of chlorite can be separted like mica flakes and are flexible but not elastic. They occur in this region in the greenstones of the slate area and are secondary minerals resulting from the the alteration of iron-magnesium silicates, such as pyroxene, amphibole, and biotite. Chlorite has no commercial value.

Chondrodite.—Magnesium silicate with hydroxyl and fluorine. Small honey-yellow crystals of chondrodite occur in the contact-metamorphose limestone of Brooks Mountain.

Danburite.—Calcium-boron silicate. A rare mineral which occurs as a constituent in the gangue of cassiterite in the Dolcoath lode, on Cassiterite Creek. Wine yellowish to yellowish brown. Luster greasy. Can not be scratched with knife but will scratch glass. Of no commercial importance.

Dolomite.—Calcium-magnesium carbonate. Very similar to calcite in physical properties but a trifle harder. Dolomite will not effervesce in cold dilute acid; calcite will. Certain strata of the Port Clarence limestone are composed of dolomite. It occurs also in small crystals in the slates of the York area. The mineral is of no economic importance.

Epidote.—Essentially calcium, iron, and aluminum silicate, differing from zoisite only in the iron present. Radial groups of epidote crystals occur at Brooks Mountain near the granite contact. It is characterized by its peculiar yellowish-green color. Is prismatic in form, and many of the prisms are furrowed or striated. Can not be scratched with a knife. Powder white or grayish. Of no economic importance.

Feldspar.—A group of minerals which are very abundant in igneous rocks. The more common members of the group are as follows:

Orthoclase	Potassium-aluminum silicate.
Plagioclase:	
Albite	Sodium-aluminum silicate.
Oligoclase	Sodium, calcium, and aluminum silicate.
Andesine	Sodium, calcium, and aluminum silicate.
Laboradorite	Sodium, calcium, and aluminum silicate.
Anorthite	Calcium-aluminum silicate.

Orthoclase feldspar occurs as the principal constituent of the acidic igneous rocks, such as granite, quartz porphyry, and syenite; the plagioclase feldspars prevail in the more basic rocks, such as greenstones, gabbros, and diorites.

Both may be present in the same rock, but to distinguish the one from the other by simple methods is not always possible. They are readily distinguished on microscopic examination. As a group the feldspars are of economic importance only in that they give information concerning the type of magma which produced them, and in a general way they may indicate what valuable minerals might be expected to be associated with them. The potash occurring in orthoclase is not of economic value because of the difficulty in separating it from the silica with which it is combined. Feldspars have smooth surfaces, with a glass-like luster, and are white or pale yellow to flesh-colored. They can not be scratched with a knife. Good examples may be seen in the larger prominent crystals of the granite of Cape, Brooks, and Ear mountains or in the granite of Tin Creek.

Fluorite.—Calcium fluoride occurs in the York region chiefly as a gangue mineral with the tin ores of Cassiterite Creek and Ear, Cape, and Potato mountains. Usually it is present as cubic crystals. The color may be white, yellow, blue, red, or green. Can be scratched with a knife, but not with a pin. Luster like that of glass. Usually breaks easily, giving flat surfaces. Can be distinguished from calcite by not effervescing in boiling acid and by its hardness.

Galena.—Lead sulphide. Commonly occurs in cubes, but may be granular. Galena in cubes is easily recognized by its form and high specific gravity. Can be scratched with a pin. A splinter fuses slowly in a lamp flame. Color of freshly broken mineral and of the powder lead-gray. Bright metallic luster of freshly broken material becomes dull after long exposure. All galena carries more or less silver, but no external characteristic serves to distinguish the kinds that carry much silver from those that carry little. The value of lead ore in this region depends almost entirely upon its silver content. Galena is one of the most widely distributed of the metallic sulphides. It occurs in beds and veins in rocks of all sorts. It is in many places associated with pyrite, sphalerite, chalcopyrite, and arsenopyrite in a gangue of quartz, calcite, fluorite, etc. Cerusite is locally a surface alteration product of galena. Galena is also common with gold and in veins of silver ores. In this district it occurs at Brooks and Ear mountains and on Lost and Rapid rivers.

Garnet.—A group of minerals of which grossularite (calcium-aluminum silicate) is the most common in this region and is usually found in the altered limestones bordering on igneous masses. Garnets may occur in good crystals showing diamond-shaped or irregular four-sided faces. They can not be scratched with a knife, are brittle, and have a glassy luster. The commonly called "rubies" of sand are red garnets rounded by stream action. Grossularite as found in this region is yellow and where only a part of the crystal is exposed may be mistaken for cassiterite, but the equidimensional crystals, diamond-shaped faces, and lower specific gravity should serve to distinguish. Before accepting a mineral as cassiterite the acid and zinc test described under cassiterite should be applied.

Gold.—Occurs in places throughout the region.

Hematite.—Nuggets of the red oxide of iron occur with the stream tin at Buck Creek. Being heavy and dark in color, it is sometimes mistaken for cassiterite. If a particle of hematite is crushed, the powder resulting is reddish brown, even though the compact mineral is black. The same test can be made by rubbing the mineral on a piece of unglazed porcelain, when a red streak will result. Hematite is not magnetic. The nodules of magnetic iron occurring with stream tin give, when treated as above, a black powder or a black streak.

Hulsite.—A rare boron-tin mineral known to occur at Brooks Mountain. It is black, has a metallic luster, and can be scratched with a pin. As it is rare and contains but 20 per cent of tin oxide it will probably have no value as an ore of tin.

Ilmenite.—Iron-titanium oxide. Occurs as an abundant microscopic constituent of the pre-Ordovician basalts and gabbros of the slate area. It is not known to occur in crystals of recognizable size in the York region. Resembles hematite, but gives a black powder or streak; not magnetic like magnetite. Used in the manufacture of ferrotitanium, but not of great economic importance. Occurs as an objectionable constituent of some magnetic iron ores. No commercial deposits known in the York region.

Kaolinite.—Aluminum silicate with water. Occurs as an alteration product of aluminous minerals, especially the feldspars of the granite and porphry dikes. It is abundant in the decomposed portion of the Cassiterite dike and elsewhere in the region, although not in the form of a deposit that might be of economic value. It has a soapy feeling, and when breathed upon gives a strong odor of clay. Can be scratched with a pin.

Limonite.—The yellow-brown hydroxide of iron. Very common as an alteration product of other minerals containing iron, such as pyrite, magnetite, pyroxene, amphibole, and mica, when they are exposed to the action of air and surface waters charged with carbonic and organic acids. Numerous varieties are known, some of which have a nearly black varnish-like exterior. It may occur as soft yellow earthy material or may be so hard and compact that a knife point will hardly scratch it. In all varieties the powder of the crushed mineral or the streak is brown. It occurs commonly on the surface of ore bodies, forming the gossan, as in the case of the lead ores of Lost River. Lake deposits in the form of bog ore are common. Bodies of commercial importance are not known in the York region.

Ludwigite.—Iron magnesium borate. A finely fibrous dark-green mineral occurring in the contact limestone of Brooks Mountain. Of no economic value.

Magnetite.—Magnetic oxide of iron. Nuggets are fairly common in the stream tin of Buck Creek. Distinguished from associated minerals by its weight, black powder, and magnetism occurs in contact-metamorphic limestone of Brooks Mountain and Tin Creek. As found in the region it is of no economic value.

Molybdenite.—Molybdenum sulphide. Occurs in small amounts associated with the cassiterite ores at Cassiterite Creek. It is lead-gray and has a bright metallic luster. When rubbed on paper it leaves a blue streak. Can be scratched with the finger nail. Commonly occurs in flakes, scales, or plates, which are flexible but not elastic. May be fine granular. Resembles graphite in color and form, but graphite leaves a black streak. Molybdenite usually occurs distributed through débris of granite, crystalline limestones, porphyry, and pegmatite. No occurrence of economic importance is known in the York region.

Muscovite.—White mica, essentially potassium-aluminum silicate. Its physical properties are the same as those described for biotite except the color. Mucovite occurs in certain phases of the granite of Ears Mountain and is the chief mica in the quartz porphyry dikes. Muscovite is the most common of the micas. It is very common in mica schists and not uncommon in certain granites. The largest and best-developed crystals occur in pegmatite dikes associated with granite. It is from such dikes that the mica of commerce (isinglass) is usually obtained. No deposits of commercial importance are known in this region.

Olivine.—Iron-magnesium silicate. Occurs as a microscopic constituent of basalt dikes and flows. Can be recognized by its yellow-green color, glassy luster, and granular form. Can not be scratched with a knife. Of no economic importance.

Paigeite.—A rare boron-tin mineral found at Brooks and Ear mountains. Lustrous, coal-black, foliated. Can be scratched with a pin. Contains about 15 per cent of tin oxide. Not important as an ore of tin.

Phlogopite.—A mica very similar to biotite in composition but containing less iron. Has all the physical propertes of biotite except color. Phlogopite is usually light brown or brownish red, with a copper-like reflection. It is commonly found in crystalline limestone or dolomite. Occurs in the limestone of Cape and Brooks mountains.

Pyrite.—Iron sulphide, called iron pyrites or white iron. A very common and widely distributed mineral in the York region. Easily recognized by its light brass-yellow color and its crystal form. Usually occurs as cubes or octohedrons. Can not be scratched with a knife. Distinguished from chalcopyrite by its greater hardness, crystal form, and paler color. A common associate of the tin and lead ores of the region. Found in the placers and very abundant in large crystals in some of the slates. It is of no economic importance as found here. Pyrite is not an ore of iron. Great deposits of it are mined and used in the manufacture of sulphuric acid.

Pyrolusite.—Manganese oxide. Iron-black to bluish black. Powder black. Luster dull. Can be scratched with the finger nail or a pin. Soils the fingers. Differs from magnetite usually in hardness and in not being magnetic. Occurs in the York region as dendrites, or plantlike figures, in the joints of the limestones at Cassiterite Creek. The source of the manganese is probably wolframite, which is iron-manganese tungstate and which on decomposition yields manganese to the circulating waters, to be deposited in the limestone fissures.

Pyroxene.—A group of silicates, chiefly of calcium, magnesium, and iron. Common constituents of igneous rocks. Of no commercial value. The color ranges from white to black, but green and brown pyroxene are most common in this region. Powder gray. Can not be scratched with a knife. Prism faces on pyroxene crystals are practically at right angles, thus differing from the 120° angles of the prism faces of amphibole. Pyroxene is sometimes confused with cassiterite but is much lighter and will not respond to the acid and zinc test outlined under the description of cassiterite. Augite, a brown variety of pyroxene, occurs in a quartz porphyry dike at Ear Mountain. Hedenbergite occurs in the contact limestones of Cape Mountain associated with tin, with which it has been confused.

Pyrrhotite.—Magnetic iron sulphide. Resembles pyrite and chalcopyrite but can be distinguished from them by its bronze color, by its hardness, and by being slightly magnetic. Is often mistaken for stannite in the tin deposits but differs in its magnetic property. Can be scratched with a knife. Luster is metallic. Powder is dark grayish black. Uusally granular. It is intimately mixed with nickel minerals at Sudbury, Ontario, in the largest nickel deposit known. Occurs in the York region at Brooks and Cape mountains and at Tin Creek.

Quartz.—Silicon dioxide. Very abundant in the region as stringers or veins and as a constituent of the granites and porphyry dikes. Clear crystal quartz or milky quartz is easily distinguished from any other mineral which it resembles by its hardness and by its lack of cleavage—that is, of smooth surfaces along which it will break. Can not be scratched with a knife and will scratch glass. Calcite is much softer. Feldspar has good cleavage. Quartz crystals are six-sided. Smoky quartz is common in the region and has been mistaken for cassiterite.

Rutile.—Titanium oxide. Occurs as a microscopic constituent of the granite at Cape Mountain. May be yellowish, brown, or black. Black rutile might be

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confused with cassiterite, but cassiterite is heavier, and the hydrochloric acid and zinc test for tin will distinguish them. Used chiefly in manufacture of ferrotitanium. No deposits of economic importance known in York region.

Scapolite.—Sodium, calcium, and aluminum silicate containing chlorine. Resembles feldspar in appearance and is best distinguished by microscopic methods. Occurs at Ear and Cape mountains in contact-metamorphic limestone near the granite masses. Of no economic value.

Scheelite.—Calcium tungstate, containing 80.6 per cent of WO_3. Occurs as a microscopic constituent of altered limestone at Cape Mountain and in cassiterite veinlets and their adjoining altered limestone at Cassiterite Creek. The occurrence is not of economic importance. Scheelite is usually yellowish to brownish white and has a glassy luster. It is heavy, comparing well in weight with cassiterite. Powder white. Can be scratched with a knife. A simple chemical test is as follows: Treat the finely powdered mineral with boiling hydrocholiric acid. A yellowish solution results, which on the addition of a little granulated zinc or tin and further boiling turns blue.

Sphalerite (*zinc blende*).—Zinc sulphide. Yellow to brown or black. Luster resinous. Black sphalerite is known at Brooks and Ear mountains, where it is distinguished from wolframite with difficulty. It differs from wolframite in being softer. A knife will scratch sphalerite but not wolframite. Sphalerite occurs in both igneous and sedimentary rocks, commonly as an associate of galena; also with chalcopyrite, pyrite, siderite, fluorite, and other minerals. It is an ore of zinc but is not known to occur in commercial quantities in this region.

Spinel.—Essentially magnesium aluminate. Different varieties contain iron, manganese, and chromium. Occurs as small black octahedrons in the contact limestone at Read's galena prospect, Brooks Mountain, where it is associated with chondrodite. Is not of economic importance.

Stannite ("*tin pyrites*").—A sulphide containing copper, tin, iron, and usually zinc. Contains 29.5 per cent of copper and 27.5 per cent of tin. Color may vary from steel-gray to yellow to brownish black. Can be scratched with a knife. Powder blackish. Luster metallic. Occurs at Lost River associated with galena and wolframite and is brown-black. Stannite is difficult to recognize, and its identity must be determined by chemical methods. It is not important as a source of tin.

Stibnite.—Antimony sulphide, commonly referred to by prospectors as antimony, but contains only 71 per cent of antimony. Color lead-gray, tarnishing to black. Can be scratched with finger nail and cut with a knife. Fuses in a match flame. Crystals usually elongated and commonly in radiating groups. Found at head of Tin Creek in a vein with calcite and on Bessie and Maple claims, west of Lost River.

Topaz.—Aluminum-flourine silicate. Commonly white or light yellow, but may be blue, green, or red. Luster glassy. Can not be scratched with a knife. Will scratch quartz. Powder white. Occurs in prismatic crystals. Commonly found in rocks of the granite type in veins and cavities. May be accompanied by fluorite, cassiterite, tourmaline, etc. In this region it is abundant as a constituent of tin ore at Lost River and occurs in veins in limestone and as a contact-metamorphic mineral in limestone adjoining granite intrusives. It is commonly associated with fluorite and zinnwaldite. Has no economic value except as a gem stone. Only minerals having gem qualities can be used for that purpose.

Tourmaline.—A complex silicate of boron and aluminum, with either magnesium, iron, or the alkali metals prominent. Crystals prismatic, often slender and strongly marked by fine lines. The cross section of the prism may be three, six, or nine sided. Can not be scratched with a knife. Luster brilliant. Color usually black, but may be brown or greenish. Powder white. Best distinguished by triangular shape of its prisms, hardness, and coal-like fracture. Tourmaline is very common throughout the York region as an associate of tin ore, but its presence does not necessarily indicate tin, as it is found in many places where tin ore does not occur. It is abundant in the granite of Cape and Ear mountains and in the adjoining limestone. The quartz stringers of Potato Mountain carry tourmaline. At Brooks Mountain and Lost River it is abundant. Although in places resembling cassiterite, it is less than half as heavy. If comparison of the specific gravities of the two minerals is impossible the hydrochloric acid and zinc test for cassiterite should be made. Tourmaline has no economic value, except in rare specimens as a gem stone.

Vesuvianite.—Essentially calcium-aluminum silicate. One of the commonest contact-metamorphic minerals in the region. Crystals are square prisms. Can not be scratched with a knife. Color brown to green. Luster glassy to resinous. Powder white. Thin edges and very fine splinters are rounded in the lamp flame, which serves to distinguish it from garnet, tourmaline, and cassiterite, for which it might be mistaken. Vesuvianite occurs on Brooks Mountain and at Tin Creek. It is usually of some hue of green, ranging from gray-green to brownish green. It is of no commeercial importance.

Wolframite.—Iron-manganese tungstate containing 76.4 per cent of WO_3. Crystals are commonly tabular but may be prismatic. Prism faces are lined. Can be scratched by a knife with difficulty, but is easily scratched by quartz. Color usually brownish black. Powder nearly black. It is about as heavy as cassiterite. Wolframite is an ore of tungsten and is in many places associated with tin ores; it also occurs in quartz, with scheelite, pyrite, galena, sphalerite, etc. It is associated with cassiterite at Cassiterite Creek. It can be distinguished from cassiterite by its hardness and in this locality by the shape of its crystals, most of which are elongated, slender prisms. Wolframite can be distinguished from black sphalerite by its greater weight and hardness. It is not so easy to prove the presence of WO_3 in wolframite as it is in scheelite, owing to the difficulty of getting wolframite into solution. The best results are obtained by first fusing the mineral with three parts of sodium carbonate on charcoal and then treating with acid. However, it is usually possible to get some material into solution by boiling with hydrochloric acid. Addition of zinc or tin to the clear solution and boiling turns it an intense blue.

Wollastonite.—Calcium silicate, a variety of pyroxene. Color white, gray, or yellow to brown. Powder white. Can be scratched with a knife. Luster vitreous to pearly. Occurs usually in granular limestone at granite contact. It occurs on Cape Mountain in proximity to the granite, locally forming white masses 3 feet or less in thickness. Of no economic value.

Zinnwaldite.—A mica, essentially a lithium, iron, and aluminum silicate, commonly associated with topaz, fluorite, and other minerals. In physical properties resembles muscovite but is yellowish to brown. It is a common constituent of the cassiterite veins of Cassiterite Creek. Of no economic value.

Zircon.—Silicate of zirconium. Occurs as a microscopic constituent of the granites of the York region. Not distinguishable in hand specimens as known to occur here, and of no economic importance. Zircon is commonly found in square prisms. Color yellow, grayish, or brownish. Will scratch glass, also quartz. Very high luster. Powder white.

Zoisite.—Essentially calcium-aluminum silicate. Occurs in small amounts in the altered limestones of Ear Mountain. Crystals are prismatic and deeply striated or furrowed. Can not be scratched with a knife. Luster glassy. Color gray, yellowish, or brown. Powder white. Of no economic importance.

LOST RIVER AREA.

GEOGRAPHIC FEATURES.

Lost River rises on the south slope of Brooks Mountain, whence it flows southward into Bering Sea, 9 miles distant. Most of its tributaries enter from the west; of these, Rapid River, 9 miles in length, is the longest. In the valley of Rapid River is a trail and a wrecked telephone line to York and Cape Mountain. The tributaries from the east are short and carry but little water. The area of this side of the Lost River drainage basin has been curtailed by the growth of many small rival streams flowing southeastward into Bering Sea.

Lost River is a swift-flowing perennial stream. Where confined to a narrow bed it is about 2½ feet deep and 25 feet wide under average conditions, but in the vicinity of Cassiterite and Tin creeks it spreads out over flats several hundred feet wide. The water of the stream is clear and cold and where stirred by currents has a beautiful bluish-green color. It is remarkably free from both vegetable and animal life.

The valley is bordered by steep barren ridges of the York Mountains, about 2,000 feet high, whose slopes range from 25° to 45°. Until the middle of August the gulches of these high hills are buried in snow and ice and from a distance appear like white streaks, gashing the gray of the hills. The distance across the valley from ridge to ridge is about 2½ miles, except at the mouth. Bordering the stream are low rounded hills having an elevation of about 150 feet above Bering Sea. Upstream these hills merge into a well-defined bench lying about 30 feet above Lost River at the mouth of Cassiterite Creek. Except for scattered patches of mosses these low-lying lands are hardly less barren than the high ridges.

Three-eighths of a mile north of Bering Sea the Lost River valley is nearly blocked by a ridge half a mile wide, an eroded remnant of the great sea terrace referred to on page 35. Through the eastern part of this barrier the river has cut a canyon. West of the river this ridge merges into a flat a little over 100 feet in elevation and about half a mile wide. To the east and west of the lower 3 miles of the river valley lies the great sea terrace, about 400 feet high. (See Pl. III.)

South of the ridge that bars the Lost River valley the stream is bordered by a low gravelly flat several hundred feet wide, dotted with limestone outcrops. This flat is incised into a stream-gravel terrace that rises 24 feet above Bering Sea. Nearly 100 feet from the strand line the waves have thrown up a gravel bar 15 feet high, through which the stream has cut its channel. During great storms from the south the waves build a temporary gravel bar across the mouth of the stream, but the porous débris thus piled up does not hold back the water, and shore currents soon destroy the bar. The river has no visible delta.

The mouth of Lost River can be reached by trail along the beach of Bering Sea, starting on the shore opposite Teller. From Teller this beach is reached by means of ferry across a narrow outlet of Grantley Harbor. The numerous streams across which the trail passes are not bridged, but under the average summer conditions light loads can be taken over this road. Severe northerly storms improve the trail by driving the waters away from the shore. From the mouth of Lost River the trail continues upstream and branches, one branch going westward up Rapid River to York and the cape and the other going northward to Cassiterite and Tin creeks and thence across the Lost River and Mint River divide, down the valley of the Mint and across a very low divide into the valley of Skookum Creek, which leads northwestward into the Potato Mountain country.

During the summer a 40-ton gasoline schooner stops on signal at the mouth of Lost River, weather permitting, about once in 14 days on its way to and from the Arctic Ocean. Freight is landed by means of small rowboats, the schooner anchoring about a mile from land. During times of fog and windy weather the boat commonly omits this stop. Larger freight boats from Seattle occasionally reach this shore and lighter their cargo by means of barges, which come from Teller for this purpose.

GENERAL GEOLOGY.

SUMMARY.

The Lost River area is underlain by a succession of limestone beds, 2,000 feet or more in thickness, which generally strike about N. 70°-80° E. and dip about 25° N. Two systems of faulting disturb these beds. The faults of one system strike parallel to the strike of the limestone beds, about N. 80° E., and generally dip steeply to the south. Those of the other system generally strike parallel to the dip of the beds, N. 20° W., and dip steeply to the west. The displacements caused by these faults appear to be mainly of the normal type; that is, the overhanging side seems to have moved downward. Slickensides on the fault surfaces show, however, that in many places the movements have been more complex, having both horizontal and vertical components.

After the faulting had occurred the limestone was intruded by stocks of granite and dikes of granite and quartz porphyry. One granite stock on Tin Creek has been exposed by erosion. Another is surmised to underlie the locality of the Cassiterite Creek tin prospect.

The dikes were injected mainly along planes having the same attitude as the strike faults, but a few, including one on Camp Creek, rose along planes having the same relative position as the dip faults. It is probable that all the dikes rose along fault planes, but this inference can not be proved because of the lack of sufficient exposures.

The intrusion of the granite and quartz porphyry was followed by the rise of hot solutions carrying tin, fluorine, and boron from the granite stocks below. These solutions caused certain alterations of the granite, dikes, and limestone, involving both the accession and removal of material.

LIMESTONE.

The limestone includes a lower group of thin gray to chocolate-colored layers with grayish-brown and dark clay partings, an upper group of pure gray layers from 1 to 3 feet thick, locally with scattered black flint nodules, and a third group of transitional beds between the two. Layers of the lower type are well exposed in the sea cliffs 2 miles west of the mouth of Lost River. (See Pl. IV, *A*.) The upper beds can be seen in the high ridges between Tin and Camp creeks. The transitional beds occur at the Lost River canyon. The

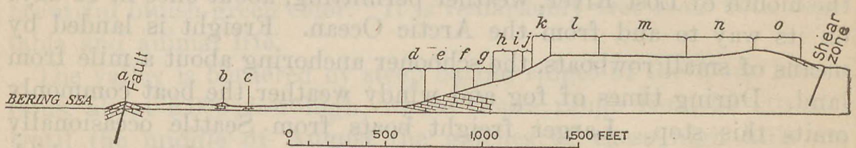


FIGURE 4.—Profile section along west bank of Lost River northward for about 3,600 feet from mouth. See text for explanation.

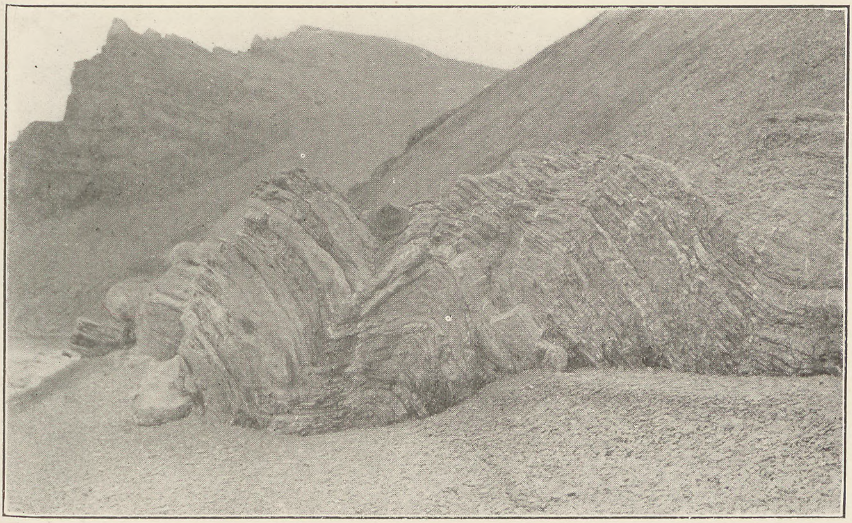
results of faulting in the area being difficult to gage because of the lack of distinctive lithologic or fossil markers, it is impossible to estimate the thickness of the three limestone groups.

The following notes on a section taken along the west side of Lost River from the sea northward about 3,600 feet illustrate the lithology and structure of the lower and transitional group of layers. The letters refer to positions so marked on the accompanying profile (fig. 4).

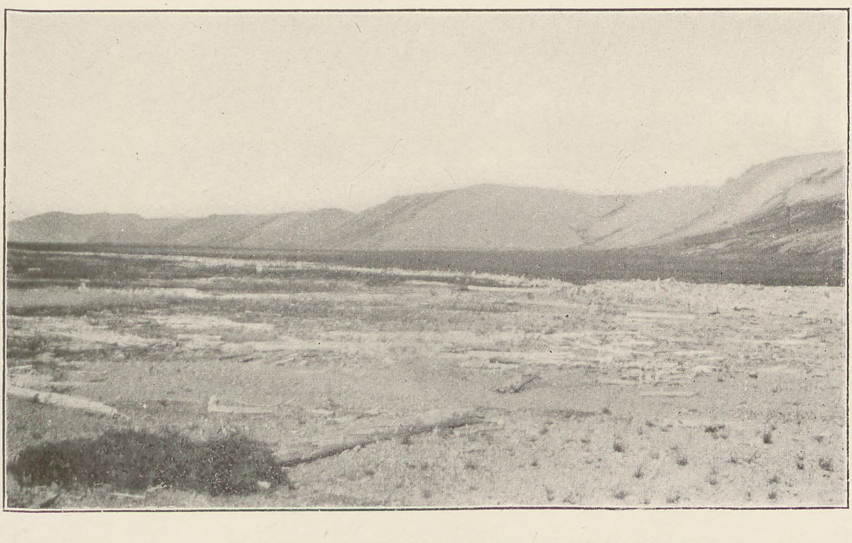
a. West bank of Lost River at mouth: Pure calcitic microgranular chocolate-colored limestone. Bedding generally obscured by fractures, but locally thin bedded. Strike N. 45° E., dip 40° S. Cut by two sets of joints spaced at intervals of 1 inch—(1) strike N. 10° W., dip 55° W.; (2) strike N. 15° W., dip 60° W. One fault strikes N. 20° W., dips 80° W., and is marked by a breccia zone 1 inch wide; the west side has moved upward. Another fault strikes N. 20° W., dips 80° W., and shows fine slickenside grooves inclined 20° S. on fault plane.

b. About 600 feet north of mouth: 10 feet of thin-bedded dark limestone with lentils of brown shale. Strike N. 20° W., dip 50° N. Overlain by 10 feet of dark pure limestone beds, 6 to 8 inches thick, with rough, hackly surface.

c. About 720 feet north of mouth: 15 feet of dark-brown thin-bedded aphanitic limestone, with rough, hackly surface. Strike N. 20° W., dip 15° N. Cut by fault that strikes N. 10° E., dips 80° E., and shows slickenside grooves inclined 5° S.



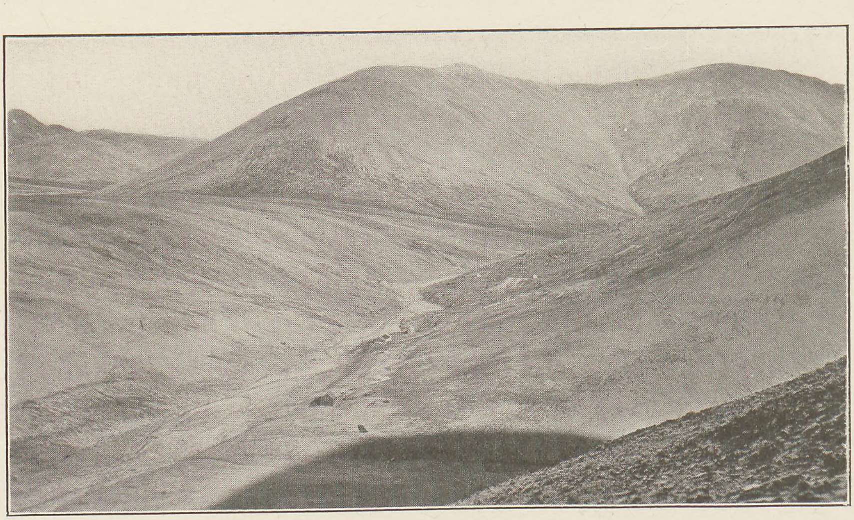
A. CONTORTED PORT CLARENCE LIMESTONE AND SEA CLIFFS WEST OF LOST RIVER.



B. SEA CLIFFS AND TERRACE EAST OF LOST RIVER.

The beach and its welcome driftwood in the foreground.

A. WORKINGS ON CASSITERITE DIKE ON EAST SIDE OF CASSITERITE CREEK (AT LEFT) AND ON THE GREENSTONE LODE (AT RIGHT).



B. LODE WORKINGS AND CAMP ON CASSITERITE CREEK.

Looking upstream. The rough surface to the right of the point where the creek disappears, near the center of the view, is the "reef rock."

d. About 1,520 feet north of mouth, elevation 3 to 60 feet above sea: Dark aphanitic brittle limestone in beds 1½ inches thick, with wavy surfaces and brown shale partings a fraction of an inch thick. Strike east, dip 20° N.

e. Overlying *d*, elevation 60 to 100 feet: Thin-bedded chocolate-colored aphanitic limestone like *a*. Same altitude as *d*.

f. Elevation 100 to 125 feet: Débris of limestone like *a* and *e*.

g. About 1,900 feet north of mouth, elevation 145 to 155 feet: Limestone débris like *f* but with thin brown shaly partings.

h. Elevation 155 to 195 feet: Dark-gray granular pure limestone débris, with vague bedding and rough, hackly surface.

i. About 2,100 feet north of mouth, elevation 195 to 224 feet: Chocolate-colored thin-bedded limestone with hackly fracture.

j. Elevation 224 to 245 feet: Chocolate-colored limestone in thin wavy beds with films of light-brown shale.

k. Elevation 224 to 300 feet: Chocolate-colored limestone with indistinct bedding, containing small black irregular flint nodules about 1 inch in diameter. Weathered surface of limestone has ash-gray color and is rough from minute flint seams.

l. From 2,300 to 2,350 feet north of mouth: No outcrops.

m. Elevation 295 to 300 feet: Dark-colored thin-bedded limestone composed of lenses of limestone 2 inches by one-fourth inch, cemented by films of shale.

n. Elevation 300 to 318 feet: Dark-colored pure limestone in beds from 2 to 8 inches thick, containing black flint nodules which weather white on exposure.

o. Elevation 318 to 370 feet: Alternations of débris of granular dark-gray pure limestone and thin-bedded gray to brown shaly limestone. At elevation of 270 feet small outcrop of gray shaly limestone, in beds of one-fourth inch thick, strike N. 70° E., dip 8° N. To the north a shear zone striking N. 70° E. and dipping steeply south.

The character and complexity of the faulting of the Lost River area are illustrated by the following tabulated notes of the fault observations made near the mouth of Lost River:

Fault observations near the mouth of Lost River.

Locality.	Strike.	Dip.	Remarks.
East bank at mouth	N. 10° W.	60° W.	Several parallel faults. Slickenside grooves on fault planes dip 25° S. Length, 1¼ inches. Widest at south end. Suggest that movement was upward toward northwest.
Do	N. 80° E.	70°-90° S	Slickenside grooves on fault planes dip 45° S. Direction of movement uncertain.
West bank at mouth	N. 20° W.	80° W.	Slickenside grooves inclined 20° S.
West bank 360 paces north of mouth.	N. 10° E.	80° E.	
East bank 28 paces north of mouth.	East	Vertical	Horizontal slickenside grooves.
East bank 567 paces north of mouth.	N. 45° W.	do	West side appears to have moved downward.
Canyon 932 paces north of mouth.	East	50° S.	Several parallel faults; south side has moved downward.
Canyon 2,800 paces north of mouth.	N. 80° E.	Vertical	South side has moved downward.
East bank S. 30° W. from peak farthest south on Saddle Mountain.	N. 65° E.	35° N.	Surface of limestone billowy. Billows are 4 to 8 feet long and 1 foot high. Both ridges and depressions cut by parallel grooves striking N. 23° W., 1½ feet long and about $\frac{1}{20}$ inch deep. Width less than $\frac{1}{20}$ inch. Grooves believed to be caused by overthrust fault.
100 paces south of last locality.	N. 65° E.	80° S.	Down curling of beds on south side of fault indicates that south side has moved upward.

QUARTZ PORPHYRY DIKES.

The quartz porphyry dikes were injected in a molten condition into the limestone along planes generally striking N. 60° E. to due east. As a rule they are vertical or steeply inclined. The inclined dikes dip more commonly to the south than to the north. The planes along which the dikes have been injected have the same attitude as those along which dislocations are known to have taken place, and it is probable that the intrusions followed the planes of dislocation. In a few places—for example, 400 paces up Camp Creek from its mouth—thin injections of the dike material took place along a fault plane striking N. 20° W. and dipping steeply west. It seems that fault planes afforded the openings through which the molten materials rose toward the surface.

Some of the dikes, such as the Cassiterite dike, have been traced continuously for nearly 2 miles; and it is probable that some of them are even longer, their continuity being hidden by slope wash and stream deposits. Their width ranges from a fraction of an inch to 40 feet or more, and averages about 5 feet.

The dike materials appear to have been at a relatively low temperature at the time of the injection, probably less than 800° C., and did not release solutions on cooling, for they had no visible effect on the limestone at the time of intrusion. Fragments of limestone showing no decomposition are found frozen into them. Limestone decomposes between 800° and 900° C., at atmospheric pressure and at a much lower temperature, about 300° C., in the presence of silica-bearing waters. Pressure raises the temperature of decomposition slightly.

The time of intrusion of some of the dikes was later than the solidification of some of the granites, notably that of Tin Creek. A dike with chilled margins cuts the granite on Tin Creek, showing that the granite had solidified, cooled, and cracked before the dike was injected. That the dikes are not contemporary offshoots of the same molten masses as the granite is also suggested by the fact that they generally contain muscovite mica, whereas the granite contains biotite.

The color and mineral composition of the dikes are fairly uniform. The fresh dike material ranges in color from a light gray to a grayish black. The dikes have a fine-grained groundmass, generally not identifiable, in which larger grains of glassy colorless or smoky quartz having angular or hexagonal forms are embedded. Few of the quartz grains exceed 0.2 inch in diameter. Less commonly the dikes contain, in addition to the quartz, visible grains of feldspar. Together the quartz and feldspar phenocrysts usually constitute only about 15 per cent of the total volume of the rock. Colorless micas are an accessory constituent.

The dikes form very few outcrops. They can be traced, as a rule, by their débris, which mingles with that of the limestone into which they were injected. Such fragments rarely exceed a foot in diameter. The surface débris marking an unaltered broad dike may rise 1 foot or more above the débris of the adjacent limestone. In places decomposed dikes underlie slight depressions a few inches below the bordering limestone. On such dikes is commonly growing a light-gray to brownish moss; and, when the surface is dry, they can easily be traced by the color contrasts between themselves and the gray limestone débris.

GRANITE.

Granite is exposed in two places in the vicinity of Lost River—north of Tin Creek and on a tributary that enters Lost River from the west about 2 miles north of the mouth of Rapid River. At the latter place the granite is on a low hill on the south side of the stream about 2 miles above its mouth. It occurs as a group of dike-like intrusions, striking northeast, about 400 paces long and 150 paces wide. The surface is covered with granite boulders about $1\frac{1}{2}$ feet in diameter. Ledges are scarce. The granite is a medium-grained quartz-feldspar-biotite rock. Several shallow prospect pits and trenches have been opened on it, but show no mineralization. The limestone adjacent to the granite appears to be unaltered except for a slight development of serpentine. A description of the granite on Tin Creek is given on pages 74–75, in the section on the Tin Creek tin prospect. At the tin prospect on Cassiterite Creek, granite probably underlies the creek bed at a depth estimated at 400 to 600 feet.

EROSION.

After the intrusion of the dikes and the granite and the development of the tin minerals, the Lost River area was eroded by streams and by the sea. Several epochs of erosion are recorded.

In spite of the steep dip and notable faulting of the limestone beds of the region, the highest ridges rise to one general level, averaging about 2,200 feet above the sea. It is believed that the beds were eroded to about this general level, either by streams or by marine planation. In the next epoch of erosion the sea cut the great sea bench now fronting Bering Sea at an elevation of about 400 feet. What the Lost River valley was like at that time is not clear, for no benches along the stream having this elevation were noted. The present epoch of erosion began with the emergence of the sea bench to its present level. The sea cliff along Bering Sea was cut by wave action. Since then there have been minor changes in the configuration of the coast by slope and shore deposits, which have caused the sea to recede from the cliff east of Lost River.

After the elevation of the sea bench, Lost River lowered its bed until it was about 100 feet above the present sea level on the bluffs north of Bering Sea. It then flowed through a broad depression about 1 mile west of the canyon. Benches of this stage about 80 feet above the river are found in the lower part of the valley. At the mouth of Tin Creek and up Camp and Cassiterite creeks they are 15 or 20 feet above stream level. The stream finally found a more direct outlet to Bering Sea when it was tapped by a gully which had cut its way back from the sea. This gully is the presnt canyon of the river.

An observer viewing Lost River valley from one of the high peaks to the east does not see the present channel. He sees the broad benches on each side of the stream and expects to find the river still flowing on them. The canyon near the mouth is a surprise, for it does not fit the width of the valley farther up.

East of Lost River the raised sea bench has been only slightly eroded by streams since its elevation, except by those which head in the York Mountains. These have cut narrow and deep trenches across the entire width of the bench.

No estimates of the amount of erosion during the first epoch, represented by the plain that bevels the tops of the York Mountains, can be made, for this plain cuts across a monoclinal succession of beds that are faulted to an unknown degree. Lost River has removed from the part of its drainage basin east of the channel about 50 per cent of the materials between its present level and the Nuluk Plateau, and from the part west of the channel perhaps 20 per cent.

The amount of tin-bearing dike rock eroded from the Cassiterite dike is probably somewhat greater than that which now remains above the level of Cassiterite Creek. This conclusion is based on the assumption that prior to erosion the mineralized part of the dike extended from the present creek upward to the level of adit No. 3. The end of adit No. 3 practically represents the east end of the mineralized part of the dike. It is probable that the mineralization of the dike was as extensive in a vertical direction as in a longitudinal direction, or perhaps even more extensive. Hence the assumption that the mineralization of the dike once extended vertically from the present creek level to the level of adit No. 3 seems to be warranted. It is therefore probable that about 150,000 tons of tin-bearing rock has been removed by erosion from the Cassiterite dike.

Prospects of tin, lead, antimony, copper, and tungsten in lodes have been located within the Lost River area. The location of the lodes is shown on Plate I. A small quantity of placer tin occurs on Cassiterite Creek, and the only important lode-tin prospect is on the same stream. Lead prospects have been opened on Tin Creek about 400 paces west of the granite, on Rapid River about 4 miles above its junction with Lost River, on a tributary of Lost River north of Rapid River, and on the west side of the Lost River valley opposite the mouth of Tin Creek (the Southern Cross lode). There is a lead-tungsten prospect near the Southern Cross lode, and about 400 paces west of the lode, across a low divide, is a small antimony prospect. Copper was found on the east side of the Lost River valley about half a mile south of the mouth of Tin Creek. Of the prospects mentioned, only one, the tin prospect on Cassiterite Creek, has been considerably developed.

PROSPECTS.

CASSITERITE CREEK TIN PROSPECT.

GENERAL GEOLOGIC RELATIONS OF THE TIN DEPOSITS.

The region in the vicinity of Cassiterite Creek is underlain by northward-dipping limestone beds which have been dislocated by a series of faults that strike nearly east and dip steeply to the south, and by another series that strike roughly N. 20° W. and generally dip steeply to the west.

After the faulting of the limestone beds they were invaded by molten materials, which probably found their way upward along fissures, as most of the quartz porphyry dikes which they formed have the same attitude as the easterly faults, and in a few places the molten materials followed certain northwesterly faults. One of the quartz porphyry dikes thus formed, the Cassiterite dike, is now being prospected for tin ore.

The injection of the dikes was followed by the rise of hot tin-bearing solutions from within the earth. These solutions caused portions of the dikes to be replaced by fluorite and other minerals, including the tin mineral cassiterite. The limestone traversed by them was partly replaced by fluorite, serpentine, pyroxene, and similar minerals. They also formed certain fissure veins cutting the limestone and to a lesser extent the dikes. The fissure veins contain a group of minerals characteristic of tin deposits, including quartz, cassiterite, fluorite, topaz, and tourmaline. Present developments indicate that the dikes contain the most promising deposits of tin. The veins cutting the limestone show no probability of future production.

Since their introduction the cassiterite and related minerals have not been disturbed by any marked faulting. Erosion has exposed them and has caused the accumulation of a little placer tin on Cassiterite Creek.

LIMESTONE.

The limestone in the vicinity of Cassiterite Creek includes thin layers with light-brownish shaly partings; thick beds of dark-gray pure limestone with distinct grain; and some thin beds with black shaly partings.

Outcrops are not common except along the high ridges and in the stream beds. Because of numerous faults, of which probably only a portion have been recognized, no attempt will be made to present a detailed section, but notes on the character and location of lime-

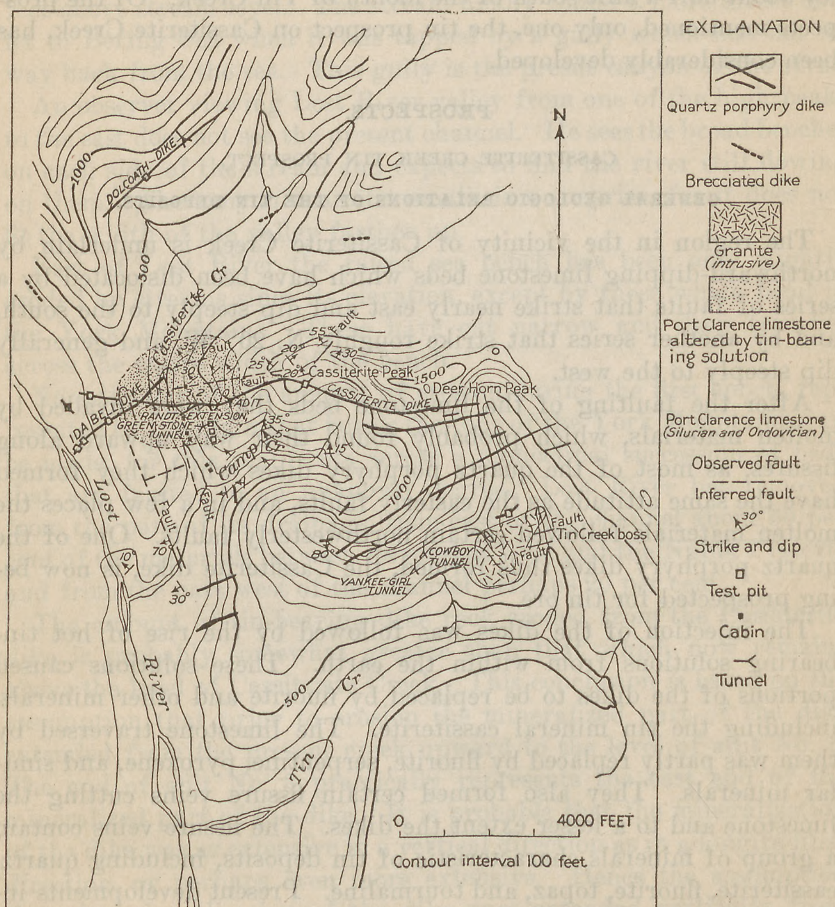


FIGURE 5.—Geologic sketch map of Cassiterite Creek and vicinity. Topography by Adolph Knopf. Elevations determined by aneroid.

stone outcrops are given with the view of setting forth the evidence for certain faults.

East of Cassiterite Creek, about 20 paces north of adit No. 3 (see fig. 5), a line running east and west marks the boundary between thin-bedded shaly limestone on the north, locally called the "reef rock," and pure gray limestone on the south. The thin-bedded shaly limestone extends northward to the area of stream and slope wash adjacent to Cassiterite Creek. The beds strike on the average N. 60° E. and dip 35° N. West of Cassiterite Creek the northern boundary of the thin-bedded shaly limestone is about 25 paces north of the Ida Bell tunnel; the southern boundary about 220 paces south of adit No. 3. On the west it extends a little beyond the top of the hill between Lost River and Cassiterite Creek. These details are given because faulting is inferred from them and will be discussed on page 54.

Outcrops of dark-gray limestone in thick beds striking N. 70° E. and dipping 25° W. extend from the top of Cassiterite Peak to the first saddle on the east. Between the saddle and Deer Horn Peak dark-gray thick-bedded pure limestone with black flint nodules alternates with thin-bedded shaly limestone.

From the top of Deer Horn Peak eastward to Chimney Peak and southward along the ridge between Deer Horn Peak and the granite knob of Tin Creek the underlying limestone is of the dark-gray pure thick-bedded variety, with scattered nodules of black flint.

At 500 paces down Cassiterite Creek from the junction of Camp Creek dark-gray pure limestone cut by closely spaced faults is exposed. The strike of the beds is obscured but is probably about N. 20° W., and the dip 35° W.

About 400 paces upstream from the mouth of Camp Creek dark-gray thick-bedded limestone is cut by closely spaced faults that strike N. 20° W. and dip steeply west.

At the junction of the second north fork of Camp Creek the dark-gray beds show a few dark shaly partings. They are traversed by seams of serpentine and contain tremolite. The upper surface of this group is covered with rounded hummocks 1½ feet in diameter and about 2 inches high. These elevations are encircled by depressions about 3 inches deep. The limestone beds in these depressions contrast sharply with the beds underneath, in that they consist of thin beds of soft, nonmetamorphosed limestone, alternating with shaly beds less than 1 inch in thickness, weathering to a light-brownish color. The conditions suggest unconformity. As they were observed in only this one place no conclusions are drawn from them.

FAULTS.

About 1,500 feet downstream from the mouth of Camp Creek outcrops of limestone on the south bank of Cassiterite Creek are disturbed by several faults that strike N. 20° W. and dip 80° W. The beds on the west side of the fault planes have moved downward with respect to those on the east. To judge by the sharp northwest-southeast boundary between the débris of thin-bedded limestone and that of pure gray limestone to the west, on the hill north of the creek, it is probable that these faults extend about 2,000 feet or more northwestward. Certain dikes north of the west end of the Ida Bell dike are in alinement with this zone of faulting.

At 450 paces upstream on Camp Creek from its junction with Cassiterite Creek faults having the same strike and dip as those just described cut beds of the pure gray limestone. At this place white fine-grained muscovite-bearing dikes as much as 8 inches in width are injected along some of the fault planes.

The southern boundary of the thin-bedded shaly limestone about 60 feet north of the tunnels, east of Cassiterite Creek (see description on p. 52), is believed to be associated with a series of fault planes. These thin beds of limestone, striking on the average N. 60° E. and dipping 15°–35° N., should, if undisturbed by faulting, extend considerably south of the tunnels. It is probable that they are cut off by a fault striking nearly east and dipping steeply to the south. On the west side of Cassiterite Creek 220 paces south of adit No. 3 the thin-bedded limestone meets the pure gray limestone along a sharp boundary that trends nearly due east. From the hill west of adit No. 3 it is clear that the southern boundary of the thin-bedded shaly limestone is considerably farther south on the west side of the creek than on the east side—a relation which can be explained by assuming that a fault, having about the same strike as the trend of Cassiterite Creek at this place (N. 10° W.), cuts through the limestone in the vicinity of the creek. If such a fault were nearly vertical and had displaced the beds in the same direction as the faults exposed farther down Cassiterite Creek and up Camp Creek—that is, if the beds west of the fault plane had been depressed—this, combined with the existing state of erosion, would bring about the present relation of the thin-bedded limestones on the two sides of Cassiterite Creek. This inference is confirmed by the fact that some of the limestone exposed in the bed of Cassiterite Creek between the mine office and the Ida Bell tunnel is broken into angular blocks about 2 feet in diameter, which have been cemented by vein materials.

The limestone in the vicinity of the tin prospects on Cassiterite Creek is cut by two sets of fissures, one striking northeast to N. 10° W. and dipping steeply east, the other striking nearly east and dipping 8°–45° S. Some of them contain tin. Other fissures occur, but these are the most prominent.

A rock trench on the east side of Cassiterite Creek 150 paces east of the mouth of the Ida Bell tunnel discloses the fact that movement of the limestone has taken place along one of the planes striking N. 85° E. and dipping 35° S., as is shown by the development of gouge and minor fractures in the adjacent limestone.

That the faults described were developed before the intrusion of the quartz porphyry dikes seems to be proved by the fact that they do not disturb the dikes, and in at least one place the dike materials were injected along a fault plane. Nor do the two sets of joints described as cutting the limestone appear to cross the Cassiterite dike. Certain tin-bearing fissure veins of the Ida Bell dike, however, have the same attitude as those tin-bearing veins in the limestone which strike east and dip gently south. The only fault displacing dike materials was seen in the workings on the Greenstone lode. It strikes N. 10° E. and dips 80° W., and the downthrow appears to be toward the west.

QUARTZ PORPHYRY DIKES.

The principal tin-bearing dikes of Cassiterite Creek are the Cassiterite dike and the Ida Bell dike. A massive irregular body of intrusive material south of the Cassiterite dike and east of the creek will be referred to as the Greenstone lode. The Cassiterite dike ranges in width from about 3 to 12 feet. It can be traced from Lost River southeastward to the top of the hill west of Cassiterite Creek and thence in a general southeastward direction to the west side of the north fork of Tin Creek. On the southwest slope of Cassiterite Peak it takes a very abrupt turn northeastward. As there are no outcrops of the dike, except in one place on Cassiterite Peak, it can be traced only by its débris on the surface. It is therefore not certain whether the very abrupt turn of the dike on Cassiterite Peak is an original feature of the dike or whether it is due to an offset caused by faulting. It is very probably original. From the portal of adit No. 2 a branch of the Cassiterite dike extends southwestward within 100 paces of Cassiterite Creek, where it appears to end, about midway between adit No. 3 and the tunnel of the Greenstone lode. (See fig. 5.)

The undecomposed portion of the Cassiterite dike consists of well-defined quartz grains, commonly with hexagonal cross section about 0.1 inch in diameter, which are embedded in a very fine grained light-colored groundmass. Besides quartz, it contains crystal grains of turbid orthoclase and clear oligoclase of about the same size as the quartz. Orthoclase incloses many of the oligoclase crystals. Foils of white muscovite mica are also common. The visible minerals make up about 20 per cent of the total volume of the rock.

The Ida Bell dike has been traced from the Ida Bell tunnel southwestward to Lost River. On top of the hill west of Cassiterite Creek it crosses the Cassiterite dike. At this place, to judge by the débris, it is about 35 feet wide. It differs from the Cassiterite dike in containing fewer feldspar grains. Quartz in sharply defined grains with hexagonal outlines is embedded in a very fine grained light-colored groundmass and constitutes about one-tenth of the volume of the rock.

The area south of the Cassiterite dike and the main channel of Tin Creek is traversed by a great many quartz-feldspar dikes of very dark color. The feldspar grains range from 0.1 to about 0.5 inch in diameter, and the quartz grains are very fine, dark, and glassy. The fine matrix in which these grains are embedded is generally black. The distribution of these dikes is shown on figure 5. One of them has been traced from the north branch of Tin Creek southwestward to the peak southeast of the mouth of Camp Creek. The same group of dikes probably extends under the stream wash of the Lost River valley and reappears on the hills south of the Southern Cross tunnel, opposite Tin Creek. (See fig. 12, p. 78.)

In the workings of the Greenstone lode a medium-grained granitic dike of very irregular shape is exposed. It does not reach the surface. In places it is only a few feet thick and dips gently southward between limestone layers, through which it cuts. A more detailed description appears on pages 69–71.

Innumerable felsitic dikes an inch or so in width cut the limestone in the vicinity of Cassiterite Creek between adit No. 3 and the Ida Bell tunnel.

BRECCIA.

Boulders containing limestone and granite pebbles found in Cassiterite Creek near the tin prospects led to a search for the ledges from which they came. It was believed that they might be from a consolidated gravel bed resting on a surface of erosion either interrupting the Port Clarence limestone beds or beveling them all. The possibility of finding tin placers associated with such a formation made this search of practical interest.

The boulders were traced to dikelike forms, most of which cut the limestone beds. The lowlands north of Cassiterite Creek, upstream from the tin prospects, show shattered débris and several outcrops of this peculiar rock. One of the best exposures is on the west bank of Cassiterite Creek at the junction of the third fork upstream from the tin prospect. It strikes N. 55° E., stands vertical, and averages 2 feet in width. The limestone beds at this place strike N. 70° E. and dip 25° N. As a rule the limestone walls of the dike are smooth and sharply defined, but here and there some of the cementing material of the dike invades them along minute cracks and appears to have been caught in the act of sloughing off a fragment of the wall. The dike was traced eastward for 150 paces to a point where it disappears under débris. It does not reappear where it should if it extended much farther.

The pebbles composing the dike are chiefly round to subangular pebbles of limestone, whose maximum diameter is about 5 inches. Five different varieties of limestone were noted, differing in color, texture, and composition. Generally the longest dimension of the larger pebbles is parallel to the walls of the dike. Here and there a distinct pebble of medium-grained granite occurs with the limestone pebbles. None over 5 inches in diameter were seen.

In places the limestone pebbles are so closely packed that the cementing material between them is a mere film of fine-grained calcite. Where the cement is more abundant it consists of fine-grained calcite with numerous secondary quartz grains and in places colorless mica.

The cement, the limestone pebbles, and the limestone bedrock have locally undergone severe alteration such as is characteristic of deep-seated conditions, which has resulted in the development of abundant tremolite in short white prisms. The outer parts of the limestone pebbles have been changed into a felt of radial tremolite needles standing perpendicularly to the surface.

Where the rock is weathered the limestone and granite pebbles stand out in relief, but the cement, because of more rapid solution, is marked by depressions. The limestone pebbles with the tremolitic borders are particularly accentuated. In many places the top of such a pebble has been broken off, exposing the inner kernel of calcite, which then dissolves out much more rapidly than the tremolized shell. In such pebbles solution has been particularly rapid along the border of the outer shell and the calcite, thus forming a horn-shaped shell tapering downward, with a small concave bump on the bottom of the inside, a form very similar to that of an ancient horn coral.

At an elevation of about 600 feet on the hill north of the first south fork of Cassiterite Creek upstream from the tin prospects a dike of this type has been traced with several interruptions for about 100 feet. In places it is nearly vertical and cuts across the beds, but at its west end it is parallel to the bedding. The dike ends abruptly in a rounded contact. The limestone inclosing this dike at the west end shows no effects from it.

On the ridge south of Camp Creek and on the crest of the hill east of the head of the north fork of Tin Creek there are some small local veinlike occurrences of these materials. Because of their being more resistant to weathering than the adjacent limestone, they stand in slight relief, amidst limestone débris.

A very significant occurrence of this kind is found on the east bank of Lost River at an elevation of about 100 feet above the stream, 1½ miles upstream from the junction of Cassiterite Creek. Here a dike composed of limestone and porphyry fragments grades into a quartz porphyry containing angular pebbles of limestone.

That these dikelike materials are not consolidated gravel beds which accumulated on an erosion surface cutting both limestone and granite, as was first surmised, is evident. They do not lie upon limestone beds but generally cut through them. Nor are they sedimentary dikes—fissures filled from the surface with rock débris, for the exceedingly close packing of the pebbles, the oblique position of some of the dikes, the interrupted veinlike character of others, and the character of the cement do not fit that explanation. The cement of the pebbles where unchanged by deep-seated alteration is not a coarse white vein calcite like that deposited by solutions underground but a very fine grained calcite like that of the pebbles.

To assume that these dikes were formed by fracturing and movement along shear planes followed locally by the invasion of molten materials is a satisfactory explanation of the larger occurrences, but not of those showing lack of continuity, changes in dip, and local sporadic appearance. How the granite pebbles got into dikes of this type that now crop out on Cassiterite Creek is puzzling. They are rounded and are discrete from the cement. No granite was seen in the cement of the etched surface of weathering, nor in several thin sections of cement. If the granite pebbles are fragments of granite from some larger mass, how did they get into their present position? The only conceivable source is from below. If they had been brought up by shearing, it would be reasonable to look for granite fragments resulting from friction all through the cement, and some of the dikes should contain granite boulders in greater number, whereas one in several feet is the usual order of abundance. These dikes may hold the key to the problem of how dikes of igneous material make way for themselves under certain conditions. Laterally some of the breccia dikes grade into porphyry with limestone fragments, and the porphyry in turn grades laterally into clean igneous dike material. Is it not probable that all the breccia dikes grade downward into pure igneous dikes? It is conceivable that the intrusion of most of the true dikes of the region has been accomplished by the molten material forcing upward and displacing zones of broken rock, and that the breccias represent the materials which were pushed upward from below by intrusive forces. On the basis of this inference the breccia dikes are tentatively called intrusive breccias.

EFFECTS OF THE TIN-BEARING SOLUTIONS ON THE QUARTZ PORPHYRY DIKES.

The tin-bearing solutions that permeated the rocks in the vicinity of the tin prospect on Cassiterite Creek came up from below, chiefly along (1) the contact between the Cassiterite dike and the limestone walls, (2) fissures cutting the limestone crisscross in all directions,

(3) nearly vertical fissures that strike roughly north, and (4) fissures that strike nearly east and dip gently south. The area most intensely affected by these solutions is elliptical, with its longer diameter parallel to the Cassiterite dike. The longer axis of this altered area extends about 250 feet west and about 1,200 feet east

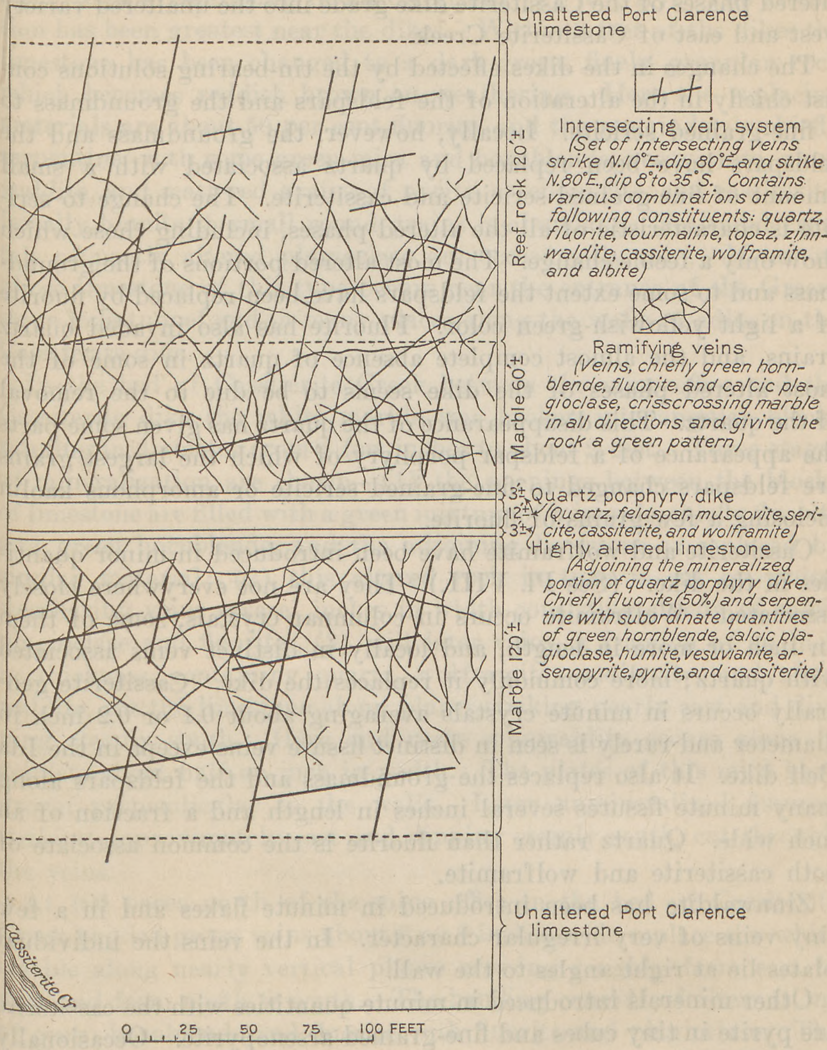


Figure 6.—Idealized sketch showing mineralization of limestone at Cassiterite Creek tin prospect.

of Cassiterite Creek. Its northern limit is in the vicinity of the Ida Bell tunnel, about 180 feet north of the Cassiterite dike, and it extends about an equal distance southward from the dike. Between Casserite Creek and adit No. 3 seems to lie the center of most intense alteration. (See figs. 5 and 6).

Within the area in which the tin-bearing solutions have been effective the Cassiterite dike and the Greenstone lode are intensely altered. The Ida Bell dike has been but slightly changed. Where most altered the Cassiterite dike and Greenstone lode have been changed to a gray or brownish soft, porous claylike mass. Intensely altered phases of the Cassiterite dike grade into the unaltered variety west and east of Cassiterite Creek.

The changes in the dikes effected by the tin-bearing solutions consist chiefly in the alteration of the feldspars and the groundmass to a fine-grained sericite. Locally, however, the groundmass and the feldspars have been replaced by quartz associated with a small amount of fine-grained sericite and cassiterite. The change to sericite is characteristic of all the altered phases, including those which show only a feeble change. The most altered portions of the groundmass and to some extent the feldspars have been replaced by fluorite of a light yellowish-green color. Fluorite has also invaded quartz grains, and the almost complete absence of quartz in some of the most altered phases of the dike seems to be due to the removal of the quartz. This disappearance of the quartz has given some parts the appearance of a feldspar porphyry of which the largest grains are feldspars changed to fine-grained sericite or amorphous kaolin inclosing a few grains of fluorite.

Cassiterite and wolframite have been introduced in minor quantities in the dike. (See Pl. VIII.) They are not everywhere closely associated. Wolframite occurs in columnar crystals, some of them an inch or more in length, and locally in distinct veins associated with quartz; more commonly it replaces the dike. Cassiterite generally occurs in minute crystals averaging about 0.1 or 0.2 inch in diameter and rarely is seen in distinct fissure veins except in the Ida Bell dike. It also replaces the groundmass and the feldspars along many minute fissures several inches in length and a fraction of an inch wide. Quartz rather than fluorite is the common associate of both cassiterite and wolframite.

Zinnwaldite has been introduced in minute flakes and in a few tiny veins of very irregular character. In the veins the individual plates lie at right angles to the wall.

Other minerals introduced in minute quantities with the cassiterite are pyrite in tiny cubes and fine-grained arsenopyrite. Occasionally a few small grains of galena, molybdenite, sphalerite, and stibnite are found in the altered dikes. Locally the dike material is almost completely replaced by round irregular grains of gray humite 0.05 inch in diameter. Topaz in microscopic radial columns is common in the silicified portions. Tourmaline needles are rare and were seen only in the Cassiterite dike.

EFFECTS OF THE TIN-BEARING SOLUTIONS ON THE LIMESTONE.

The pure gray limestone adjacent to the Greenstone lode and the Cassiterite dike in the vicinity of Cassiterite Creek was changed to white granular vesuvianite-bearing marble cut by greenish replacement veins crisscrossing in all directions (Pl. VI, *A*). The alteration has been greatest near the dikes. Within 3 feet of the dikes the limestone has been changed to a dark-green, finely granular rock which becomes reddish brown on weathering. Here the replacing materials are about 50 per cent fluorite, and the remainder is chiefly serpentine, with some green mica and hornblende, vesuvianite, zinnwaldite, and scattered grains of pyrite, arsenopyrite, and cassiterite. Locally humite in small round grains is abundant. Scattered crystals of partly altered plagioclase are occasionally seen. Metamorphose limestone of this type occurs near the entrance of the Greenstone lode tunnel and in many places along the walls of adits on the Cassiterite dike.

In the bed of Cassiterite Creek between the mine office and the Cassiterite dike the white marble was broken into angular blocks ranging in diameter from a few inches to about 2 feet. Three stages of mineralization are shown—(1) the openings between the blocks of limestone are filled with a green mixture of minerals, chiefly fluorite and green hornblende, and the adjoining limestone is replaced by similar material; (2) this altered rock in turn is cut by white-weathering veins several inches in width consisting chiefly of calcic plagioclase and fluorite; (3) still later veins, a fraction of an inch in thickness, containing quartz, wolframite, cassiterite, and zinnwaldite, cut the limestone along planes striking nearly east and dipping steeply south. Here and there zinnwaldite occurs alone in veinlets about half an inch in width. The plates of this mica have grown perpendicular to the walls. Later unmineralized fissures, striking approximately east and dipping steeply south, cut through the veins.

At 100 paces north of the mine office in the bed of Cassiterite Creek banded green veins about 6 or 8 inches wide replace the white marble along nearly vertical planes crossing roughly from east to west and from north to south. The banding consists of alternations of green hornblende and fluorite with fluorite and plagioclase. The vertical parallel banding grades into a concentric banding, like that of the altered limestone adjoining the granites of Tin Creek. Cores of white marble about a foot in diameter commonly remain within the concentric rings of green materials. Both in mineral composition and in structure these veins resemble those bordering the granites of Tin Creek. (See p. 75.)

The thin-bedded shaly limestone or "reef rock" north of the Cassiterite dike on the east side of Cassiterite Creek and that on the west side of the creek have been very intensely altered by the tin-bearing solutions. (See Pl. V, *B;* Pl. VII.) The shaly bands have become hardened and stand out conspicuously on weathering. They consist of fine-grained, colorless mica, embedded in a very fine groundmass of indistinguishable minerals.

A very complex network of fissure and replacement veins cuts the "reef rocks." (See Pl. VI, *B*.) The replacement veins, like those that cut the white marble, usually crisscross in all directions and are only a few inches wide. The fissure veins trend in various directions, but most of them fall into two groups—one striking about N. 10° E. and standing vertical or dipping steeply to the east, the other striking N. 80° E. and dipping from 8° to about 35° S. Their maximum width is about 2 inches, and in the scattered outcrops in which they occur they usually can not be traced for more than about 20 feet. The following mineral combinations have been observed in the veins, of which about a dozen were seen: (1) Quartz, zinnwaldite, wolframite, cassiterite, with the wolframite more commonly in the walls adjacent to the vein; (2) quartz, zinnwaldite, acid plagioclase, tourmaline, topaz; (3) quartz, fluorite, cassiterite, with tiny nests of zinnwaldite; (4) quartz, zinnwaldite, wolframite, topaz; (5) quartz, cassiterite, plagioclase, topaz; (6) quartz, cassiterite; (7) quartz, zinnwaldite, plagioclase.

The richest cassiterite vein observed in the limestone was in the rock trench on the east side of Cassiterite Creek 100 paces from the Ida Bell tunnel. Here a cassiterite-zinnwaldite-quartz vein striking N. 80° E. and dipping 36° S. fills a fissure along which the limestone beds were displaced before the vein was deposited. The cassiterite crystals are about an inch in length and show a well-developed four-sided prism, whose edges are beveled by a secondary four-sided prism. A major and minor pyramid terminates them. Their color is light brown and their luster adamantine. This vein is cut by a vertical quartz-wolframite vein, 1 inch in width, which strikes north.

On the west side of Cassiterite Creek 20 paces north of the southern limit of the "reef rock" and about 10 feet below the summit of the hill two cassiterite veins were found, both striking nearly due east. One dips 50° S. and contains quartz, zinnwaldite, topaz, and wolframite. Its width is about 1 inch, of which about 2 per cent is cassiterite. The other vein dips 70° N. and is about half an inch in width. It contains quartz, fluorite, and cassiterite, the last in minute scattered grains.

The alteration of the limestone seems to fall into at least two distinct stages, which were probably continuous in time.

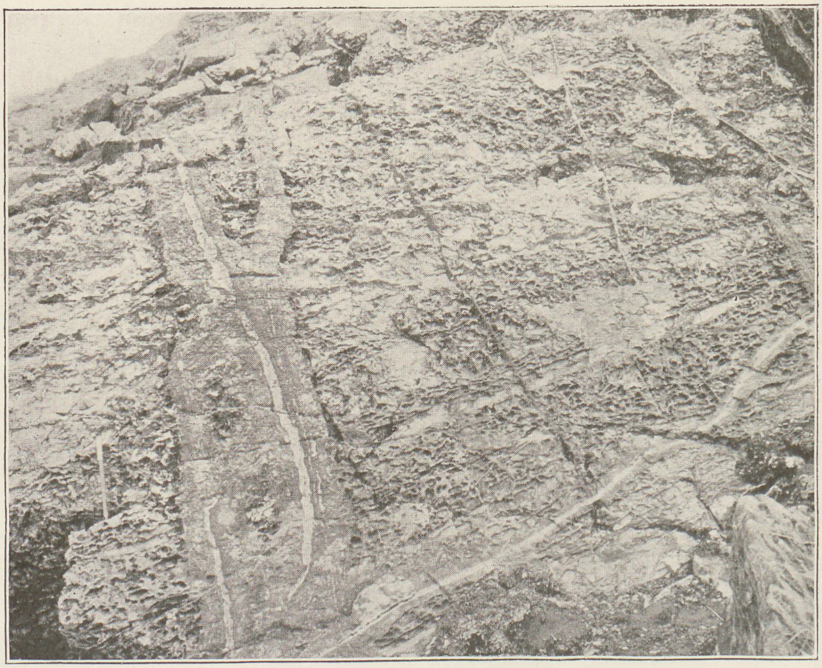
A. POLISHED SURFACE OF ALTERED LIMESTONE NEAR CASSITERITE LODE.

The white areas are marble; the dark seams are green crisscrossing replacement veins consisting chiefly of hornblende and fluorite.

B. THIN SECTION OF CASSITERITE VEIN IN LIMESTONE NEAR CASSITERITE LODE.

Enlarged 12 diameters. Radial topaz diverging from vein wall. Dark areas are cassiterite.

A. ROUGH SURFACE OF "REEF" LIMESTONE NEAR CASSITERITE LODE.
Ridges represent hardened shale partings; depressions are underlain by calcite. Note straight crisscrossing veins.



B. ROUGH SURFACE OF "REEF" LIMESTONE.
Dark vein consists chiefly of hornblende and fluorite; white veins chiefly of calcic plagioclase and fluorite.

MINERALIZATION OF "REEF" LIMESTONE, CASSITERITE CREEK.

In the first stage the limestone that was most altered was changed chiefly into fluorite, hornblende, zinnwaldite, and serpentine, with lesser amounts of calcic plagioclase, chondrodite, vesuvianite, pyrite, arsenopyrite, and possibly cassiterite. Rock showing this intensive alteration grades into crisscrossing veins of fluorite, calcic plagioclase, and green hornblende cutting granular marble, with minor amounts of the silicates and sulphides characteristic of the more altered portions. The changes involved consisted in the loss of carbon dioxide and the local introduction of silica, alumina, iron, magnesium, sodium, potassium, lithium, sulphur, arsenic, and tin. It is conceivable that some of these materials, such as silica, alumina, and magnesium, were picked up by the solutions in the limestone. Most of the other materials must have come from other sources.

In the second stage of alteration the materials formed in the earlier stage were cut by fissure veins containing various combination of quartz, fluorite, tourmaline, zinnwaldite, topaz, acid plagioclase, cassiterite, and wolframite. These materials are distinctively of deep-seated origin, being derived from the siliceous and the most soluble constituents of magmas, such as fluorine, boron, lithium, sodium, and potassium, with other substances, notably tin and tungsten.

DEVELOPMENTS.

During the season of 1918 the development work on Cassiterite Creek was in charge of J. F. Halpin, of New York City. For the greater part of the summer 22 men were employed in cleaning out rock falls and ice from the drifts and in mine timbering. Most of the energies of the crew were spent in rehabilitating the mine and preparing it for examination and sampling. At the end of the season there were about 1,375 feet of underground drifts on the property, one raise of 100 feet, two winzes, and several crosscuts. The mine equipment included a bunkhouse accommodating about 25 men, mine office, blacksmith shop, barns, and two small warehouses on the beach at the mouth of Lost River. The mine office on Cassiterite Creek is connected by telephone with one of the buildings on the beach.

Descriptions of the underground workings on Cassiterite Creek follow. Maps showing the location of the underground workings and their general character are given in figures 7–9. The principal developments are on the Cassiterite dike. East of the creek it is opened by three tunnels, referred to as adits or tunnels Nos. 1, 2, and 3; the lowest is No. 3. West of the creek the dike is opened by the Randt Extension tunnel. Minor tunnels have been opened on the Ida Bell dike and Greenstone lode.

Adit No. 3.—At 430 feet east of Cassiterite Creek the Cassiterite dike is opened up by adit No. 3, 650 feet in length. The elevation of this adit is 61 feet above the creek. From the portal the tunnel trends S. 80° E. for 170 feet, east for 130 feet, and S. 85° E. for 350 feet. At 170 feet from the portal a crosscut extends 5 feet north from the main tunnel. A winze 20 feet deep has been sunk on the north side of the main tunnel 220 feet from the portal. During the season

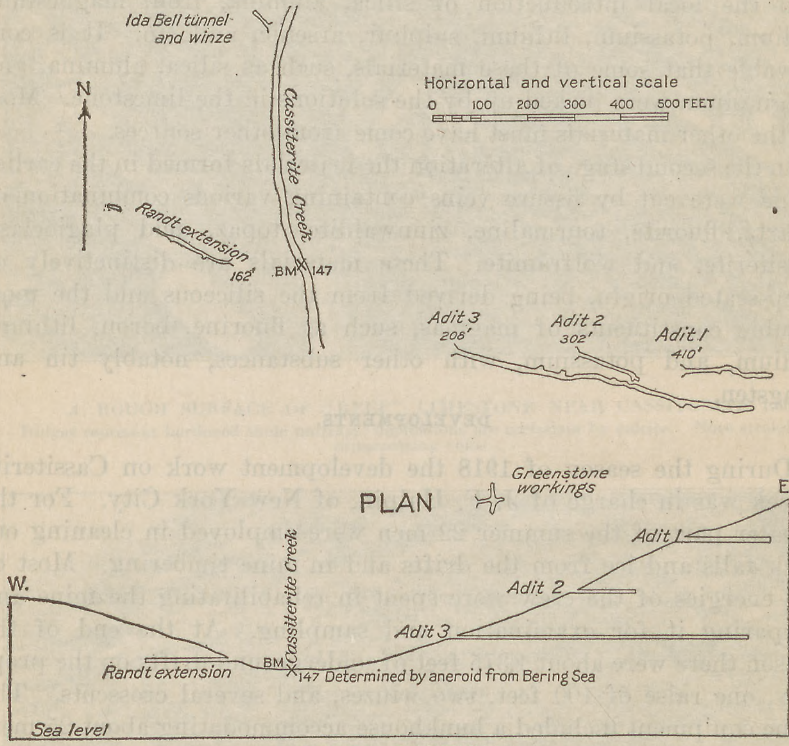


FIGURE 7.—Plan of lode workings on Cassiterite Creek and cross section of workings on Cassiterite dike.

of 1918 a raise was cut at 325 feet from the portal of the tunnel to adit No. 2, 100 feet higher. Small crosscuts have been opened up on the south side of the tunnel at 490, 520, and 580 feet from the portal.

Adit No. 3 does not expose the full width of the Cassiterite dike at any one place but swings from one wall to another in its course. At 170 feet from the portal the width of the dike is 11 feet; at 208 feet from the portal it is only 3 feet. From the narrowest part of the dike to the end of the tunnel the width of the dike exposed averages between 11 and 12 feet. The width of the dike in the whole length of the tunnel probably averages 9 feet.

The dip of the Cassiterite dike is 67° S. at 130 feet from the portal and only 45° S. where the dike is narrowest. At 220 feet from the portal the dip is 75° S.

During the season of 1918 the examination of the tunnel was hindered by ice, a fraction of an inch to several inches thick, covering the walls. The ice crystals were arranged in aggregates of thin hexagonal plates, roughly an inch in diameter. The most favorable conditions for examination prevailed in the early part of September, when the walls had partly thawed off and sample gouges had been cut at intervals of 5 feet.

Nearly all of the Cassiterite dike in adit No. 3 is soft and ranges in coherence from that of clay to that of a very firm shale. The color varies from a gray to a very light olive-green. The gray portion is firmer than the greenish portion. The gray dike material is a porphyry with very distinct phenocrysts of quartz, commonly hexagonal in cross section and constituting about 10 per cent of the volume of the material. The feldspars are also fine grained and include orthoclase and oligoclase. The softer greenish material is a porphyry in which what appear to have been feldspar phenocrysts about 0.1 inch in diameter constitute about 30 per cent of the volume of the rock. These phenocrysts are composed of very fine-grained sericite and amorphous kaolin, with tiny granules of fluorite. The groundmass is a very fine grained mixture of sericite, amorphous koalin, fluorite, and fine granules of quartz. Locally, as at 300 feet from the mouth of the tunnel, the feldspars and groundmass have been replaced by quartz, with accessory colorless mica, cassiterite, and topaz.

The relations of the gray quartz porphyry to the more thoroughly decomposed feldspar porphyry were not entirely clear, because of the ice in the tunnel. Two relations are possible: They may represent two distinct dikes, or the feldspar porphyry may be an alteration product of the quartz porphyry formed by the removal of quartz by fluorine solutions. The latter view is probably the right one. No fresh feldspar porphyry appears to be exposed on the surface, whereas quartz porphyry is very common. The feldspar porphyry is found only in places where the dike has been intensely altered. If the quartz porphyry and the feldspar porphyry were two distinct dikes the width of the composite dike would vary considerably, but this is not true of the Cassiterite dike.

The alteration of the Cassiterite dike, as observed in adit No. 3, consists chiefly in a decomposition of the feldspars and the poorly differentiated groundmass into a mixture of fine-grained sericite and kaolin. The more decomposed phases of the dike have been partly replaced by fluorite, which in the most altered portions composes about one-third of the dike. Fluorite is also found here and there in very thin veinlets or stringers. Next to the fluorite, the most abundant mineral replacing the dike is a lithia mica, which is also found to some extent in veins. Thin needle-like aggregates of green tourmaline are seen occasionally. Cassiterite occurs in small aggregates of grains about 0.1 to 0.2 inch in diameter, usually replacing the groundmass or the feldspars, and is occasionally found adjacent to very thin gashes that are mostly no more than 3 or 4 inches in length. Locally cassiterite in minute scattered grains is associated with quartz. Microscopic radial topaz and colorless mica replace the groundmass and feldspars. Wolframite in small columnar crystals is seen here and there, either independently or in close association with cassiterite. Pyrite is found in scattered cubical aggregates and is usually associated with arsenopyrite. Copper-bearing minerals, either chalcopyrite or stannite, in very fine grains, were observed in a few places. Their copper content is indicated by a faint green stain. A few tiny plates of molybdenite were found on the dump of adit No. 3.

Adit No. 2.—At a distance of 630 feet east of Cassiterite Creek the Cassiterite dike is opened by adit No. 2. The elevation of the portal is 162 feet above the creek. From the portal the adit trends S. 68° E. for 67 feet, S. 70° E. for 54 feet, and S. 60° E. for 24 feet. Its average width is about 8 feet, and its height about 6½ feet. At 125 feet from the portal a crosscut 5 feet long extends from its south side. The width of the dike at the east end of the adit is about 8 feet. At no other place was the full width of the dike observed. The dip is steep to the south.

Only the gray quartz porphyry type of dike was observed in adit No. 2. The rock has about the firmness of a strong shale. The feldspars and groundmass are altered to amorphous kaolin and sericite and show replacement by fluorite. The introduction of secondary minerals other than fluorite seems to be slight. In a few places scattered grains of cassiterite replace the dike rock. At the east end of the tunnel the secondary mineralization appears to have been especially feeble.

Adit No. 1.—The portal of adit No. 1 on the Cassiterite dike is 900 feet east of Cassiterite Creek, at an elevation of 100 feet above adit No. 2. From the portal the adit runs east for 75 feet, curves northward for about 15 feet, and resumes an easterly direction. The total length is about 180 feet, the average width about 8 feet, and the height 6½ feet.

The full width of the dike was not seen at any one place but probably averages between 8 and 11 feet. (See pp. 64–65.) The dip is steep to the south. The dike is all of the soft gray quartz porphyry type seen in adit No. 2. The visible results of secondary mineralization are inconspicuous, consisting only of scattered tourmaline veinlets a fraction of an inch wide and a few thin stringers of cassiterite about 0.2 inch wide and 5 inches long. There are some scattered pyrite crystals, and in one place a feeble malachite stain was seen.

Randt Extension tunnel.—West of Cassiterite Creek the Cassiterite dike is opened by the Randt Extension tunnel, about 15 feet above the creek. The tunnel is 180 feet long. From the portal it trends S. 65° W. for 60 feet, S. 60° W. for about 76 feet, and S. 65° W. for 44 feet. The west end of the tunnel is about 80 feet below

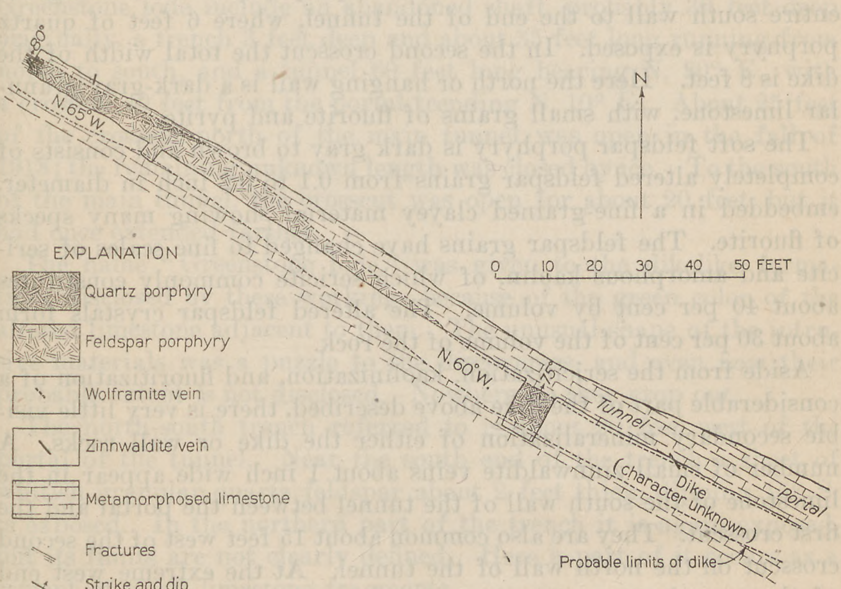


FIGURE 8.—Geologic sketch map of Randt Extension tunnel.

the surface of the hill. The average width of the tunnel is about 6 feet. At 60 feet from the portal a 10-foot crosscut has been opened on the south side of the tunnel, and at 155 feet from the portal another crosscut, 3 feet in length, has been excavated on the south side. (See fig. 8.)

The entire north face of the tunnel is composed of an altered silicated limestone, commonly containing crystals of secondary pyrite. Oxidation has changed most of the surface of this limestone to a brown granular mass. In the first crosscut on the south side of the tunnel, 60 feet from the portal, the Cassiterite dike is 8 feet wide and dips 75° N. The first 6 feet of this dike nearest the tunnel is a light-gray, dense, fresh-looking quartz porphyry. Its quartz crystals are irregular in shape, are about 0.1 inch in diameter, and constitute about one-fifth of the rock by volume. The minerals of the groundmass are not recognizable by the eye. The last 2 feet of the dike is soft, brown, and kaolinized. Quartz grains appear to be lacking.

At 20 feet west of the first crosscut a soft feldspar porphyry appears on the south wall and widens toward the west. At 10 feet east of the second crosscut this rock occupies nearly the full width of the tunnel, but a hard quartz porphyry similar to that of the first crosscut appears on the north wall. The strike of the contact plane between the soft feldspar porphyry and the hard quartz porphyry is N. 75° W., and the dip appears to be 65° S. From a point 15 feet west of the second crosscut the quartz porphyry extends along the entire south wall to the end of the tunnel, where 6 feet of quartz porphyry is exposed. In the second crosscut the total width of the dike is 8 feet. Here the north or hanging wall is a dark-gray granular limestone, with small grains of fluorite and pyrite.

The soft feldspar porphyry is dark gray to brown and consists of completely altered feldspar grains from 0.1 to 0.2 inch in diameter, embedded in a fine-grained clayey material showing many specks of fluorite. The feldspar grains have changed to fine scales of sericite and amorphous kaolin, of which sericite commonly constitutes about 40 per cent by volume. The altered feldspar crystals form about 30 per cent of the volume of the rock.

Aside from the sericitization, kaolinization, and fluoritization of a considerable part of the dike above described, there is very little visible secondary mineralization of either the dike or wall rocks. A number of small zinnwaldite veins about 1 inch wide appear in the limestone of the south wall of the tunnel between the portal and the first crosscut. They are also common about 15 feet west of the second crosscut on the north wall of the tunnel. At the extreme west end of the tunnel a quartz-wolframite vein 2 inches wide is exposed. The wolframite crystals, which are about 2 inches in length, show excellent cleavage and occupy the central part of the vein. Besides wolframite, the vein has small scattered patches of zinnwaldite and fluorite.

The relation of the decayed feldspar porphyry and the fresh quartz porphyry in this dike has not been satisfactorily determined. The separation between the two appears to be sharp. If they represent two distinct intrusions the total width of the compound dike thus formed would be expected to vary considerably, but this does not appear to be the case, as the dike seems to maintain a uniform width of about 8 feet. Nor does it seem probable that the same dike material could solidify into quartz porphyry in one place and into feldspar porphyry a few feet away. If such differentiation were possible it seems that it would be related to the wall rock, but the distribution of the quartz porphyry and feldspar porphyry shows no dependence on the proximity of the wall rock.

One of the outstanding differences between the two rocks is that the feldspar porphyry is much softer and is highly kaolinized. This difference suggests that the lack of quartz in the feldspar porphyry is due to its removal by the fluorine-bearing solutions. The quartz grains in the less altered phases are commonly corroded.

Workings on Greenstone lode.—On the east side of Cassiterite Creek at an elevation of about 55 feet above the creek level, are the workings on the Greenstone lode. They are about 300 feet south and 50 feet east from the portal of adit No. 3, the longest tunnel on the Cassiterite dike. (See figs. 7 and 9.) The workings on the Greenstone lode include an abandoned shaft, probably 30 feet deep originally, a trench 3 feet deep and about 35 feet long running from north to south, and a tunnel 60 feet long bearing N. 80° E., with a crosscut 40 feet from the portal trending N. 10° E. About 25 feet of the crosscut north of the main tunnel was open in the fall of 1918; the remaining unknown length was closed by ice. To the south of the main tunnel, the crosscut was open for about 20 feet, but it had once extended farther.

The name "Greenstone lode" was given to the dikelike formations disclosed by these workings because of the green color of the altered limestone adjacent to them. The unusual shape of the intrusive materials was a puzzle to the discoverers, and even now their probable extent is not disclosed. Nowhere do they crop out.

The north-south trench referred to is about 20 feet west of the portal of the tunnel. Near the south end of the trench a sheet of whitish granular quartz feldspar about 2 feet thick, dipping 15° S. is exposed. In the northern part of the trench it is again exposed, but its limits are not clearly defined. Here a part of it occurs as a cement of small limestone fragments.

In the tunnel the north wall as far as the crosscut is composed entirely of a dark-green massive silicated limestone, which owes its color to the secondary minerals. The south wall is composed of the same material, except near the portal, where an irregular area of the broken limestone is cemented with the white dike material. East of the crosscut the main tunnel is in the white granular quartz-feldspar rock, which is here soft, amorphous, and kaolinized. At the east end of the main tunnel the dike is cut off by a fault striking N. 10° E. and dipping 80° W. If this fault plane were projected northward, it would cut through adit No. 3 about 140 feet from the portal. The fault plane is bounded on the east by a white granular marble containing brown garnet. The dike rock and the marble are separated by gouge about 10 inches wide. The nature of the breaks along the fault plane shows that the materials west of the fault have moved downward with reference to those lying to the east. How much

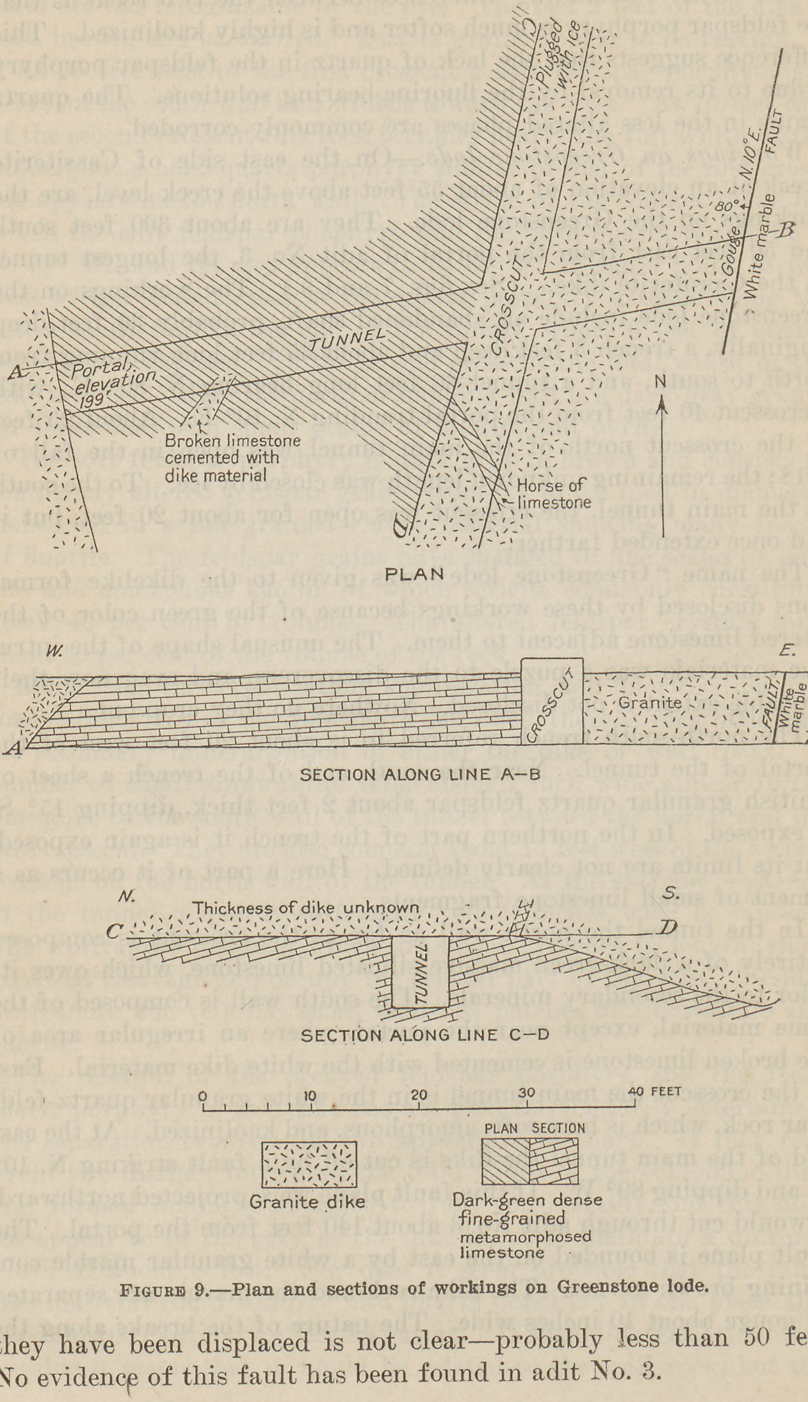


FIGURE 9.—Plan and sections of workings on Greenstone lode.

they have been displaced is not clear—probably less than 50 feet. No evidence of this fault has been found in adit No. 3.

In the crosscut northward from the main tunnel the wall on the east side is composed of the white, altered dike material. On the west wall the lower 6 feet is dark-green silicated limestone, and this is overlain by the white dike, whose thickness is unknown but is probably less than 10 feet, for otherwise its upper surface would be exposed on the surface of the hill. This dike material is nowhere exposed on the surface, the surface being mantled by loose limestone fragments. The dike is too soft to form coarse débris.

In the crosscut southward from the main tunnel the east wall is composed entirely of the white dike, except in one place where a horse of the green altered limestone extends across the crosscut. The lower 6 feet of the west wall is composed of the green silicated limestone, which is overlain by an unknown thickness of the white dike. About 15 feet south of the main tunnel the base of the white dike dips about 15° S. and descends to the floor of the crosscut.

The white dike, although its dimensions are not completely known, is a sheetlike intrusion of unknown thickness and of very irregular boundaries. It limits can not be predicted. It may widen out to great size at a moderate depth, or it may have the opposite character. It can, however, be expected to continue to considerable depth. It may even be larger than the Cassiterite dike, for its grain is uniform and of moderate size, a condition suggesting the slow cooling of a large intrusive body.

Embedded in the white dike material are numerous small secondary cubes of pyrite, which average about 0.3 inch in diameter, and here and there a small plate of molybdenite or a tiny stibnite crystal. There is nothing to suggest, however, that the molybdenite and stibnite are present in economic quantities. A few nests of purple fluorite were seen. Grains of cassiterite were not observed underground, but pannings from some samples of the decayed dike rock on the dump showed black cassiterite crystals about one-eighth of an inch in diameter.

Because the extent of the dike is unknown, no estimates of tonnage can be made, but it is probably considerably greater than present developments show. The dike may be difficult to follow because of its shape. Drilling to outline its shape and composition could be done advantageously before extensive underground work is undertaken, even for exploration.

Ida Bell tunnel.—About 180 feet north of the Randt Extension tunnel the Ida Bell dike is opened up by a tunnel 55 feet long, 15 feet above the level of Cassiterite Creek. The strike of the dike at this place, to judge from the débris on the surface, is N. 60° E. The tunnel strikes N. 45° W. and averages about 7 feet in height and 6 feet in width. At the west end of the tunnel a winze 69 feet deep has been sunk. This was filled with water in 1918. The tunnel is timbered all the way, and hence visible exposures are few.

The exposures in the tunnel do not indicate the exact width of the dike. It is probably more than 10 feet wide. Most of the dike in the tunnel is fresh and in this respect differs greatly from the Cassiterite dike, to the south. On the south wall, however, at the extreme end of the tunnel, the dike is decomposed into a soft, claylike material.

The freshest dike material consists of quartz crystals with sharp hexagonal outline embedded in a fine-grained matrix of angular quartz and sericite. Some thin sections show no quartz, but a fine-grained groundmass of sericite and fluorite in roughly cubical grains about 0.1 inch in diameter, serpentine in irregular masses and in roughly rectangular areas, and a few scattered grains of arsenopyrite.

The north wall at the northwest end of the tunnel consists of limestone made up of layers of gray fine-grained calcite about 3 inches thick alternating with layers of light-green serpentinized rock. The limestone beds strike N. 10° E. and dip 30° E.

On the north wall of the tunnel, 35 feet from the entrance, are two quartz-cassiterite veins, each three-quarters of an inch thick (Pl. VIII, *B*). The strike N. 40° E. and dip 40° S. In some places the entire width of each vein is composed of cassiterite; in others it is all quartz. Both cassiterite and quartz occur next to the wall. At 40 feet from the portal two quartz-cassiterite veins, each about half an inch in width, occur in the north wall. One of them strikes northeast and dips 15° S.; and other strikes N. 60° E. and dips 25° S. They have knife-edge walls, and no cassiterite was seen in the wall material. The quartz and cassiterite show the same relation to each other and to the wall as in the veins 35 feet from the entrance. At 10 feet from the west end of the tunnel, on the south wall, are several quartz-cassiterite veins, about a quarter of an inch thick, which strike N. 75° E. and dip 15°–20° S.

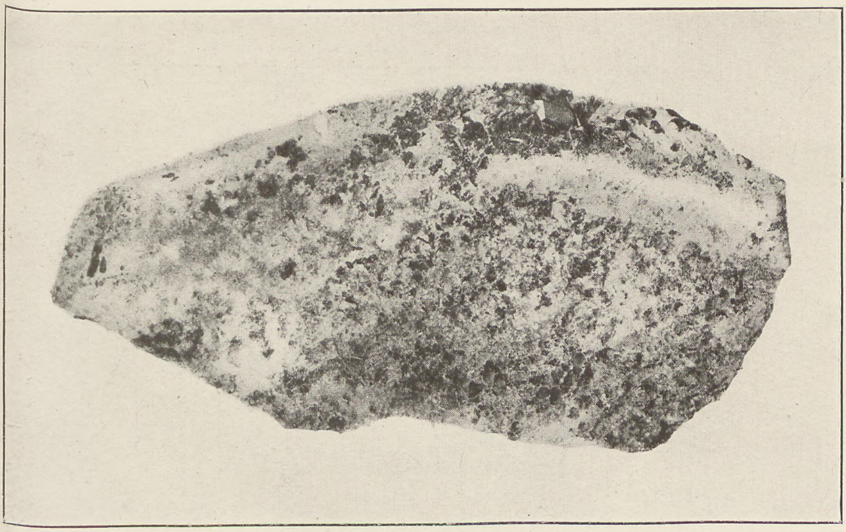
If projected southward, the quartz-cassiterite veins of the Ida Bell tunnel would intersect the Cassiterite dike at depths ranging from 50 to 250 feet below creek level. The higher figure may give some intimation as to the depths of the region from which the tin solutions emanated.

PROBABLE TONNAGE OF TIN-BEARING DIKE ABOVE THE LEVEL OF CASSITERITE CREEK.

Estimates of the probable tonnage of tin-bearing dike rock above the level of Cassiterite Creek justified by the developments in 1918 apply only to that portion of the Cassiterite dike extending from Cassiterite Creek westward 200 feet and eastward 1,080

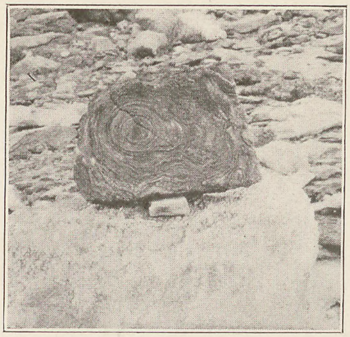
A. CASSITERITE AND WOLFRAMITE REPLACING CASSITERITE DIKE.

The rounded black particles are cassiterite. Note two columnar crystals of wolframite on the left. The white parts are fine-grained porphyry. The rounded grains near the bottom are chiefly quartz.

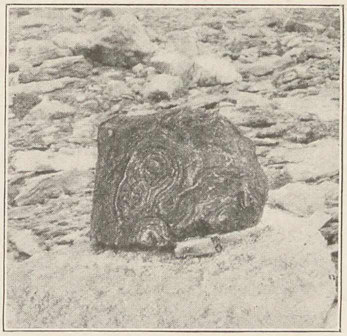


B. CASSITERITE VEIN FROM IDA BELL DIKE.

The dark part of the vein is cassiterite; the light part is quartz. The wall is fine-grained porphyry



A.



B.

C.

D.

CONCENTRIC BANDS OR ORBULES NEAR LIMESTONE CONTACT AT TIN CREEK.

A, Orbule produced by contact metamorphism; *B*, reverse side of orbule shown in *A*; *C*, maximum orbule, diameter 8 inches; *D*, irregular orbules. Dark bands consist chiefly of hornblende, fluorite, and magnetite; white bands chiefly of fine-grained fluorite and calcic plagioclase.

feet. The width of the dike west of the creek averages 8 feet. Very little is known about the width of the dike between the creek and adit No. 3, a distance of 430 feet, but in the tunnels east of the creek it ranges from 3 to 11 feet, and 9 feet is probably a fair average. The weight of the dike rock has been estimated as 1 ton to 12 cubic feet. It is therefore probable that 107,488 tons of tin-bearing dike rock is available above the level of Cassiterite Creek.

Estimates of the tonnage in the Ida Bell dike and the Greenstone lode can not be made at present. The tin content of the visible portion of the Ida Bell dike appears to be low, and present developments do not suggest the extent of the Greenstone lode.

TIN CONTENT OF THE CASSITERITE DIKE.

Mill tests carried through two seasons on dike materials obtained by trenching through the middle of a 2,000-ton dump thrown out from adit No. 3 are said to have averaged 4 per cent concentrates. Assays of the concentrates are reported as averaging 62.33 per cent tin and 11.08 per cent tungsten.

PROBABLE EXTENT OF THE TIN DEPOSITS OF THE CASSITERITE DIKE BENEATH THE LEVEL OF CASSITERITE CREEK.

As the cassiterite in the Cassiterite dike was deposited by hot solutions rising from below, it probably extends to considerable depths in about the same abundance as near the present surface. The southward-dipping tin veins of the Ida Bell tunnel and the rock trench east of the creek from the Ida Bell would, if they extended far enough, intersect the Cassiterite dike at a maximum depth of about 300 feet. This intersection may represent a center of dispersion of the tin solutions.

There is some probability, however, that at a depth of 400 to 600 feet below Cassiterite Creek the limestones and possibly the dikes are replaced by a massive intrusion of granite like that of Tin Creek or Brooks Mountain. The indications favoring this probability are the innumerable small porphyry dikes in the limestone adjacent to the creek, the massive intrusions of granitic material in the form of the Greenstone lode, and the intense contact alteration of the limestone beds. On Tin Creek the development in the limestone of the green concentrically banded silicates ("orbules") is restricted to a zone within 10 feet of the border of the granite. (See p. 75.) It is probable that the similar orbules in the limestone on Cassiterite Creek are also in close proximity to a large intrusion of granite. The narrowness of the altered limestone zone adjacent to other granites in the region suggests that the bed of Cassiterite Creek at the tin prospect is not far from large intrusive masses below. At Cape, Brooks, and Ear mountains and at other places in the region where granite intrusions are exposed the zone adjacent to the granites in which the country rock has been changed into a condition similar to that of the altered limestone of Cassiterite Creek is measured at the maximum in the hundreds of feet.

It is difficult to forecast the state of mineralization of the granitic masses that undoubtedly underlie Cassiterite Creek at a comparatively shallow depth. They may be deeply sericitized and more or less impregnated with tin-bearing minerals like the tin-bearing portion of the Cassiterite dike. If a large tonnage of tin-bearing rock is ever to be mined at this locality it must come from masses of this character. On the other hand it is equally possible that mineralization may disappear when these granitic intrusives are reached. So far as known, this is the case at Brooks Mountain, at Ear Mountain, and to a less marked degree at Cape Mountain. It is to be hoped that the future developments at Cassiterite Creek will show a departure from the general rule of the region in this regard. Only deep exploration will answer the question.

PLACER TIN ON CASSITERITE CREEK.

Placer tin in the form of cassiterite in fine grains averaging about 0.2 inch in diameter lies in the bed of Cassiterite Creek between the Ida Bell dike and the junction of Camp Creek, a distance of more than 2,000 feet. The width of the stream gravel is about 100 feet, and the depth about 4 feet. The placer tin rests on a very irregular surface of limestone having irregularities over 2 feet in height. The stream wash associated with the tin is mostly very coarse, including boulders of the "reef" limestone 2 feet in diameter. Thorough tests of the quantity of placer tin at this place have not been made. The quantity in the creek bed probably does not exceed 50 tons. In 1918 about 1 ton of placer material was taken out by means of sluicing near the junction of Camp Creek.

TIN CREEK TIN PROSPECT.

The granite area of Tin Creek is several hundred feet northwest of the junction of the north branch with the main stream. It is roughly semicircular and has a diameter of about 1,200 feet. The northern border trends northeast and follows a nearly straight line, a peculiarity suggesting that it is marked by a fault. Force is added to this suggestion by several faults striking east and dipping steeply to the north on the limestone ridges east of the granite and by similar zones of fracturing along the north fork of Tin Creek.

The granite crops out chiefly on the southeast side of a dome-shaped hill rising about 500 feet above Tin Creek. To the northwest this hill is separated from still higher hills by a low saddle. Small exposures of the granite are also found in the bed of the north branch of Tin Creek.

Quartz, feldspar (orthoclase and sodic plagioclase) and small scattered scales of brown mica are the chief mineral constituents of the granite. The grains of these minerals are nearly all of the same size, about 0.1 inch, and show no marked variation from the border toward the interior of the outcrop.

The granite is cut by a quartz porphyry dike about 8 feet wide, which extends into the limestone toward the southwest. It can also be traced toward the northeast within about 100 feet of the north branch of Tin Creek. That this dike was injected when the granite was consolidated is shown by its chilled border.

The limestone intruded by the granite is of a light-gray color, with a granular ashlike appearance on the weathered surface. It is a nearly pure calcite with a few irregular nodules of black chert.

Within 500 feet of the border of the granite the cherts were bleached white by the intrusion. The limestone within this zone has been changed to a white coarse-grained marble, individual grains of which commonly measure half an inch in length. Along the northwestern border of the granite, where the contact between the limestone and the granite is exposed, the limestone has been replaced by a mass of greenish minerals from 3 to 10 feet wide. These green minerals extend outward along fissures radiating from the granite contact, but they do not invade the granite. Near the fissures the green mineral mass is finely banded parallel to the fissures. Away from the fissures this parallel banding grades into a concentric banding which has been brought into relief by weathering. The concentric bands form circular to elliptical bodies ranging in diameter from 1 inch to about 2 feet. Certain bands inclose smaller concentrically banded bodies or nodules. Some of the concentric bodies flatten out with reference to one another, as if their growth had produced mutual interference (Pl. IX).

In a few places the core of a concentric band is a circular or elliptical area of white marble, the original limestone. The darkest bands consist chiefly of hornblende, with some magnetite and fluorite. The lighter-colored bands consist chiefly of fluorite and limy plagioclase. Fluorite is the chief constituent of these bands. Other minerals observed are pyroxene, garnet, and vesuvianite. Cassiterite, pyrite, and arsenopyrite have also been found. An excellent description of these concentric bodies is given by Knopf.[22]

The restriction of this green mineral mass to the limestone side of the contact, the great difference in composition between it and the

[22] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, pp. 44–45, 1908.

limestone, its development along fissures extending into the limestone, and the fact that it incloses circular areas of limestone show that it has replaced the limestone. Hot solutions containing fluorine, aluminum, silicon, sodium, magnesium, iron and some tin, sulphur, and arsenic, appear to have come up along the granite contact and entered into reaction with the limestone, thus setting free carbon dioxide and with the lime forming a group of lime-bearing silicates. The parallel banding along the fissures and the concentric banding away from the fissures appears to have resulted from a process of rhythmic interaction between the solutions and the limestones.

The introduction of the solutions that altered the limestone preceded the injection of the quartz porphyry dike into the granite, for this dike cuts through the green silicate zone. Whether the solutions that altered the limestones had any effect upon the granite is uncertain. No effect was noted. Solutions similar to those which altered the limestone have affected the granite locally, as shown in a few tiny quartz stringers that have been observed to contain a little cassiterite. A shallow prospect pit on the top of the granite has exposed slightly altered granite containing sulphides, including pyrite and arsenopyrite, and Knopf reports microscopic amounts of cassiterite. The feldspars of the granite in this place are altered to sericite, a change which is characteristic of the effects produced by tin-bearing solutions elsewhere.

DOLCOATH TIN-BEARING DIKE.

The Dolcoath tin-bearing dike is about 1 mile north of the Cassiterite Creek tin prospect, at an elevation of 1,200 feet on the south slopes of the high ridge northwest of Cassiterite Creek. (See fig. 5, p. 52.) The present developments have shown no merchantable ore, but the mineral associations of the deposit are very interesting.

The Dolcoath dike has an average strike of about N. 50° E. and a general northward dip of about 68°. It has been traced on the surface by débris for about 3,700 feet but probably does not maintain a uniform width for this distance. The width, where the dike has been crosscut, averages about 2½ feet. Its color is a dark gray. The chief constituents are scattered minute crystals of plagioclase feldspar, approximating labradorite, and of quartz, embedded in a fine-grained groundmass.

In most places the original character of the rock is nearly obscured by sericite and secondary minerals, chiefly colorless micas, with quartz, tourmaline, danburite, chlorite, pyrite, and arsenopyrite in small crystals. Cassiterite is not found in visible amounts but occurs in microscopic crystals.

The limestone beds adjacent to the dike strike nearly east and dip 30° N. They are thin bedded, with shaly partings, and show a regional change, not dependent on the dike, to granular white marble with an abundance of small white tremolite needles. These needles are especially prominent along the shaly seams.

Near the dike the limestone contains seams of green minerals, which appear to be like those so common in the limestone near the Cassiterite Creek tin prospect. Seams of this sort lying parallel to the bedding can be seen near the portal of the tunnel. (See fig. 5.) Knopf[23] found danburite, topaz, arsenopyrite, cassiterite, and tourmaline in both limestone walls within 6 inches of the dike.

Movement of the beds since the dike was introduced appears to have taken place, but the dike itself apparently was neither displaced nor severed. At the portal of the tunnel the beds show slickenside grooves on a vertical plane striking N. 60° E. The grooves are gently inclined to the west, and indicate an eastward and upward movement of the south wall. In the shaft (see figs. 5 and 11) a 6-inch seam of gouge lies between the dike and the hanging north wall. This gouge, together with certain fractures, indicates a downward movement of the hanging wall.

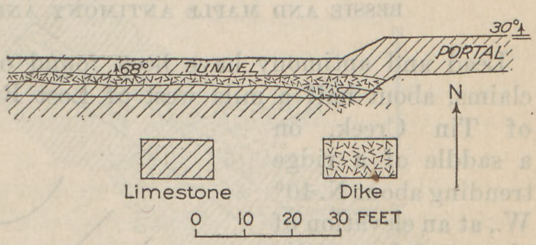


FIGURE 10.—Geologic sketch map of Dolcoath tunnel.

The accessible portion of the Dolcoath tunnel was about 100 feet long in 1918. For the first 25 feet from the portal the tunnel trends westward and is in limestone. Thence it runs southwestward for about 10 feet and cuts through two branches of the dike separated by a horse of limestone. The first dike from the portal is 2 feet wide, the one farther in about 5 feet. About 35 feet from the portal these branches unite and continue as one dike, 2 feet wide, exposed on the roof of the tunnel for 70 feet or more to the west. (See fig. 10.)

The dike as exposed in the tunnel is a soft gray claylike mass, with very little visible mineralization. In the wide branch cut by the southwest turn of the tunnel a lump of arsenopyrite about 8 inches in diameter was found embedded in the dike. Three other lumps of this sort were seen in the last 70 feet of the tunnel. Besides arsenopyrite these lumps contain small amounts of danburite, tourmaline, and topaz.

The shaft is about 1,300 feet west of the tunnel, and is about 25 feet deep. Here the dike is 2½ feet wide, strikes N. 60° E., and dips 70° N. It is soft and of a brownish color from limonite stains. Closely spaced strike fractures cut the dike parallel and transverse to the dip.

[23] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, p. 51, 1908.

The limestone on the hanging wall at the shaft has been replaced by a sheet 6 inches wide, chiefly arsenopyrite and fluorite. This sheet is sharply separated from the dike but invades the limestone along tiny fissures. About 6 inches of dark-brown gouge lies between the arsenopyrite and the limestone hanging wall. The sheet of arsenopyrite is cut by fractures having the same strike but a different dip, as shown in figure 11. Both gouge and fractures indicate that the hanging wall has moved downward, and that this movement took place after the arsenopyrite was deposited. The limestone beds dip about 30° N. and are of about the same character as those at the tunnel.

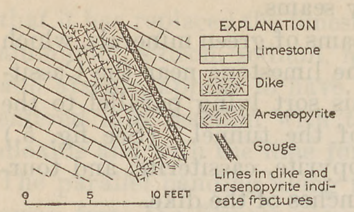


FIGURE 11.—West wall of Dolcoath shaft.

BESSIE AND MAPLE ANTIMONY AND LEAD CLAIMS.

Lead and antimony have been found on the Bessie and Maple claims, about half a mile west of Lost River, opposite the mouth of Tin Creek, on a saddle of a ridge trending about N. 10° W., at an elevation of about 900 feet. (See fig. 12.) The saddle is underlain by thin-bedded shaly limestone, which on the eastern slope of the ridge strikes N. 55° W. In an exposure on the west slope of the saddle the strike is N. 10° W., and the dip 30° E. The knob south of the saddle is underlain by beds of dark-gray pure limestone that strike east and dip 30° N. They appear to be separated from the thin-bedded limestone to the north by a zone of faulting which causes the two types of limestone to meet in vertical contact. The southeastern slopes of the

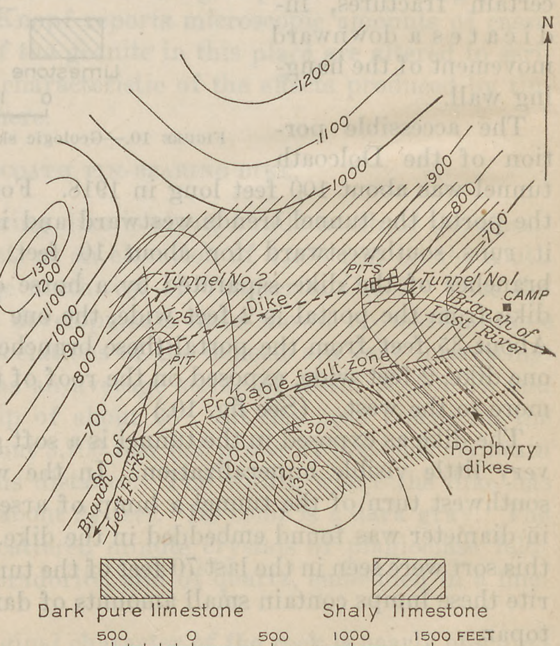


FIGURE 12.—Sketch of area around Bessie and Maple claims.

saddle and the knob to the south of it are cut by a great many dikes of dark-colored quartz porphyry striking N. 50° E.

On the east slope of the saddle, at an elevation of about 750 feet, the Southern Cross tunnel, trending N. 55° W., has been driven into the hill for a distance of 150 feet (fig. 13). Nearly all of it cuts through very fine grained thin-bedded limestones showing two sets of fractures, one striking N. 10° W. and dipping steeply west, the other striking east and dipping south. Locally these fractures are very closely spaced, and movement of the beds has taken place along them.

At 130 feet from the portal the tunnel cuts through a soft gray dike decayed into a claylike material, 20 feet wide, striking northeast and dipping 65° S. Along the south wall of the tunnel, between the dike and the portal, several galena-limonite veins striking N. 60° W. and dipping steeply south are exposed. Their maximum width is about 3 inches. No metallic mineralization was noted west of the dike.

About 100 paces west of the portal of the tunnel, at an elevation of 840 feet, a small trench exposes a soft white kaolinized dike striking about N. 70° E. Although only 2 feet wide, it is very probably the same dike that is seen in the tunnel. Five feet north of it the trench crosscuts a hard brecciated gray fine-grained dike for a distance of 2 feet. The total width of this dike is said to be 8 feet. The fragments, which are of all sizes up to about 2 inches, are cemented with thin seams of galena and pyrite, with some chalcopyrite.

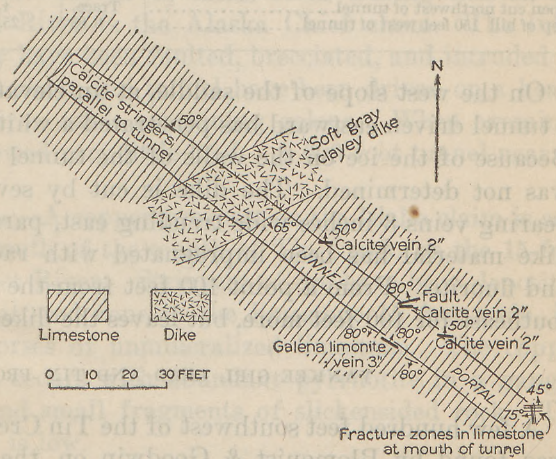


FIGURE 13.—Geologic sketch map of Southern Cross tunnel.

At 79 paces N. 70° E. from this trench, the same dike appears to be exposed and shows the same sort of mineralization. On platting the relative positions of the dike and the tunnel it appears that if the tunnel were extended farther it would reach the dike.

About 500 paces S. 20° W. from these exposures of the brecciated lead-bearing dike, at an elevation of about 750 feet on the west slope of the saddle, a trench cuts through frost-broken materials of a lead-bearing dike of the same character. The ledge is not shown, but the similarity of all these materials and the alinement of this spot with the other exposures make it probable that stringers and dikes of this kind underlie the saddle between the two extreme points at which they have been found. They may not be strictly continuous, however, nor constitute a considerable body of ore.

Assays of lead-bearing rock from the Bessie and Maple claims given to the Geological Survey by Messrs. W. B. O'Brien and Alex. McIntosh are as follows:

Assays of rock from Bessie and Maple claims.

Location.	Gold (ounces to the ton).	Silver (ounces to the ton).	Lead (per cent).	Tungstic oxide (per cent).	Tin (per cent).
Tunnel	Trace.	19.8	9.1	3.2	1.45
Open cut northwest of tunnel	Trace.	4.2	.5	0	.3
Top of hill 150 feet west of tunnel	0.03	25.6	4.6	Trace.	.77

On the west slope of the saddle, at an elevation of about 750 feet, a tunnel driven eastward has penetrated a white soft kaolinized dike. Because of the ice on the walls of the tunnel the width of the dike was not determined. The dike is cut by several vertical stibnite-bearing veins 3 inches wide trending east, parallel to the dike. The dike material has been impregnated with radial green tourmaline and fluorite. From a point 100 feet from the portal the tunnel runs southeast for 100 feet more, but leaves the dike.

YANKEE GIRL LEAD AND TIN PROSPECT.

A few hundred feet southwest of the Tin Creek boss of granite lead was found by Blomquist & Goodwin on the Yankee Girl claim. (See fig. 5, p. 52.) A short tunnel on the claim was inaccessible in 1918, and nothing to throw light on the dimensions and relations of the lead deposits could be seen on the surface. About a ton of lead-bearing rock lay on the dump, and some had been sacked. Part of the mineralized material is a yellow soft granular gossan containing numerous crystals of cerusite half an inch in maximum length. Another part is firm and heavy, consisting chiefly of copper-bearing pyrite, arsenopyrite, and fluorite replacing calcite. Arsenopyrite was introduced after fluorite. A faint greenish copper carbonate stain covers the surface of the rock in places. In thin section the hard material shows a fine-grained indistinguishable groundmass of serpentinous material containing numerous small crystals of cassiterite. Arsenopyrite is the chief constituent. The Cow Boy tunnel, driven by the same men several hundred feet higher up the hill, was in barren limestone.

OTHER PROSPECTS.

No other prospects were being worked in 1919. Descriptions of the wolframite-topaz lode on the west side of Lost River, the Alaska Chief lead claim on Rapid River, and the Idaho copper claim south of the mouth of Tin Creek are given by Knopf,[24] from whose report the following notes have been condensed.

Wolframite-topaz lode.—The wolframite-topaz lode is on the ridge west of Lost River, opposite the mouth of Tin Creek. The mineralization has taken place along a fault zone running nearly due east. An open cut shows a stringer lode 1 foot wide, in which the vein materials are wolframite, galena, stannite, topaz, and fluorite. The wall rock is a dense, fine-grained limestone showing no alteration.

Alaska Chief claim.—About 4½ miles from Bering Sea on the north side of Rapid River is the Alaska Chief claim. The limestones in this locality have been faulted, brecciated, and intruded by quartz porphyry. A shaft and tunnel have been driven on a heavy porous body of red iron oxide containing galena. When examined in 1918 the dump showed very little lead. A 600-foot tunnel near by struck no ore.

Idaho copper claim.—A copper prospect on the Idaho claim is several hundred yards south of the mouth of Tin Creek, on the 15-foot bench that fronts Lost River. Stringers of ore have been deposited in an irregularly shattered zone in the limestone 15 feet wide, including numerous horses of unmineralized limestone. The copper mineral chalcopyrite occurs with abundant pyrrhotite in a gangue of calcite, fluorite, and small fragments of slickensided rock. The percentage of copper is low.

BROOKS MOUNTAIN.

GEOGRAPHIC FEATURES.

Cassiterite has not been found on Brooks Mountain. Hulsite and paigeite, two rare tin and boron minerals, were found in minute quantities by Knopf[25] on the southwest slope of the mountain in 1908. The occurrence of these tin minerals, the intrusion of granite into limestone, and the contact alteration of the limestone adjacent to the granite, ally this area with certain other tin-bearing localities of the York region, particularly those of Cassiterite and Tin creeks and Cape and Ear mountains. The facts known regarding Brooks

[24] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, pp. 57–60, 1908.

[25] Idem, p. 43.

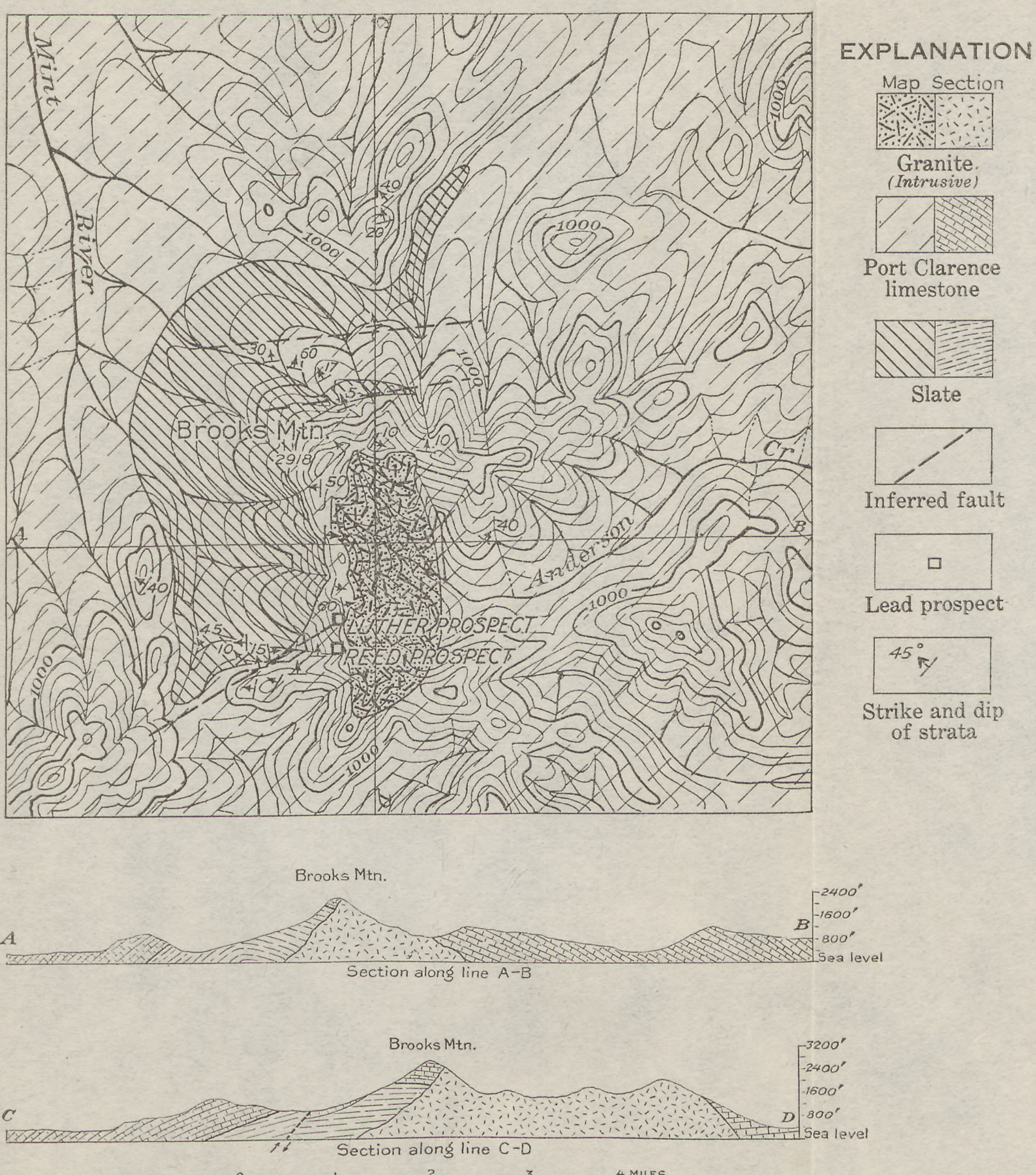
Mountain do not justify the hope that important tin deposits will be found here.

From an east-west ridge that marks the head of the Lost River basin Brooks Mountain extends northward for 2½ miles as a narrow, precipitous ridge, 2,000 to 2,900 feet high. A short distance north of the highest point it turns east and extends 2 miles farther. It has the highest peak in the York Mountains. Its western slope is the steepest. In places cliffs 400 feet high descend westward from the crest. Below them are steep slopes of loose, angular fragments, which slide under foot. The eastern slopes, although steep, can be scaled anywhere and form a great amphitheater, the site of many gullies joining Anderson Creek. The landscape at Brooks Mountain has the barren, rugged aspect characteristic of the York Mountains.

The mountain has been carved by the streams of the Arctic and Bering Sea drainage systems out of folded slates and limestones intruded by granite. Its height as compared with its surroundings is due mainly to the hardening which the limestones and slates have undergone through the action of the granite. This hardening has enabled them to resist their removal by frost and stream action more effectively than the rocks around them.

The only marked contrasts in the surface features of Brooks Mountain itself are those between the granite and the area of hardened, altered limestone adjacent to the granite. Although flanked by steep slopes, the limestone shows a nearly even crest line, indicating a nearly uniform resistance.

The granite surface can be distinguished miles away by its spiny protuberances. It is dotted with towers as much as 80 feet high, though true spires are lacking. This great irregularity of the granite surface is due to the fact that the massive granite is cut by two principal sets of fissures, one striking nearly east and dipping steeply south, the other striking nearly north and dipping 70° E. Less prominent fissures strike north and dip 20° E. Thus the granite is naturally cut into blocks 10 feet or more in length. The disintegration of the granite is accomplished almost entirely by frost, as solution is practically absent. Frost action breaks the granite into a coarse rubble, averaging about 1 inch in diameter. Disintegration starts at the surface and penetrates downward along the fissures. Wind, running water, and gravity remove the waste. Erosion is most rapid in the most fractured parts and where freezing and thawing alternate most frequently, as on southerly exposures. By these processes of disintegration and removal of the disintegrated materials the least fractured blocks are brought into relief.



GEOLOGIC MAP AND SECTIONS OF BROOKS MOUNTAIN

GENERAL GEOLOGY.

SUMMARY.

The rocks at Brooks Mountain include an unknown thickness of black slate overlain by at least 1,000 feet of limestone. The contact between the slate and limestone is not exposed, hence it is not certain whether the slate was eroded before the limestone was laid down upon it. The lower 100 feet of the limestone consists of black slaty layers a fraction of an inch in thickness interbedded with thin layers of gray fine-grained limestone. From this fact it would appear that there is a gradation from slate to limestone. The slates, however, are more intensely folded than the basal limestone beds. In position and character they are like the slates of other parts of the York region. Outside of the Brooks Mountain area the evidence is strong that the slates lie uncomformably below the limestones, hence it is probable that they bear the same relation here. (See Pl. X.)

The slate and limestone beds in the Brooks Mountain area have been buckled up into an arch whose axis strikes N. 10° W. and which is essentially parallel to the crest of Brooks Mountain. The west limb of this arch dips at an angle of about 30°. The east limb is much steeper, and it is probable that the west limb has been thrust over the eastern part of the arch. This inference is suggested by the fact that the slate and limestone contact on the west slope of the mountain is about 300 feet below the crest, whereas at the base of the east side of the mountain this contact is below the surface. Only limestone appears at the eastern foot of the mountain at the head of Anderson Creek.

Both slates and limestones have been dislocated by a fault, striking N. 70° E. and probably dipping steeply to the south, at the escarpment that forms the south end of the Mint River valley. Faulting is shown by the relations of the limestones and slates. The limestones on the escarpment dip northward; the slates in the valley to the north have a similar northward dip but are intensely contorted in the vicinity of the limestones. The limestone beds, if projected, would occupy regions underlain by the slates to the north. It is inferred that the limestones lying south of the fault plane have been depressed with respect to the slates lying north of it.

Along the axis of the slate and limestone arch a large mass of granite has been injected. The molten material apparently followed the paths of least resistance offered by the arch and may have come up along an overthrust fault plane dipping steeply westward.

Dikes are rare in the Brooks Mountain area. One dacite porphyry dike was found in the slates on the east side of the valley, descending northwestward from the first saddle north of the highest peak of Brooks Mountain. Knopf found a pegmatite dike in the vicinity of the limestone and granite contact at the southeast end of Brooks Mountain.

Since the intrusion of the granites the area has been carved into its present relief by the action of streams. The weak slate west of Brooks Mountain was removed more rapidly than the granite and the hardened slate and limestone adjacent to the granite. Only a small part of the granite mass has been exposed by erosion, and it is probable that the surface erosion has descended into the granite at most only a few hundred feet.

SLATE.

The slate, where unaffected by the granite intrusion, has an exceedingly fine grain, the individual particles being barely discernible even under the microscope. The black color is due to finely divided carbonaceous material. Fine-grained quartz and delicate shreds of brown mica are the principal constituents. Slate is not exposed in contact with the granite, but from several hundred feet to 1,000 feet west of the exposed granite contact the slate is altered to a very dense, compact brown mass which has lost its original platy character. It is very faintly banded and resembles some fine-grained rhyolites. The minerals are slightly coarser than in the unaltered slate, and the carbonaceous material has been aggregated into tiny rodlike brown masses.

LIMESTONE.

On the west side of the head of the Mint River valley about 100 feet of thin-bedded basal limestone with black shaly graphitic partings is exposed in a number of places. Similar basal beds of black shaly limestone are exposed in the valley northwest of the highest peak of Brooks Mountain. West of the Mint River valley these basal limestones are overlain by at least 900 feet of thin-bedded gray limestone with brown shaly partings. The gray limestone in turn is covered by an unknown thickness of pure gray granular limestone in beds averaging about 3 feet in thickness.

At the south end of Brooks Mountain the limestone in contact with the granite is mostly of the pure gray type. About 400 feet west of the exposed contact with the granite it has been changed into a very coarse white marble traversed by seams of greenish silicates, which have replaced the calcite. The minerals replacing the calcite consist chiefly of a yellowish-green boron-bearing vesuvianite and a monoclinic pyroxene, usually diopside near the contact and either augite or hedenbergite farther away. The minerals known to replace the limestone near the granite contact include vesuvianite, diopside, grossularite, augite, hedenbergite, phlogopite, and fluorite. Of minor importance are scapolite, tourmaline, hulsite, paigeite, ludwigite, galena, pyrrhotite, black sphalerite, and chondrodite. The occurrences of lead are described in more detail on pages 86–87.

North of the white marble the limestone adjacent to the granite is of the thin-bedded type interlayered with shale. Along the crest, in the vicinity of the highest peak of the mountain and westward for about half a mile, this limestone has been converted into an exceedingly fine grained mass resembling chert. Microscopic examination of this material shows that the calcite has nearly all disappeared and has been replaced chiefly by thin layers of vesuvianite and colorless pyroxene alternating with grossularite. Farther west the original calcitic layers still remain, but they have become coarser in grain and the shaly layers have undergone a recrystallization. Weathering emphasizes the shaly layers and gives the rock the same appearance as that of the "reef" north of the tin prospect on Cassiterite Creek.

GRANITE.

The granite area of Brooks Mountain is elliptical, extending about 2½ miles from north to south and about 1 mile from east to west. Except along the southern part of the mountain, all of the granite area lies on the east slope.

The granite contact dips less steeply toward the west than toward the east, as is indicated by the great width of the area of contact-metamorphic limestone west of the granite. That the eastern surface of the granite is very steep is shown by exposures along the northeast side of the granite area and by the narrowness of the zone of altered limestone on this side of the mountain.

Away from the border the granite consists mainly of very coarse crystals of orthoclase averaging about 1½ inches in length, which constitute about three-fourths of the volume of the rock. Between the orthoclase crystals is a coarse-grained matrix composed chiefly of orthoclase with minor quantities of acidic plagioclase and coarse angular grains of glassy quartz. Within 3 feet of the limestone contact the granite has an even grain of medium size. The minerals are the same as in the interior, except for the presence of small crystals of green hornblende, which takes the place of the biotite. On the weathered surface of the granite occur scattered knots or protuberances about 2 inches in diameter. They have a fine, even grain and consist chiefly of orthoclase with an abundance of the green hornblende that is characteristic of the border. Two generations of quartz are present in these knobs. One with hexagonal outline is older than all other minerals; the other lacks crystal outline and was the last mineral to crystallize.

The granite shows no visible evidence of having been affected by hot solutions after it had solidified. Samples taken within a few inches of the border show the secondary development of fine microscopic needles of green tourmaline, which penetrate the feldspars. These needles are probably related in origin to the tourmaline found in the altered limestone adjacent to the granite. Chemical decay of the granite by weathering is almost entirely absent. As previously noted, the granite disintegrates into a coarse rubble in which all the original minerals are present.

PROSPECTS.

READ LEAD PROSPECT.

On the Read claims, near the contact of the granite and limestone on the southwest slope of Brooks Mountain, at the head of the first east branch of Mint River, are several shallow trenches and a shaft about 20 feet deep. When they were examined in 1918 slope wash had covered the exposures in these openings, and the only clue as to the character of the rock and mineralization was obtained from samples on the dumps. Knopf, who examined this prospect in 1918, says that a trench 20 feet from the granite contact disclosed an ore body 3½ feet wide, striking N. 15° W. and dipping 60° E., into the granite. He reports that assays made of this ore in Nome ran 34 per cent of lead and 11 ounces of silves to the ton, and that several other assays are said to have shown results ranging from $17 to $44 to the ton.

The ore on the dump consists of pyrrhotite intergrown with galena in small irregular lenticular masses about 0.4 inch in length. In places galena of the same character is embedded in a black opaque sphalerite, which has been reported to contain 19 per cent of ferrous iron. The gangue of this ore consists of calcite replaced by vesuvianite, diopside, phlogopite, tourmaline, and fluorite. Fluorite is intimately associated with the sulphides.

Several hundred feet down the slope from these prospects a small trench cuts through a mass of altered limestone in which Knopf discovered the mineral hulsite, a previously unknown compound of tin and boron.

LUTHER LEAD PROSPECT.

Across the divide from the first east branch of Mint River, at an elevation of about 2,000 feet, there is a lead prospect consisting of one trench 30 feet long, 12 feet deep, and 10 feet wide on a claim owned by W. B. Luther. It is 20 feet north of the limestone and granite contact. Within 4 feet of the granite the limestone has been converted to a yellowish-green hard granular mass, consisting chiefly of vesuvianite. At 20 feet beyond this point it is changed to a white granular marble, traversed by seams of green minerals similar to those which replace the calcite at the contact. At the north end of the trench the limestone has been replaced by the green silicates along a fissure striking north and dipping steeply east. The minerals replacing the limestone include tourmaline in black columns several inches in length and vesuvianite. Vuglike openings in the mass of metamorphic minerals show an occasional cube of galena one-sixteenth of an inch in diameter.

Descriptions of several other small prospects in the vicinity of the granite contact are given in Knopf's report, already cited.

MINERALIZING SOLUTIONS.

That the alteration of the limestone was effected by gases or solutions or both is shown by the fact that they followed fissures which traverse the limestone. From a comparison of the original minerals of the limestones with those deposited by the solutions it is concluded that the solutions introduced fluorine, boron, chlorine, lead, copper, zinc, sulphur, and tin into the limestone. They also carried silica, alumina, magnesium, and iron. From the limestone they removed carbon dioxide in very large quantities. Pure limestone was almost completely replaced by silicates. Impure limestone some distance from the granite lost carbon dioxide, and the materials remaining underwent a recrystallization, probably with very little introduction of material. Such are the hard, finely banded chertlike phases of the altered limestone.

It is not proved that these solutions traveled through the granite mass now exposed, for the granite so far as known shows no changes that such solutions might have effected. It is conceivable that they passed through when the granite was unfavorable for interaction with the solutions. The border of the granite shows a faint introduction of tourmaline in the form of fine needles penetrating the feldspars. It is also along the contact that the limestone is most altered. The alteration is not due to an interaction of the granite with the limestone, for the granite contact has the sharpness of a knife-edge, but to the intense action of the solutions. To judge by results the solutions were most effective in causing deposition and replacement along the granite and limestone contact, and this may have been the principal path along which they moved.

Some of the constituents which the solutions carried, namely, fluorine, chlorine, and the metals, are so foreign to the content of ordinary surface solutions that they are believed to have been released in hot solutions from the granite during the process of cooling.

PROBABILITY OF FINDING TIN AND OTHER MINERALS IN COMMERCIAL QUANTITIES AT BROOKS MOUNTAIN.

Studies made at Brooks Mountain do not warrant the hope that tin or other ores will be found in commercial quantity. This conclusion, however, can not be regarded as final. The chances of finding ore in the granite are the poorest. Wherever studied the granite shows no visible alteration. It would be useless to undertake underground prospecting on the granite unless places were found where a considerable body of it shows alterations of a character similar to those which have affected the tin-bearing dikes in the vicinity of Cassiterite Creek. It is important to bear in mind that such places would not be easily recognized. Because of the softness of the altered rock it would be eroded rapidly and thus underlie depressions that would be easily covered by slope wash of fresh granite.

Mineralized portions in the limestone area therefore bear a relation to the surface generally the reverse of that shown by the mineralized granite. Because of their relative hardness silicates, such as vesuvianite, tourmaline, and others characteristic of the metamorphosed limestone, tend to stand out on the weathered surface and are therefore easily discovered. It is probable that nearly all mineralized areas of the present limestone surface have been seen. Such deposits in the limestone are found only near the granite contact or adjacent to fissures that extend near the contact. They have an irregular shape, and it is possible that some of those now exposed are larger farther down. The proportions of mineralized rock and limestone at the present surface, however, are very probably similar to those found at greater depths. They are more likely to be large where the granite and limestone contact has a gentle dip, as on the west side of Brooks Mountain, than where it is steep.

POTATO MOUNTAIN.

GEOGRAPHIC FEATURES.

About two-thirds of the tin produced in North America has come from the Potato Mountain area, where, thus far, the Buck Creek placers have been the chief source of ore.

The Potato Mountain area is a part of the slate belt, which is characterized by a mild relief of 200 to 600 feet and great expanses of tundra-covered hills. The topography is in marked contrast with the rugged limestone ridges, 2,000 to 2,500 feet high, that form the York Mountains, to the east. (See Pl. I and fig. 4.) As a rule, the areas of accentuated relief in the slate belt can be accounted for by the presence of pre-Ordovician basalt or gabbro, or locally other igneous intrusive rocks. Potato Mountain, which consists of four rather well defined knolls from 1,200 to 1,400 feet high, alined in a northeasterly direction and extending for a distance of about 2 miles, is the highest prominence of the slate belt and rises near its northern extremity. Potato Mountain is due partly to granite porphyry dikes which intrude the slate, and partly to numerous quartz veins that cut the mountain mass in all directions, thereby increasing its resistance to erosion. The porphyry dike strikes northeast and coincides with the trend of the mountain mass. It is not everywhere exposed, being in part concealed by talus on the mountain slope, and in part not yet revealed by erosion. The relation of intrusive dike overlain by slate is well shown in an excavation on the northeast slope of the next most northerly mound, where the slates are exposed arching above the dike rock.

ROCKS.

The slate of the Potato Mountain area is fine textured, is sandy to calcareous, and ranges in degree of metamorphism from shalelike to well-cleaved varieties. It is interbedded with a few strata of yellowish fine-grained sandstone, bluish clayey sandstone, and sandy limestone a few inches in thickness. The beds dip in general at a low angle toward the east.

Intruding the slate is a quartz porphyry dike, already referred to as having in part caused the mountain mass. Ramifying quartz veins which range in width from a few inches to a fraction of an inch are to be seen almost everywhere on the area and in some places form a stockwork. One quartz ledge is traceable for several miles. It cuts Sutter Creek at the mouth and extends up Buck Creek to West Fork, where it swings almost due north. No other acidic rocks were observed in the district. Pre-Ordovician basalts and gabbros do not occur in the immediate vicinity of Potato Mountain.

ECONOMIC GEOLOGY.

The occurrence of cassiterite in the rocks of the Potato Mountain area is not commonly observed. A study of the placer concentrates, however, shows that it is found in at least two associations, namely. with quartz and with porphyry. Knopf[26] also reports it to occur "intergrown with arsenopyrite in a gangue of radial actinolite." No deposit of lode tin in commercial quantity has yet been discovered in the area.

Quartz carrying cassiterite is present chiefly as stringers, a fraction of an inch to several inches in width, in the slate. Some of these stringers evidently carry gold, as gold is present in small

[26] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, p. 33, 1908.

quantities in the placers of Buck Creek. The only porphyry observed in the area which might be a source of cassiterite is the large dike referred to as cutting the mounds. No cassiterite, however, was observed in the specimens examined.

Numerous attempts have been made to locate the source of the tin ore. Prospecting has been confined to Potato Mountain and the country adjacent to it. Thus far the attempts have met with but little success, and no promising lode has been uncovered. There is, however, good reason to consider Potato Mountain as the probable source of the placer tin, because (1) cassiterite nuggets as much as several pounds in weight have been picked up on the mountain, (2) quartz veins cutting the slate locally show cassiterite crystals, (3) the stream placers are limited to those streams that head in the mountain, and the coarseness and angularity of the tin decrease with distance from the mountain, (4) placer tin from the headwaters of the creeks shows attached particles of porphyry and quartz, whereas in that from the lower parts of the creeks most of the crystals are clean or attached to bits of quartz only.

LODE DEVELOPMENTS.

A quartz ledge, traceable for several miles, crosses Sutter Creek near the mouth, occurs in the bed of Buck Creek, and at West Fork leaves the stream to continue northward with a strike of N. 10° E. The ledge is in places as much as 100 feet wide. It has the appearance of felsite rock including numerous shale particles. Microscopic examination shows it to consist chiefly of well-developed quartz crystals arranged in radial and coxcomb structure about nuclei of shale. It represents a filled fissure reopened by repeated movement along the fracture zone so that small particles of shale from the vein wall adhered to the vein filling and upon further introduction of vein material became incorporated in the quartz mass.

Numerous prospect pits have been sunk at different points along the outcrop of the vein, and assays are said to have been made. No tin or other mineral of economic value was observed, and the assays are reported to have been unfavorable.

At the head of Buck Creek, on the divide between Peluk and Fox creeks, are several shallow prospect trenches on the Red Fox claim. One trench exposes what appears to be either a vein or decomposed dike rock about 6 inches thick dipping 35° W. and striking north and east. The beds of slate inclosing it dip at a low angle toward the north. The dike rock has the appearance of a limestone, and microscopic examination shows it to consist of calcite with a little quartz and to be cut by veinlets of serpentine (chrysotile) inclosing a sprinkling of sulphide crystals. The mineralization is scanty, and the total sulphides form but a fraction of 1 per cent of the rock. The rock is sheared and fractured and is seamed with veinlets of calcite.

At 150 paces north of the Red Fox claim there is a shaft (figure 14) which was filled with water at the time of visit but was reported to be 30 to 40 feet deep. The material on the dump is black slate cut by quartz stringers a quarter of an inch in width and a little rust-

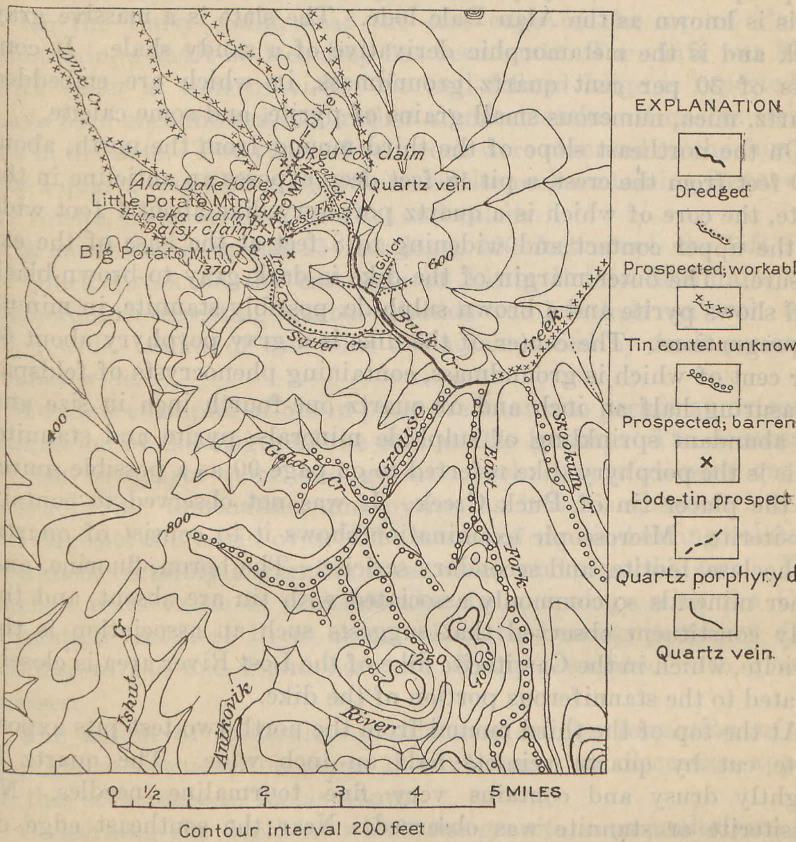


FIGURE 14.—Sketch map of Potato Mountain area, showing tin claims and prospects.

covered quartz showing drusy cavities containing pyrite crystals and stannite in quantities of a fraction of 1 per cent of the rock.

On the dump of an east-west trench 20 feet long and 10 feet deep, 150 paces northwest of the shaft, some pyritiferous quartz but no other mineralized rock was observed.

Débris of a fine-grained massive dacite showing considerable sulphide mineralization occurs on the mound just southeast of the Fox Creek divide. The rock contains plagioclase feldspar, quartz, mica, and pyrite in a groundmass consisting chiefly of feldspar and shows considerable secondary calcite. On the southeast slope of this mound a prospect trench exposes light-gray porphyry débris, with phenocrysts of rectangular feldspar 1 inch in length and quartz phenocrysts a quarter of an inch in diameter. About 80 per cent of the rock is dense, compact groundmass. Some pyrite cubes and tourmaline druses were the only evidences of mineralization observed.

At 160 paces farther down the slope to the southeast a pit 15 feet deep exposes slate cut by quartz stringers of an average size of 1 inch. This is known as the Alan Dale lode. The slate is a massive gray rock and is the metamorphic derivative of a sandy shale. It consists of 30 per cent quartz groundmass, in which are embedded quartz, mica, numerous small grains of pyrite, and some calcite.

On the northeast slope of the third mound from the north, about 100 feet from the crest, a pit 18 feet deep exposes an anticline in the slate, the core of which is a quartz porphyry dike about 1 foot wide at the upper contact and widening to 8 feet at the base of the exposure. The outer margin of the dike is dark gray to brown-black and shows pyrite and a brown sulphide, possibly stannite, in minute impregnations. The center of the dike is a gray porphyry about 60 per cent of which is groundmass, containing phenocrysts of feldspar measuring half an inch and of quartz one-fourth inch in size and an abundant sprinkling of sulphide minerals, pyrite and stannite. This is the porphyry dike referred to on page 90 as a possible source of the placer tin of Buck Creek. It was not observed to contain cassiterite. Microscopic examination shows it to consist of quartz, orthoclase, biotite, and secondary sericite. The boron, fluorine, and other minerals so commonly associated with tin are absent, and the only constituent observed that suggests such an association is the sericite, which in the Cassiterite dike of the Lost River area is closely related to the stanniferous portion of the dike.

At the top of the third mound from the north two test pits expose slate cut by quartz veinlets half an inch wide. The quartz is slightly drusy and contains very fine tourmaline needles. No cassiterite or stannite was observed. Near the southeast edge of the mound six or more pits show slate breccia with fragments 4 to 8 inches in size cemented by quartz. The quartz is rusty and drusy and contains tourmaline needles. No other evidence of mineralization was observed.

In the saddle to the south of the third mound from the north a trench 100 feet long exposes a banded slate cut by quartz stringers which contain tourmaline and some slight showing of sulphides.

On the top of Little Potato Mountain a shaft 9 feet deep on the Eureka claim exposes quartz containing crystals of resinous cassiterite and tourmaline in drusy cavities. About 1 ton of ore is reported to have been taken from this shaft to York. The slate at this locality is generally cut by quartz stringers several inches in width which carry sulphides. Melanterite, a white to greenish sulphate of iron, occurs as an incrustation of some rock surfaces in this locality. Microscopic examination shows that the quartz and tin ore occur in distinct bands associated with tourmaline and arsenopyrite, the tourmaline crystals penetrating both the quartz and the cassiterite crystals.

On the Daisy claim, near the east edge of the top of Potato Mountain, a shaft 25 feet deep has been sunk. The shaft was filled with water at time of visit. No well-defined ledge is reported to have been encountered, but rather a concentration of quartz stringers in the slate. Two types of vein rock were observed on the dump—one a quartz vein filling, the other a zoisite rock containing 85 per cent of zoisite, hedenbergite, fluorite, and calcite.

A north-south tunnel 25 feet long, 100 feet above the left fork of Buck Creek on the east side of Little Potato Mountain, cuts numerous intersecting quartz-sulphide veinlets half an inch to 1 inch wide. Some of the veins are accompanied by fault gouge 10 inches wide.

Too few examples of ore in place are known to permit an extended discussion of the origin of the ores at this locality. The occurrence of tin in quartz veins and granitic rock associated with quartz, arsenopyrite, tourmaline, and pyrite, as here, is characteristic of tin deposits the world over. The source of the tin-bearing solutions is almost certainly a granitic mass which underlies the area. That such a mass exists is probable also from analogy with the Cape Mountain and Lost River areas, where tin-bearing porphyry dikes similar to the one found here are closely associated with granite masses.

The action of mineralizing solutions in the formation of tin deposits is discussed on pages 123–124, and that discussion applies to this occurrence so far as known.

Concerning the depth at which the granite mass underlying the area occurs figures in feet or hundreds of feet can not be given. However, from outcrops of the dike overlain by slate it is certain that only the upper parts of the dike have been exposed at this point. Further evidence of the marginal position of these exposures with respect to the source of mineralization lies in the association of the tin minerals with quartz. This position is analogous to that of the quartz-cassiterite occurrence in the Cassiterite Creek area, where the quartz-cassiterite veins of the Ida Bell dike extend farther from the center of mineralization than any other combination of cassiterite-bearing minerals.

It is certain that the porphyry has been mineralized by tin-bearing solutions, as the association of cassiterite and porphyry in pieces of float has been observed. It is equally obvious from examination of the outcrop that cassiterite is not uniformly distributed throughout the dike.

As exposures are few and poor, prospecting can perhaps best be directed by considering the occurrence as analogous with other better-known occurrences in the York region. At Lost River the mineralized porphyry is in the form of an ore shoot and consequently fails to persist along the outcrop. In that portion of the dike which has been acted upon by tin-bearing solutions the feldspar constituent, especially, has suffered alteration (sericitization), as a result of which the rock is softened and made more susceptible to decay when exposed to the air.

To apply the same principle to Potato Mountain, the most favorable place to prospect would seem to be the saddles between the mounds, it being borne in mind, however, that the upper contact of a dike is likely to be irregular and the saddles may be due to a low point on the dike, as well as to difference in its resistance to erosion as just outlined.

The Iron Creek placers show cassiterite associated with porphyry, and the creek heads between Big Potato and Little Potato mountains. If further work is contemplated in that vicinity the porphyry dike should be sought for and explored in depth.

TIN PLACERS.

Cassiterite was identified in the gravels of Buhner Creek by Alfred H. Brooks in 1900. In the course of prospecting for gold on Buck Creek some mineral, thought by the miners to be iron, had been found. By comparison with material from Buhner Creek it proved to be cassiterite. Buck Creek has since that time been the chief source of tin on Seward Peninsula. From 1900 to 1911 mining was done on the creek by hand and automatic scraper. About 324 tons of tin ore averaging about 50 per cent of metallic tin was recovered in this way. In 1911 the York Dredging Co., and in 1915 the American Tin Mining Co. installed dredges on Buck Creek. Since 1911 all the ore recovered has been won by dredging.

Placer-tin concentrates produced on Buck Creek, 1911–1919, in short tons.

1911	93	1917	146
1912	174	1918	55
1913	60	1919	56
1914	100		1,194
1915	160		
1916	150		

The average assay of dredge concentrates is about 68 per cent of metallic tin. Some gold occurs in the concentrates. In 1912 an average of $32 gold to the ton was reported. An amalgamation barrel is installed on the American Tin Mining Co.'s dredge in which concentrates from the upper 18 feet of riffles are treated.

The accompanying map (fig. 14) shows the distribution of placer ground so far as known. Work thus far has been confined to the streams southeast of Potato Mountain, and the productive ground has not extended much below the mouth of Buck Creek.

The worked placers have shown an average yield of about 8 pounds of concentrates, averaging about 68 per cent of metallic tin to the cubic yard. Smaller creeks in the area have run as high as 21 pounds of concentrates to the cubic yard.

The bedrock is slate. It is very uneven and shows many irregularities in the form of waves or channels parallel to the stream course 18 to 20 inches deep and 3 to 5 feet apart. It is soft and easily dug, and its surface carries most of the tin. The gravels consist of slate with a little quartz. More than 60 per cent of the gravel passes a 2-inch mesh, and nearly all of it is less than a foot in greatest dimension. The average depth of gravel is 5 feet. So little clay is present in the upper creek that the American Tin Mining Co. found difficulty in constructing a dam to retain water for its dredge. Most of the cassiterite occurs as small, slightly rounded crystals, although occasionally nuggets weighing from 1 to 8 pounds are encountered. But little foreign material adheres to the placer tin, as is shown by the high metallic content of the concentrates. Some magnetite and considerable hematite are present in the placers in nodules as much as several pounds in weight.

The York Dredging Co. has worked from Sutter Creek, a tributary of Buck Creek, to the mouth of Buck Creek and down Grouse Creek to East Fork. The tenor of the gravel at this point did not permit further working, so this may be considered the lower limit of the pay ground. The American Tin Mining Co. is dredging on upper Buck Creek, just below West Fork. The average width of gravel dredged on Buck and Grouse creeks is 80 feet, and the average depth of gravel 5 feet.

The ground still remaining to be worked and shown to be dredgeable comprises upper Buck Creek, Left Fork, and Peluk creeks (headwater tributaries of Buck Creek), several small gulches tributary to Buck Creek, and a strip of ground of undetermined width bordering either side of the dredged area on Buck Creek and extending to the mouth. This border area has been drilled and is known to be workable, but it lies below steep tundra-covered banks and the overburden which must be removed by groundsluicing is considerable. It is conservatively estimated that an area equal to about one-fourth the dredged area of Buck Creek and at least as valuable per yard as that area is thus available.

Sutter Creek is reported to be dredgeable above the mouth, and Iron Creek, a small tributary of Sutter Creek, shows high-grade ground adaptable to shoveling in but not to dredging.

Grouse Creek above Buck Creek and below Left Fork contains no tin, or at least too little for mining, so far as known. Skookum Creek, Left Fork, and Mint River are barren of tin.

It is thus evident that according to available data the Buck Creek placers would seem to be about two-thirds exhausted. It is perhaps now time to turn attention to the streams northwest of Potato Mountain which head on its flanks and flow into Lopp Lagoon. Most of these streams are reported to show tin, and several have recently satisfied prospectors as to their dredging possibilities. Plans are said to be under way to install a dredge on these waters in the near future. They have never been extensively prospected, but the result of the work done and their favorable position with reference to Potato Mountain would justify further exploration. These streams will not be so adaptable to easy working as those southeast of the mountain, owing to their low gradient, as they flow for most of their length through the wide tundra flats south of the lagoon. Here groundsluicing may prove impossible, and the tundra will consequently be a handicap. It is even possible that no great concentration has resulted in these streams, owing to their meandering and constantly changing courses in past geologic time.

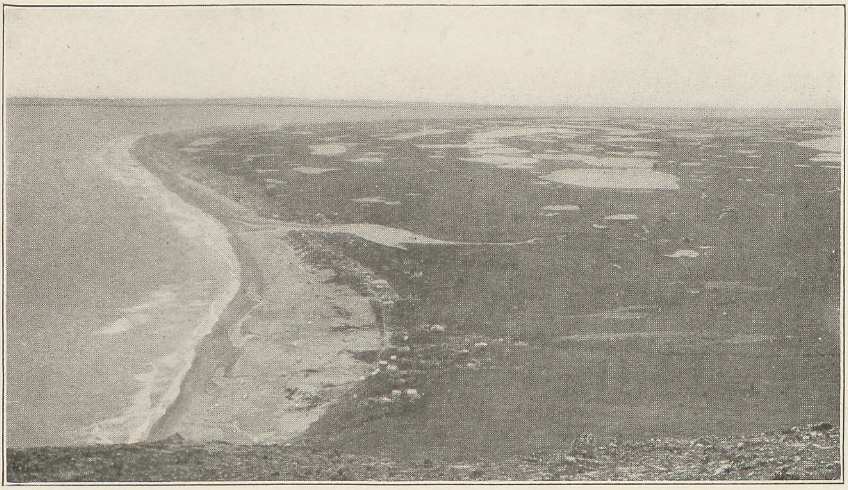
CAPE MOUNTAIN.

GEOGRAPHIC FEATURES.

Cassiterite occurs in association with granite intrusions at Cape Mountain. Although considerable money has been expended here in prospecting, no commercial bodies of ore have been discovered. In 1918 all workings were abandoned and inaccessible, owing to rock falls and the formation of ice. The following notes on the tin ores of Cape Mountain are based mainly on surface examinations of the ledges and materials on the dumps.

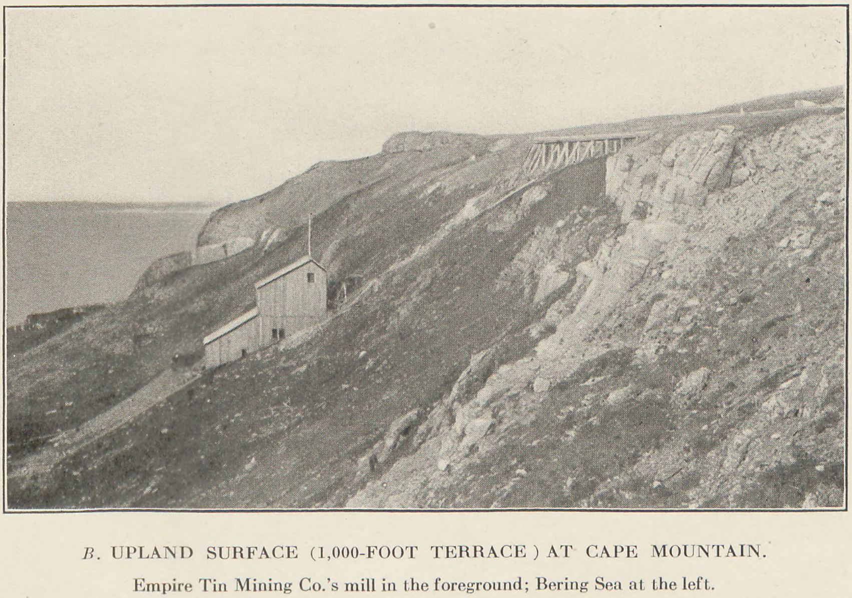
Cape Mountain is at the extreme west end of Seward Peninsula, where the shores of the Arctic Ocean and Bering Sea converge and form Cape Prince of Wales. It is a dome-shaped peak rising out of the sea to an elevation of 2,300 feet from a base nearly 4 miles wide. A narrow terrace flanks the mountain at an elevation of 1,000 feet (Pl. XI, *B*). Above 1,000 feet the slopes are very steep and in places difficult to scale.

The locality can be reached by following the sea beach from York, a distance of 12 miles. A light wagon can be taken over this route



A. ARCTIC COASTAL FLATS, CAPE PRINCE OF WALES, AND KINGEGAN MISSION, FROM CAPE MOUNTAIN.

Bering Strait in the background.



B. UPLAND SURFACE (1,000-FOOT TERRACE) AT CAPE MOUNTAIN.

Empire Tin Mining Co.'s mill in the foreground; Bering Sea at the left.

except during severe south winds. The telephone line that once connected the cape with Nome, 140 miles away, was wrecked by a storm in 1913 and has never been repaired. During the open season gasoline schooners sailing between Nome and Kotzebue Sound, in the Arctic Ocean, pass the cape at intervals of about two weeks and stop on signal. There is no safe landing place near by, and storms and fogs are more common than fair weather.

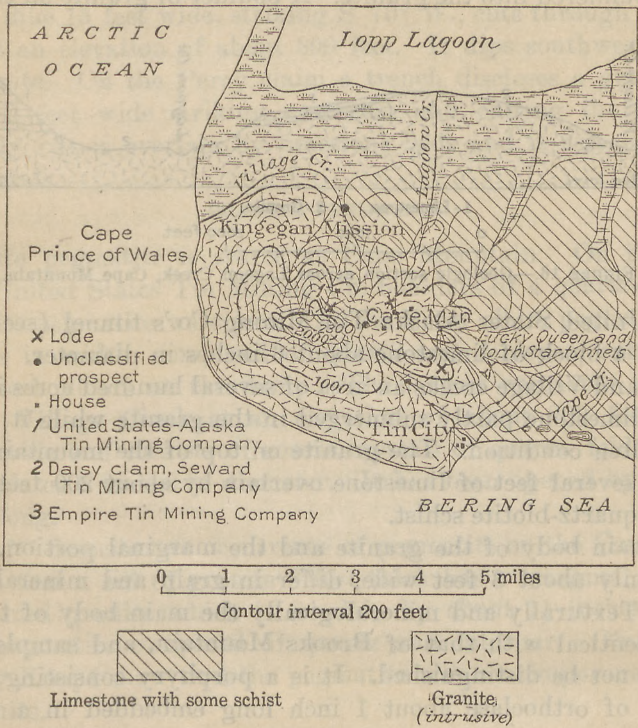


FIGURE 15.—Geologic sketch map of Cape Mountain.

GENERAL GEOLOGY.

SUMMARY.

A large granite intrusion constitutes the core of the mountain. Bordering it on the north and east are limestone beds into which the granite has been intruded. In places portions of the limestone roof, which once covered the granite, still remain. The granite is closely associated with granitic dikes, granitic pegmatites, and quartz veins. Both the limestone and the granite show contact-metamorphic phases. The youngest rock of the area is an intrusion of black olivine porphyry, which in the form of dikes cuts both limestone and granite. (See figs. 15–17.)

GRANITE.

The visible portion of the granite intrusion is a dome-shaped mass about 3 miles in diameter and over 3,000 feet high. The contact surface with the limestone appears to be nearly vertical on the east but dips more gently to the north. It is irregular, the granite having welled upward into the limestone along vertical planes and also between the limestone beds. Occasionally limestone blocks are found which foundered into the granite. A boulder of granite on the dump

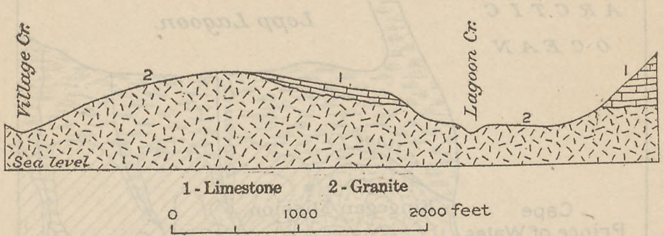


FIGURE 16.—Geologic section across Lagoon Creek, Cape Mountain.

of the United States Alaska Tin Mining Co.'s tunnel (see fig. 15) contains a block of limestone about 6 inches in diameter. Between Lagoon and Village creeks an area of several hundred acres is underlain by limestone partly submerged in the granite while it was still in a molten condition. The granite on top of the mountain is covered by several feet of limestone overlain by about 200 feet of fine-grained quartz-biotite schist.

The main body of the granite and the marginal portion, in most places only about 3 feet wide, differ in grain and mineral composition. Texturally and mineralogically the main body of the granite is identical with that of Brooks Mountain, and samples of the two can not be distinguished. It is a porphyry consisting of large crystals of orthoclase about 1 inch long embedded in a medium-

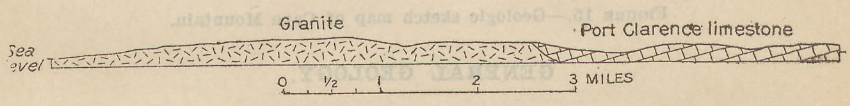


FIGURE 17.—East-west section through Cape Mountain. (See fig. 15.)

grained matrix of orthoclase, sodic plagioclase, angular crystals of smoky quartz, and minute flakes of brown biotite.

The grain of the marginal portion is uniform and generally of medium size. Feldspar is very prominent, and biotite appears to be absent. In this respect also the granite of Cape Mountain resembles that of Brooks Mountain.

Dikes and sills of granite several feet in width appear to be very common along the margin of the granite and represent offshoots from the granite mass. In grain and composition they resemble the marginal portion of the granite. As a rule they have minute irregular openings lined with druses of quartz and tourmaline and locally plates of muscovite mica. On Village Creek, at an elevation of about 600 feet above the sea, below the confluence of the small streams that constitute the head of the creek, a vertical granite dike 2 feet wide, striking N. 60° W., cuts through the limestone. It is full of druses of tourmaline and muscovite. On the road between the sea and the tunnels of the Empire Tin Milling Co, a granite dike 15 feet wide, striking S. 70° W., cuts through the limestone at an elevation of about 800 feet. It dips southwest, toward the granite. On the Percy claim a trench discloses a granite dike about 10 feet wide striking northeast and cutting the limestone vertically. It is overlain by limestone beds and is associated with tin minerals.

GRANITE PEGMATITE.

Granite pegmatite is scarce at Cape Mountain. On the dump of the United States Tin Mining Co. boulders of a quartz-feldspar-muscovite pegmatite were seen. At the Percy claim pegmatite veins 2 inches in width, composed of quartz and feldspar, cut through limestone boulders on the dump. The largest pegmatite dike seen was on Village Creek at an elevation of about 200 feet. It is 10 feet wide and consists of coarse crystals of quartz, feldspar, and biotite plates 5 inches in diameter. It has been opened by a tunnel 15 feet long.

Knopf[27] describes an occurrence of pegmatite on the Canoe claim. He says that a sill of granite 8 feet thick has a marginal phase of fine-grained granite which is overlain by about 1½ inches of very coarse pegmatite composed of quartz and feldspar. Observations made by Knopf show that the pegmatite was contemporaneous with the granite.

QUARTZ VEINS.

Tin-bearing quartz veins, so far as known, occur only in the granite. In both granite and limestone quartz veins are scarce. Pieces of quartz-vein material were found on the dump of the Empire Tin Mining Co.'s workings. At the tunnel of the United States Alaska Tin Mining Co., on the north slope of Cape Mountain, at an elevation of 1,850 feet, a quartz vein bearing N. 45° W. (magnetic) is said by Knopf to cut the granite. He reports that secondary quartz, tourmaline, and sericite occur in the granite adjacent to this vein. In 1918 a boulder of vein quartz containing several crystals of yellowish-brown cassiterite about half an inch in diameter was found on the dump of the tunnel, the only cassiterite seen at this place.

[27] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, p. 37, 1908.

At only one other place was vein quartz observed, namely, on the road between the sea and the Empire Tin Mining Co.'s workings. Here at an elevation of about 1,000 feet a 2-inch quartz vein cuts through the limestone and dips southwest.

LIMESTONE.

The limestone at Cape Mountain is composed chiefly of calcite, with some admixture of quartz. In color it is generally white to bluish gray. Beds of quartz sand, now changed to quartzite, averaging about 5 inches in thickness, occur at intervals of about 15 or 20 feet. On top of Cape Mountain the limestone is overlain by a fine-grained quartz-biotite schist about 200 feet thick, which appears to be conformable with the limestone.

East of the granite contact the limestone beds dip toward the granite at an angle of about 15°. Between Lagoon and Barluk creeks they dip east. North of the granite intrusion they dip north, away from the granite. It does not appear that the intrusion of the granite has produced the present attitude of the limestone beds.

The changes which the limestone has suffered because of the intrusion of the granite fall into two classes—those which involve the introduction of materials and those which do not. The changes which do not involve the introduction of materials are as follows: Near the contact the limestone has been changed into a very coarse white marble, in which calcite grains half an inch in diameter are common. The quartz sand associated with the limestone has been changed into a dense white quartzite by the recrystallization of the quartz grains. Wollastonite was commonly formed by a reaction between the calcite and the quartz grains, and locally the quartz beds have been changed completely into wollastonite. The change from calcite and quartz to wollastonite involves the loss of carbon dioxide from the calcite and the combination of the lime and silica.

Close to the contact the limestone was locally invaded by hot tin-bearing solutions which converted it into a heavy medium to coarse-grained rock. The altered zones appear to have a maximum width of only a few feet and are found immediately adjacent to the granite and along fissures that cut the limestone in the vicinity of the granite. This altered limestone was seen in place only at the Percy claim. (See fig. 15.) Here narrow seams of green secondary minerals, a few inches wide, lie adjacent to a dike and also cut through the limestone. The principal minerals of this green rock are green pyroxene and green tourmaline. Minor constituents are pyrite, pyrrhotite, fluorite, scapolite, accessory sphalerite, quartz, and cassiterite. About 15 tons of tin-bearing altered limestone lies on the dump of the Percy claim. The cassiterite is yellowish brown, fine grained, and irregularly distributed through the rock. Some of the boulders are very rich in cassiterite. It was impossible to enter the tunnel from which this rock came, and hence statements as to its extent underground can not be made.

ALTERATION OF THE GRANITE BY TIN-BEARING SOLUTIONS.

The tin-bearing solutions that altered the limestone along the granite contact have also affected the border portion of the granite itself. On one of the dumps of the Empire Tin Mining Co.'s workings samples of granite were found showing a local fracturing along which minute seams of cassiterite and tourmaline had been introduced. They formed a cement and also replaced the feldspars. Pyrite, in minute scattered grains, accompanied the cassiterite and tourmaline. Knopf reports that in tunnel No. 2, called the North Star tunnel, a fractured zone of granite 18 inches wide showing visible amounts of both cassiterite and tourmaline occurs at 270 feet from the portal.

Granite dike materials thrown out on the dump of the Percy claim showed tourmaline, sulphides, and sericite. No visible cassiterite was noted.

SUMMARY OF OCCURRENCE OF TIN AT CAPE MOUNTAIN.

Tin, in the form of cassiterite, is known to occur as a constituent of quartz veins, as a replacement of limestone near the granite contact, and in granite near the limestone contact. The principal associates of the tin are tourmaline and pyrite. It is impossible to state whether any of these occurences will yield tin in commercial quantities. In view of the excellent exposures on Cape Mountain, it would seem that if quartz veins of considerable magnitude were present they could easily be discovered, because such veins would form strong outcrops, and, therefore, because of the scarcity of quartz-vein material on the surface it is improbable that large deposits of vein quartz occur on Cape Mountain.

Large deposits of tin in the limestone would also tend to form conspicuous outcrops on the surface. The cassiterite and the minerals associated with it in the contact limestone resist weathering much better than the unaltered limestone; hence weathering brings such deposits into relief. The lack of such outcrops suggests a lack of notable deposits of this kind at the present surface. It is possible that in places they may have been covered by slope wash. Such replacement deposits are very irregular in form, and the lack of them at the surface does not preclude the possibility that valuable deposits of this kind may exist at depths along the granite contact. It is more probable that large deposits of this type would occur where the contact plane between the granite and limestone has a gentle dip than where it dips steeply. The chances of finding such deposits are, therefore, better underneath the limestone north of the granite than along the eastern border.

Altered marginal phases of tin-bearing granite are weak materials, owing to the development of sericite and sulphides, and do not tend to form conspicuous exposures. They are easily covered up by slope wash and are not readily found. It is impossible to estimate the extent of the deposits of this marginal type.

DEVELOPMENTS.

Facts previously published regarding the developments at Cape Mountain indicate that the Empire Tin Mining Co. has three tunnels on the east side of the mountain at an elevation of about 1,200 feet. Of these tunnels, No. 2 is the longest, its drifts and winzes aggregating 750 feet in length. This company also has a 5-stamp mill at the beach, a barn, a 7-room house, a blacksmith shop, and several minor buildings.

The United States Alaska Tin Mining Co. has a shaft 22 feet deep and a 7-foot tunnel trending S. 40° W. for 270 feet on the north side of Cape Mountain, at an elevation of 1,650 feet. On the beach the company has a 10-stamp mill, which has never been operated.

On the Percy claim is a tunnel probably less than 100 feet long, a shaft about 15 feet deep, and several trenches.

PRODUCTION OF TIN ORE.[28]

Concentrates amounting to 10 tons are reported to have been shipped from Cape Mountain. These were produced by the Empire Tin Mining Co. (formerly the Bartels Tin Mining Co.) in 1906.

PLACER TIN.

It is reported that a small amount of placer tin was discovered on Tin City Creek in 1918. The extent of this deposit is unknown, but probably it is unimportant, because of the small size of the stream.

EAR MOUNTAIN.

GEOGRAPHIC FEATURES.

Ear Mountain is 50 miles north of Teller and 15 miles south of Shishmaref Inlet. It can be reached from Teller by three or four days' travel over trails that are usually passable for pack horses in the summer. In dry weather wagons have gone over the trail. For

[28] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, p. 407, 1913.

the last 20 miles the trail runs mostly over tundra. Travel from Shishmaref Inlet to Ear Mountain is almost as difficult. The inlet is very shallow and is navigated only by light dories and Eskimo skin boats.

Ear Mountain is isolated, like Cape Mountain. It rises from a base about 4 miles in diameter to a height of about 2,300 feet. Above 1,000 feet the slopes steepen. The mountain culminates in three peaks or mounds of which the one farthest southwest is the highest, standing about 2,300 feet above sea level. Most of the mountain is underlain by granite, the surface of which is covered with a rubble of frost-broken rock and dotted with towers of granite 50 to 100 feet high. Here, as at Brooks Mountain, the development of these towers is controlled by fissures. From two such towers which rise from the south side of the central peak and which from a distance have the appearance of two huge ears the mountain receives it name.

The country surrounding Ear Mountain is a low, gently rolling plateau from 600 to 800 feet high, cut by numerous stream valleys. Nearly all of it is covered with a brown peat bog. Low willows grow along the valleys, and in summer horses can be foraged along the small streams.

GENERAL GEOLOGY.

SUMMARY.

The rocks that underlie Ear Mountain include dark quartz-biotite schist intruded by gabbro and thin-bedded limestone with shaly partings. Both schist and limestone dip northward at angles ranging from 15° to 45° and are intruded by a dome-shaped granite mass, steep sided on the south, east, and west but dipping more gently on the north. (See figs. 18 and 19.)

At the granite contact certain contact-metamorphic changes have affected both the schist and the limestone and locally the granite itself. These changes consisted in the expulsion of water and carbon dioxide from the limestone and the recrystallization of the materials remaining into heavy lime-bearing silicates. Locally this contact metamorphism has also involved the introduction of new materials by solutions. Some of the constituents of these solutions were derived from the granite intrusions, namely, boron, fluorine, chlorine, tin, lead, copper, and sulphur. These materials were introduced chiefly into the limestone but locally also into the border portions of the granite.

After the intrusion of the granite and the development of the contact alterations, erosion by streams carved this mountain from the rocks of the region, thus laying bare the granite and its associated materials. The relative resistance to erosion of the granite and of the contact-metamorphic rocks bordering it has caused them to be-brought into relief. Frost action has been the chief process by which materials were prepared for steam transportation. The streams

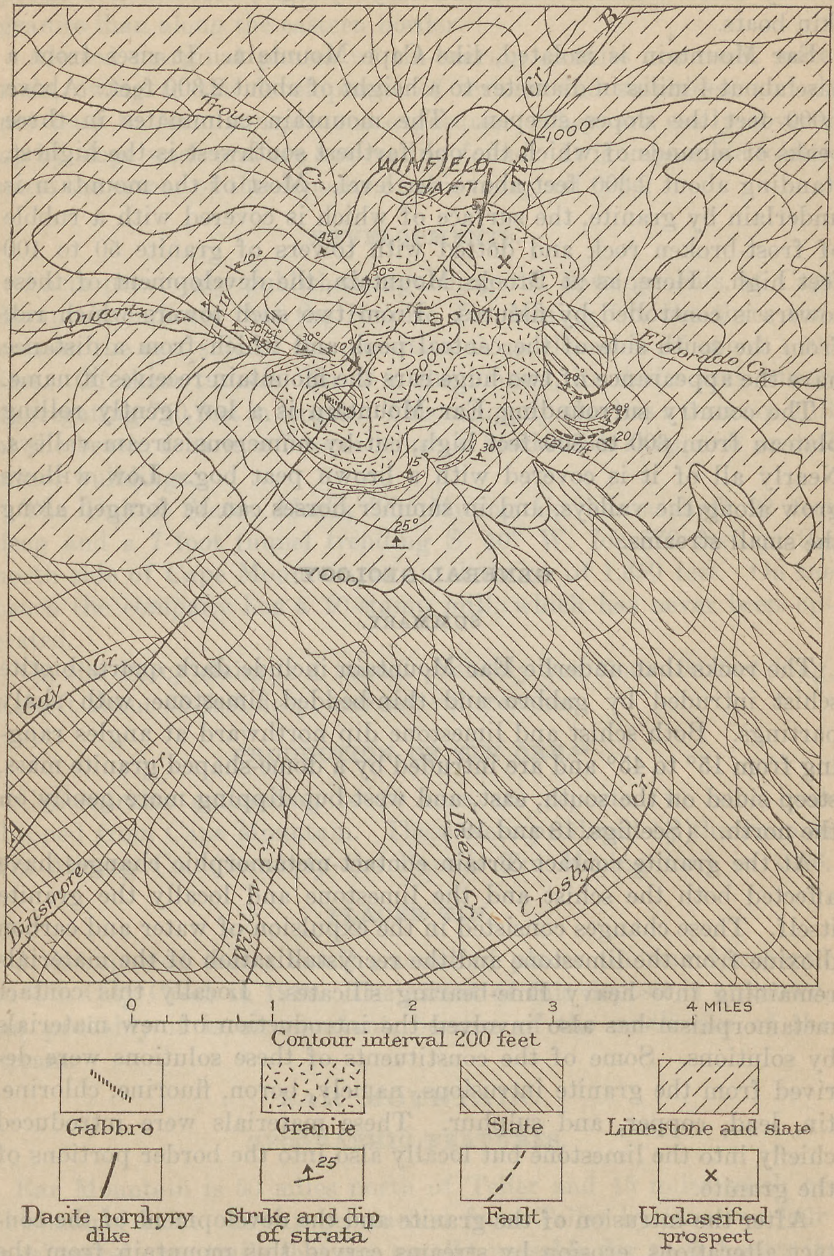


FIGURE 18.—Geologic sketch map of Ear Mountain. *A–B*, line of section, figure 19.

flowing from the mountain have produced a slight concentration of the tin as stream placers.

QUARTZ-MICA SCHIST AND ASSOCIATED BASIC INTRUSIVE ROCKS.

The quartz-mica schist is a dark graphitic rock, composed chiefly of very fine grained quartz of irregular outline and minute shreds of brown biotite mica. The mica plates have a parallel arrangement and occur in very thin wavy bands. As a rule the bedding is indistinct, but a faint banding due to alternation of mica and quartz layers is very common.

On the east mound of Ear Mountain the quartz-mica schist underlies nearly all of the north slope and appears to alternate with limestone on the south slope. The position of the schist beds on the south slope is indicated by débris except at one outcrop in which the schist beds dip 30° SW., a direction almost opposite to that of the limestone beds near by.

The schist also underlies the top of the highest peak of Ear Mountain. Here it is not in contact with the limestone but has been intruded by the granite.

Alternations of schist and limestone are found in the bed of Quartz Creek. The relations of these schist beds to the limestone is not clear

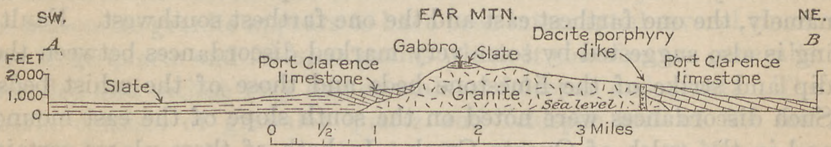


FIGURE 19.—Section through Ear Mountain along line A–B, figure 18.

in all places. Some of them are overlain by limestone beds having the same strike and dip as the schist. In other places the schists dip much more steeply than the limestones, which everywhere dip about 30° N. Near the end of the Quartz Creek canyon, at an elevation of 900 feet, beds of black graphitic schist striking nearly north are inclined steeply to the west. In dip and strike this outcrop is clearly discordant with that of the limestone beds in this vicinity.

The schist on top of the highest peak of Ear Mountain is intruded by a vertical dike of basalt 15 feet wide, trending N. 50° W. This dike can be traced to a more massive basic intrusion about 100 feet wide on the northwest side of the peak. On microscopic examination the rock of the larger mass is found to be a slightly schistose altered gabbro. A faint schistosity is also visible in the hand specimen. The mineral constituents are limy plagioclase embedded in a matrix of hornblende which incloses numerous small grains of magnetite. The hornblende shows a tendency toward parallelism and probably is an alteration product of augite or a similar pyroxene.

The relation of the quartz-mica schist of Ear Mountain to the black slate of the York area is uncertain. Several facts, however, suggest

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that the two belong to the same formation. They are alike in their composition and in their finely laminated structure. The chief constituents of both are fine-grained quartz, brown mica, and carbon. Both the quartz-mica schist and the slate are intruded by basic igneous rocks whose schistosity and other secondary structural features indicate that they were intruded before the slate and limestone beds were folded. Faults have disturbed the relations of the slate and limestone of the York area. The quartz-mica schist and limestone of Ear Mountain are similarly disturbed by faulting. Black slates like those of the York area apparently underlie all the territory between Ear Mountain and Idaho Gulch. The principal facts which suggest the identity of the quartz-mica schist of Ear Mountain and the slate of the York area are, therefore, their similarity of mineral composition, lamination, instrusions, faulting, and association with limestone.

Some of the schist beds at Ear Mountain appear to be conformable with the limestone beds; others are not. Their present distribution is probably due to faulting, for although they are older than the limestone they seem to overlie it on two of the peaks of Ear Mountain, namely, the one farthest east and the one farthest southwest. Faulting is also suggested by some very marked discordances between the dip and strike of the limestone beds and those of the schist beds. Such discordances were noted on the south slope of the east mound and in the gulch of Quartz Creek. In both of these places certain alterations of limestone and slate have been interpreted as due to faulting because of discordance in structure between the two. At Black Mountain a similar repetition of limestone and schist beds has been proved to be due to faulting.

LIMESTONE.

The limestone beds at Ear Mountain consist of alternating layers of finely granular calcite, usually about 1 inch in thickness, and thin layers of crenulated clayey material. On weathering the clay seams stand out in prominent relief. The attitute of the limestone beds is fairly uniform. On both the south and the north sides of the mountain they dip 15°-40° N. and generally strike N. 70° E. It is apparent from this uniformity in the position of the limestone beds that the granite has invaded them without producing any marked changes in their position.

GRANITE.

The exposed portion of the granite intrusion of Ear Mountain is dome shaped, and the base is about 2 miles in diameter. All sides of this dome appear to be steep except the north side, but this side also cuts across the limestone beds. The surface of the granite is very irregular. Large dikelike masses project upward from the main body of granite into the schist and limestone. Most of these projecting masses trend east. Offshoots of this type are common on the south slopes of the mountain.

Two types of granite are exposed. The main mass is an even-grained rock composed chiefly of orthoclase crystals of square outline associated with quartz, sodic plagioclase, and a little brown biotite. On the surface small knots 2 or 3 inches in diameter weather out in many places and resemble similar forms in the granite of Brooks Mountain. They are generally of finer grain than the granite in which they are embedded, but their mineral composition, except for a larger quantity of brown biotite, is the same.

A minor portion of the granite is a light-colored muscovite-bearing rock with prominent quartz crystals. Dikes of this kind a few feet in width crop out on the south slope of the mountain east of Crosby Creek at an elevation of 1,400 feet. A larger area of unknown form is exposed south of the Quartz Creek canyon, and another in Vatney Gulch, on the northeast side of the mountain. The crystallization of the muscovite granite appears to have been interrupted several times. The large quartz and feldspar grains which it contains are generally corroded and inclose very fine crystals of feldspar and quartz. The matrix consists of granular quartz and feldspar and of the last minerals to crystallize, namely, fluorite and muscovite. Muscovite is prominent. In the occurrence from Vatney Gulch Knopf found minute crystals of cassiterite embedded in the muscovite.

The fissures of the granite were studied with the view of determining their origin and ascertaining whether they were related to the mineralization of the granite and adjacent limestone. The directions of fissuring are not uniform. Outcrops near each other may show entirely different systems of fracturing. North-south and east-west vertical fissures are the most abundant. Fissures trending in intermediate directions, northeast and northwest, are not so common, and many of them show gentle dips, either to the north or to the south. Some of the north-south and east-west fissures also dip at low angles. The spacing of the fissures changes abruptly. As a rule, gently inclined fissures are closely spaced and develop a platy structure. Wide spacing no doubt has been an important factor in causing some outcrops to persist much longer than others and thus to form pillars and towers.

The fissures appear to be independent of the surface of the granite. It is difficult to interpret them as shrinkage cracks developed in a uniformly cooling magma. If they are shrinkage cracks, they suggest uneven distribution of heat, a condition which may have been caused by the movement of vapors or hot solutions from within. The black tourmaline crystals covering some of the walls of fissures show that heated solutions circulated through parts of the granite.

Strike, dip, and spacing of fissures cutting granite of Ear Mountain.

Location.	Elevation (feet).	Strike.	Dip.	Spacing interval.
West side of Deer Gulch	1,700	North-south	8° E.	1 to 3 feet.
		North-south	80° E.	
Head of Deer Creek divide	....	North-south	Vertical	3 feet.
		N. 50° W.	Steep north	Closely spaced.
		N. 65° E.	do.	Do.
		Horizontal	....	Do.
Near head of Crosby Creek	....	N. 20° E.	15° N.	Do.
		N. 40° W.	Vertical	Several feet.
		East-west	do.	Do.
Do	....	N. 60° E.	15° S.	Closely spaced. Platy structure.
Ridge east of Deer Creek	....	N. 60° E.	32° S.	4 to 8 inches.
Do	1,800	N. 35° W.	30° E.	Closely spaced.
		N. 40° W.	80° E.	10 feet.
		N. 80° W.	80° N.	
		North-south	Vertical	
Do	2,000	East-west	85° N.	
		N. 20° W.	70° W.	
		N. 50° E.	30° S.	Closely spaced.
Do	2,220	N. 30° E.	15° S.	Widely spaced.
		N. 70° W.	Vertical	Do.
		North-south	do.	
Do	2,360	N. 70° E.	80° S.	Walls coated with tourmaline.
		East-west	Vertical	Widely spaced.
		N. 50° W.	do.	
Ridge extending northwest from Central Peak	2,200	N. 30° W.	35° E.	Closely spaced.

QUARTZ-AUGITE PORPHYRY.

The youngest known rocks of the Ear Mountain area are quartz porphyry dikes that were injected into the granite and limestone after the granite had cooled sufficiently to chill the margins of the dikes. Two dikes of this kind, striking north and N. 20° E., crop out on the north side of the mountain. They are about 20 feet wide and have been traced for several hundred feet. They have a chocolate-colored dense groundmass, without visible grain, in which large crystals of quartz and feldspar and a few of augite are embedded. Augite crystals as much as 2 inches in length have been found. Both feldspar and quartz show frayed and corroded edges. The feldspar is the limy plagioclase bytownite. The groundmass consists of microscopic crystals of plagioclase somewhat less limy than the large ones and an abundance of fine-grained biotite. The rock may be classed as a dacite.

CONTACT METAMORPHISM.

LIMESTONE.

The limestone and quartz porphyry adjacent to the granite and the marginal portion of the granite itself have undergone certain changes resulting from the intrusion. Some of these changes involve the introduction of new materials.

In the limestone these effects extend several hundred feet beyond the visible contact. Far from the contact the changes consist in recrystallization and coarsening of the calcite layers and hardening of the shaly seams. Limestone of this type grades into a rock in which nearly all the calcite has disappeared and the original calcite and clayey layers are replaced by alternating bands of grossularite and light-green pyroxene, either diopside or hedenbergite, vesuvianite, and similar minerals. This change has involved the loss of carbon dioxide and a recrystallization of the remaining materials into heavy lime-bearing silicates. Within a few feet of the contact the introduction of new materials is indicated by the development of tourmaline, axinite, scapolite, paigeite, and occasionally cassiterite, chalcopyrite, pyrite, and pyrrhotite.

A large assortment of contact-metamorphic minerals is found on the dump of the Winfield shaft. The minerals that have replaced the limestone at this place include green pyroxene, grossularite, vesuvianite, fluorite, and microscopic crystals of scapolite, cassiterite, axinite, topaz, danburite, arsenopyrite, pyrite, and chalcopyrite. South of Eldorado Creek the contact metamorphism of the limestone has developed a banded rock resembling a gneiss. The calcite seams of the original limestone persist, but the clayey layers have been replaced by black needles of tourmaline. In the Quartz Creek canyon the limestone shows very intense contact-metamorphic changes, and it is here that Knopf found the tin mineral paigeite in the form of small black particles embedded in the limestone. Associated with the paigeite are tourmaline, vesuvianite, zoisite, fluorite, phlogopite, chalcopyrite, and magnetite.

Limestone lying on a prospect dump near the head of Tuttle Creek shows changes to a very dense fine-grained mass of tourmaline and axinite. Accessory minerals are pyroxene, quartz, fluorite, calcite, and cassiterite in microscopic grains.

GRANITE.

The chief contact alteration of the border portion of the granite consists in the development of black tourmaline, which also very commonly replaces the granite along certain fissures. Tourmalinized granite crops out at the head of Quartz Creek, and pieces of similar rock lie on the dump of the Winfield shaft.

QUARTZ PORPHYRY DIKES.

Where the quartz porphyry dikes cut the granite border, as at the Winfield shaft, they show strong tourmalinization. Commonly the tourmaline crystals invade and replace the large feldspars of the dike in preference to other materials. Films of cholcopyrite border the tourmaline crystals or fill cracks in them. The chalcopyrite was evidently introduced after the tourmaline.

TIN DEPOSITS.

At Ear Mountain tin in the form of cassiterite has been found (1) as very small and microscopic grains embedded in the muscovite of certain muscovite granite dikes, (2) in microscopic grains in contact-metamorphic limestone, and (3) in microscopic grains replacing quartz porphyry. The muscovite granite has no commercial possibilities. In neither the contact-metamorphic limestone nor the quartz porphyry have visible amounts of cassiterite been found, but assays of materials of this type from the Winfield shaft are reported to have shown as much as 3 per cent of tin.

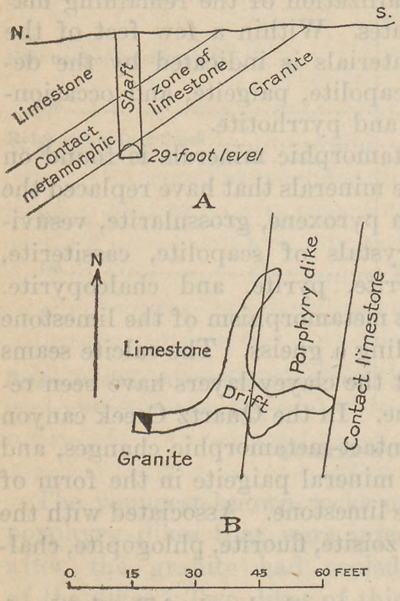


FIGURE 20.—Sketch of Winfield workings, Ear Mountain. A, Vertical north-south section through shaft; B, plan of 29-foot level. From diagrams furnished by E. A. Winfield.

DEVELOPMENTS.

In 1918 no work had been done at Ear Mountain for several years and all underground workings were inaccessible. At only two places has extensive underground work been done, namely, on the Winfield property and in Vatney Gulch. In Vatney Gulch, on the north side of the mountain, a body of quartz porphyry was opened by a shaft and a drift 112 feet long. No visible cassiterite was found, and assays showed only traces of tin.

The Winfield shaft, 29 feet deep, has been sunk on the north side of the mountain 10 feet north of the granite contact and 30 feet east of a quartz-augite porphyry dike striking north. (See fig. 20.) From the bottom of the shaft an incline was sunk 40 feet to the northeast. Both shaft and incline are in contact-metamorphic limestone. Some drifting was done westward from the shaft and has crosscut the quartz porphyry. The great variety of contact-metamorphic limestone minerals on the dump include conspicuous lenses of chalcopyrite, but their position underground could not be determined because the shaft was filled with ice. The following assays given to the Geological Survey by Mr. E. A. Winfield, of Teller, show both tin and copper:

Assays of mineralized rock from E. A. Winfield prospect, Ear Mountain.

Location.	Tin.	Copper.	Zinc.	Impurities.	Iron.	Gold.	Silver.
Surface croppings	None.	None.				None.	None.
30 feet west of bottom of shaft on first level	3.46	Trace.		69.60		Trace.	Trace.
Dump	3.7	Trace.		66.3		Trace.	Trace.
Average dump from shaft and incline	2.36	4	1.04	54.20		Trace.	Trace.
Not reported	None.	None.	None.		13	Trace.	Trace.
Do	18.72					None.	None.

BLACK MOUNTAIN.

LOCATION AND GENERAL FEATURES.

No tin has been found at Black Mountain, but it is described here because the area contains a granite stock and quartz porphyry dikes intruded into limestone and slate, similar to those of the tin-bearing localities of the York Mountains. The contact-metamorphic changes of the limestone and slate are the same as those seen at Brooks Mountain and in other intrusive areas except that no introduction of fluorine, boron, or tin was noted. Another reason for studying this area lay in the fact that it offered data on the relations of the limestone and slate.

Black Mountain comprises a group of nearly isolated hills, of which the highest has an elevation of 2,200 feet, about 5 miles north of Bering Sea, between Don and California rivers. When seen from the sea its dark color contrasts sharply with the dull grays of the adjacent limestone region. It can be easily reached from the beach by going up Don River and its branch Tozer Creek.

GENERAL GEOLOGY.

SUMMARY.

The Black Mountain area is underlain by black graphite slate intruded by pre-Ordovician basalt and gabbro dikes, stocks, and sills. (See Pl. XII and figs. 21–22.) The slate and basic intrusive rocks were covered by an unknown thickness of the Port Clarence limestone. Both slate and limestone were tilted northward and broken along fault zones striking in general east. The granite and quartz porphyry intrusions followed. The granite caused the development of contact-metamorphic minerals in the adjacent limestone and slate. After the intrusion of the granite and quartz porphyry dikes the area was carved by streams to its present state of relief. The granite and its contact-metamorphic border, resisting erosion better than the surrounding slate and limestone, have formed Black Mountain. The slate, being weak, has been removed more rapidly than the limestone, and hence underlies most of the valleys of Tozer and Skull creeks and the low area extending eastward from Black Mountain down the Agiapuk Valley. The greenstone sills injected parallel to the slate beds, because of their superior resistance to weathering, form elongated ridges parallel to the strike of the slates, steep on one side and gentle on the dip slope. Stocklike injections of greenstone into the slate have weathered into low cones.

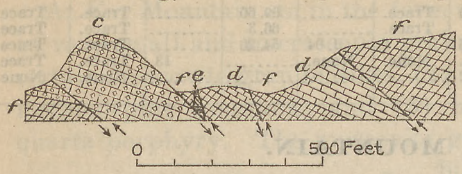


FIGURE 21.—Section at head of Deer Branch. *c*, Metamorphosed limestone; *d*, Port Clarence limestone; *e*, gabbro and basalt; *f*, slate.

After the region had been eroded into nearly its present form lavas were extruded in several places. The largest flow of this kind within the area lies east of California River.

FAULTS.

Several faults striking in general east have dislocated the rocks of the Black Mountain area. One of these faults is well exposed. The position of the others was inferred from field relations.

Within 500 paces north of the main limestone contact-metamorphic area of Black Mountain, there are two isolated lenses of limestone inclosed by slate. A fault is exposed at the one farther north. This limestone lens, about 800 feet long and less than 100 feet thick, is overlain by beds of black slate striking N. 70° W. and dipping 50° N. The limestone itself strikes east and dips about 36° N. The fault plane separates the limestone from the overlying slate along a knife-edge contact. At the west end of the outcrop the fault strikes N. 70° W., but at the east end it curves southeastward. The dip of the fault plane is 45° N. From the evidence afforded by the fault itself it is impossible to say whether the slate moved up or down with reference to the limestone.

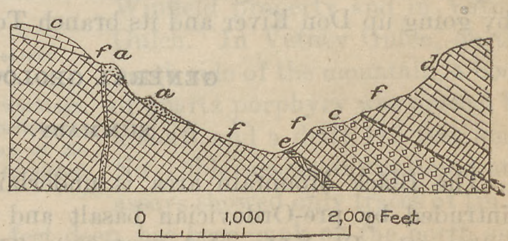
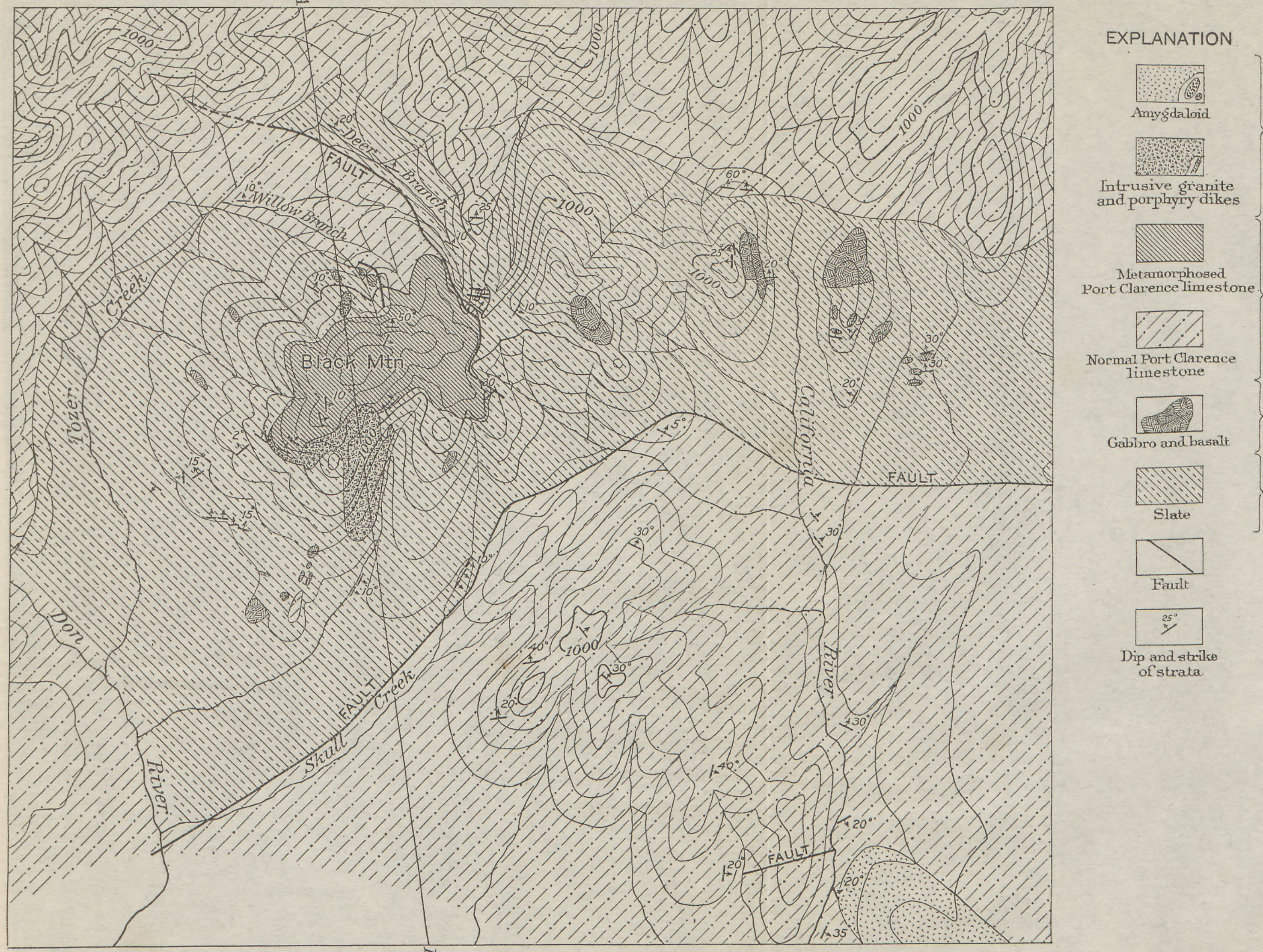


FIGURE 22.—Section near Willow Branch. *a*, Amygdaloid; *b*, porphyry dikes and quartz; *c*, metamorphosed limestone; *d*, Port Clarence limestone; *e*, gabbro and basalt; *f*, slate.

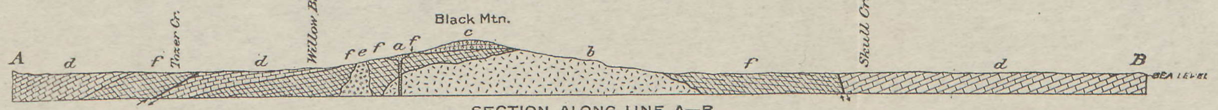
The conditions leading to the isolation of this limestone lens between beds of slate are believed to be essentially as follows: Limestone beds and slate beds underlying them were tilted northward and later cut by an undulating fault striking roughly east and dipping



GEOLOGIC MAP OF BLACK MOUNTAIN, ALASKA

1 0 1 2 3 MILES

Contour interval 200 feet



SECTION ALONG LINE A—B
Scale same as map

a, Amygdaloid; *b*, porphyry dikes and quartz; *c*, metamorphosed limestone; *d*, Port Clarence limestone; *e*, gabbro and basalt; *f*, slate.

about 45° N., a dip which is steeper than the inclination of the beds (fig. 23, A). On a horizontal plane through the beds the trace of the fault plane, because of its undulations, divides the horizontal surface into two parts, of which the one to the south is composed of slate and a lens of limestone (fig. 23, B). Still later the overhanging side was upthrust along the fault plane (fig. 23, C) and was thus brought to overlie the limestone lens shown in figure 23, A and B. Erosion followed the thrust faulting and wore the surface down to a nearly horizontal plane. The lens of limestone became isolated and inclosed by

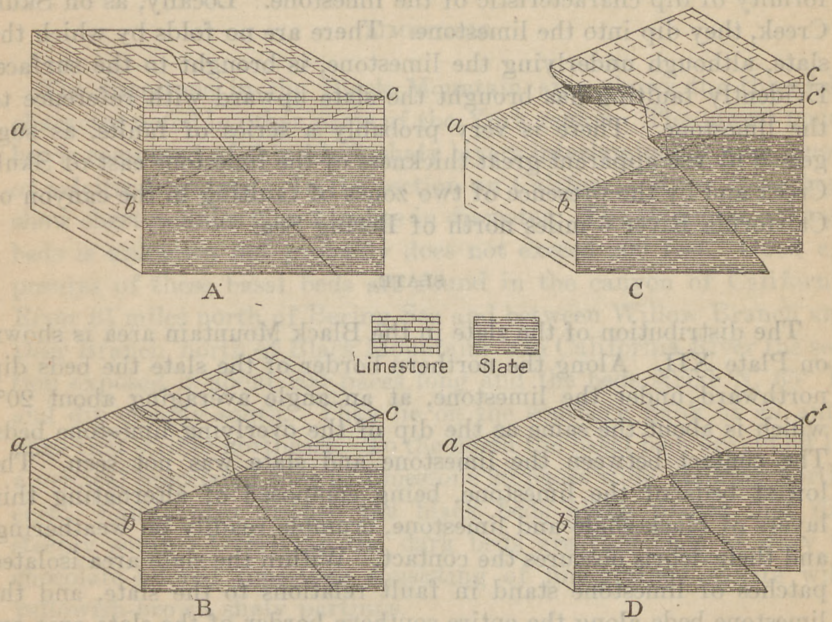


FIGURE 23.—Block diagram showing how a limestone lens became surrounded by slates through faulting and erosion. A, Position of limestone and slate before faulting; B, trace of fault on plane *a–b–c* before displacement; C, hypothetical position of fault blocks after displacement; D, condition after erosion has cut block C down to *c'*, flush with *a–b*. Note isolated patch of limestone in slate.

slates (fig. 23, D). Further erosion would finally cause this lens to disappear.

Within 500 paces south of the fault just described two other faults of the same character have been inferred from the relations of slate and limestone. In this locality nonmetamorphosed limestone rests upon contact-metamorphosed limestone, as if this faulting had taken place after the intrusion of the granite.

Faults of the same general type appear to mark the slate and limestone contact of Black Mountain from the basin of California River westward to Deer Creek. The limestone beds along this contact, dipping uniformly northward, would, if projected northward, extend into slate. It seems from this that the slate has been brought upward with reference to the limestone. A local condition of this sort has also been observed near the head of the South Fork of Willow Branch. (See fig. 22.)

The largest fault of the area is inferred to follow the southern border of the slate belt. The limestone beds in the hills between Skull Creek and California River dip 15°–50° N. Even at the contact with the slate their dip is northward. The slate beds north of the limestone generally dip to the north but do not show the uniformity of dip characteristic of the limestone. Locally, as on Skull Creek, they dip into the limestone. There are no folds by which the slate, although underlying the limestone, is brought to the surface. Evidently faulting has brought the slate upward with reference to the limestone. There is very probably a series of faults, as suggested by the apparent great thickness of the limestone east of Skull Creek and by the presence of two zones of faulting in the canyon of California River 6 miles north of Bering Sea.

SLATE.

The distribution of the slate in the Black Mountain area is shown on Plate XII. Along the northern border of the slate the beds dip northward under the limestone, at an angle averaging about 20°, which is about the same as the dip of the overlying limestone beds. The contact between the limestone and slate was not seen. The lowest beds of the limestone, being composed of alternating thin layers of black shale and limestone, crumble readily on weathering, and their débris obscures the contact. Within the slate area isolated patches of limestone stand in fault relations to the slate, and the limestone beds along the entire southern border of the slate area are inferred to be faulted against the slate.

Throughout the area the slate is remarkably uniform in character and of exceedingly fine grain. Microscopic study shows that it is composed of very fine grained quartz laminae alternating with thin laminae composed of scales of wavy brown mica. Scattered through it are particles of black carbonaceous material, which in the vicinity of the granite contact are aggregated into small irregular rodlike particles. The granite has also effected a change in the color of the slate. Away from the granite contact the slate is black. Near the granite it has a brown color like that of maple sugar, and in hardness, color, and grain resembles some varieties of rhyolite.

PRE-ORDOVICIAN BASALT AND GABBRO.

The basalt and gabbro are green rocks, generally composed of nearly parallel columns of green secondary hornblende associated with limy plagioclase decomposed into quartz, calcite, and other minerals. Many of the intrusions are distinct sills from 3 to 40 feet thick injected between the slate layers. Intrusions of this type are very well exposed west of Skull Creek and on the east side of California River near the Luther prospect. At the latter place the sills are repeated at intervals of several hundred feet and form a series of east-west hogback ridges with gentle north slopes. East of the granite there are several large stocks of greenstone, one of which is nearly a mile in diameter.

LIMESTONE.

The limestone in the Black Mountain area shows the threefold character noted in other parts of the York region. The lowest member is composed of thin black shaly layers interlaminated with lenses of calcitic limestone. In the section on California River these beds show chert nodules 2 or 3 inches in diameter. The thickness of these beds is unknown but probably does not exceed 200 feet. Good exposures of these basal beds are found in the canyon of California River 6½ miles north of Bering Sea and between Willow Branch and Deer Branch, north of Black Mountain. On California River the section exposed is about 200 paces long and the beds strike N. 65° E. and dip steeply south. They lie on the southern flank of an anticline that strikes northeast. To the north the basal beds are cut off by a vertical brecciated zone of limestone 20 paces wide, striking northeast. Faults also disturb the black beds along planes that dip steeply south. Overlying the dark beds are thin beds of gray to chocolate-colored limestone consisting of fine-grained calcite with yellowish-brown shaly partings.

In the section between Willow Branch and Deer Branch the thin-bedded black limestone is covered by several hundred feet of the thin-bedded limestone interlaminated with yellowish-brown shale. The same relation between these two members of the limestone series exists at other places along the northern border of the slate area.

The uppermost member of the limestone series consists of thick-bedded gray, pure limestone, without shaly or sandy constituents. The average thickness of the beds is from 1 to 2 feet. These beds are well exposed on the hills between Skull Creek and California River. In the section east of Skull Creek about 4,000 feet of the uppermost thick-bedded limestone seems to overlie at least 2,000 feet of the thin shaly layers, but this thickness of limestone is probably only apparent. Faults no doubt affect this section and cause a repetition of beds.

GRANITE.

The granite intrusion forms the core of the Black Mountain area. The portion exposed is irregularly elliptical and is about 1 mile in length. The limestone cover has been stripped off only on the southeast side. The granite surface is very steep on this side, but toward the northwest its slope is probably moderate, to judge by the width of the contact-metamorphic area in that direction. Like other intrusions of granite in the York region, it appears to be inclined in the same direction as the sediments into which it is intruded but more steeply.

The granite of Black Mountain is an even-grained rock, composed chiefly of orthoclase with small amounts of quartz and sodic plagioclase. Biotite occurs in very small brown plates. In grain and mineral content it resembles the granite of Tin Creek and Ear Mountain.

ALTERATION OF THE LIMESTONE BEDS BY THE GRANITE.

The thin-bedded shaly and graphitic limestones which lie at the granite contact show alterations similar to those of the limestones at the contact of other granites of the York Mountain region. Near the border the calcite has completely disappeared and the rock has been changed into fine to medium grained silicates, chiefly colorless garnet, vesuvianite, and pyroxene, probably augite or hedenbergite. These minerals occur in thin alternating laminae. Sulphides, including both pyrite and arsenopyrite, have been introduced as minute scattered grains and very thin seams. No minerals of economic value have been found associated with them.

QUARTZ VEINS.

Quartz stringers about 1 inch in width are very common in the slate, both parallel to and across the slate layers. Valuable minerals have not been found in them. The largest quartz vein was found on the saddle north of the head of the South Fork of Willow Branch. It is 3 feet wide, strikes about N. 20° E., and was traced for several hundred feet. It appears to be composed of a clear white unmineralized quartz.

QUARTZ PORPHYRY DIKES.

Two quartz porphyry dikes were found in the Black Mountain area. One, 3 feet wide, crops out at an elevation of 1,200 feet on a peak west of California River. It strikes north. The other, about 5 feet wide, is exposed at an elevation of 250 feet on the south slope of the granite. It strikes east and was traced for several hundred feet. These dikes are composed of small scattered quartz grains about one-eighth of an inch in diameter and small white feldspar phenocrysts embedded in a black dense, fine-grained groundmass that forms 95 per cent of the rock. Both dikes were found in the slate, but they probably belong to the period of granite intrusion and are therefore younger than the limestone.

AMYGDALOIDAL OLIVINE BASALT.

Three bodies of amygdaloidal basalt were found in the Black Mountain area. Their identity of character makes it probable that they came from the same magmatic reservoir. Except for a finer grain they are like the black dike in the tunnel of the Empire Tin Mining Co. at Cape Mountain.

The largest of these bodies is on the east side of California River. Here several thousand acres is underlain by boulders of this rock as much as 10 feet in diameter, broken by frost action. The rock is a very vesicular surface flow poured out on the eroded surface of the Port Clarence limestone. The fine groundmass is black. In it are scattered grains and segregations of olivine. Microscopic study shows that the groundmass consists of fine laths of calcic plagioclase in which are embedded larger crystals of augite and olivine that crystallized after the feldspar.

About 400 paces west of the limestone contact west of Skull Creek stands a small cone 30 feet high composed of a broken mass of vesicular, slaggy black lava. It is full of blow holes several inches long. Segregations of olivine grains 1 inch in diameter were seen here and there. Under the microscope the rock is seen to consist of glass in which tiny needles of calcic plagioclase are embedded. Olivine forms scattered crystals. In composition this lava is like the flow east of California River. Its recent extrusion is suggested by the freshness of the glass.

On the slope south of the south fork of Willow Branch black lava of the vesicular type appears at elevations of 900 and 1,200 feet. At the higher elevation three beds of ash and bombs of scoriaceous, ropy, and vesicular black lava, each about 15 feet thick, are separated by beds of massive black lava several feet thick. Small angular inclusions, about 2 inches long, of white dense, grainless rock like certain phases of the metamorphic limestone are embedded in the lava. Microscopically this lava is like that in the cone west of Skull Creek. The glassy groundmass constitutes about 80 per cent of the volume of the rock. The remainder consists of small grains of olivine about 0.1 inch in diameter.

COMPARISON OF THE TIN DEPOSITS OF THE YORK REGION WITH THE OTHER TIN DEPOSITS OF THE WORLD.

ASSOCIATION WITH GRANITE.

The data on the characteristics of the tin deposits of the world in this discussion have been taken chiefly from a paper by Ferguson and Bateman.[29] In their close association with granite batholithic intrusions the tin deposits of the York region resemble tin deposits throughout the world, which, barring a few apparent exceptions, are all in granites or near granite intrusions. All of them are also closely related in age to the intrusive granite with which they occur. In some of the apparent exceptions to the association with granites the tin occurs with rhyolite, quartz porphyry, or andesite. Most of these apparent exceptions are in little-known areas, hence the total absence of granite may not have been proved for all of them.

The granite batholiths with which most tin deposits are associated have not been eroded deeply, and as a rule portions of the roof remain. The deposits are generally at or near the border of the granite. Where they appear far within an eroded granite area there is generally reason for believing that the border was not far removed vertically. Tin deposits found several miles from an exposed granite contact have certain characteristic features indicating that the granite is at a shallow depth below them. The deposits are more likely to occur where the original surface of the granite is gently inclined than where it is steep.

All these characteristics fit the tin deposits of the York region. The granitic intrusions represent stocks from a common batholith and are only slightly exposed. Portions of the roof remain in all of them. Mineralization of the invaded rock is greatest where the slope of the granite border is relatively gentle. Thus the limestones north of the Ear Mountain and Cape Mountain stocks and west of the Brooks Mountain stock show the most intense mineralization. Mineralization does not extend far from the contact where the border is steep.

Where the granite stock with which the tin minerals are associated is exposed the mineralization probably does not extend more than 200 feet from the contact. None of these tin deposits are directly above the tops of the granite stocks. The granite inferred to underlie the Cassiterite Creek tin deposit may be some somewhat deeper than 200 feet, because tin solutions may be expected to have traveled farther vertically from the top of a stock than from the sides. No close estimate of the depth of the granite stock inferred to underlie

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[29] Ferguson, H. G., and Bateman, A. M., Geologic features of tin deposits: Econ. Geology, vol. 7, pp. 209–262, 1912.

Potato Mountain can be given, though to judge by the condition of the slate it may be about 1,000 feet.

COMPOSITION OF GRANITE ASSOCIATED WITH TIN DEPOSITS.

The granites associated with tin deposits throughout the world, so far as known, are alkaline rocks low in magnesia and lime. Almost without exception they contain more potash than soda. Orthoclase is generally the most abundant mineral. The plagioclase feldspars are sodic. Biotite is usually more common than either hornblende or muscovite. The acidic dikes associated with the granites usually have about the same chemical characteristics as the granites themselves, but silica is commonly a little higher in the dikes.

The granites of the York tin region are also of the normal type, orthoclase being their dominant constituent. Plagioclase feldspars are subordinate and are of the sodic type. In all the granites biotite is the chief mica except in certain dikelike forms at Ear Mountain, which contain a conspicuous amount of muscovite as the last product of crystallization. The granite at Brooks Mountain contains biotite except in a border zone about 3 feet wide which contains a green hornblende.

The dikes that are closely associated in time with the granites and tin deposits of the York region are generally of the acidic type. Muscovite is commonly the predominant primary mica. At Ear Mountain an augite dacite porphyry altered by tin-bearing solutions cuts the granite.

KINDS OF ROCKS INTO WHICH TIN-BEARING GRANITES ARE INTRUDED.

In the York region, the tin-bearing granites are intruded into slate and limestone. A compilation of the rocks invaded by the tin-bearing granites of the world indicates that the nature of the invaded rock has no bearing on tin deposition. Ferguson and Bateman mention schist 16 times, slate 11, quartzite 7, sandstone 6, shale 2, limestone 6, gneiss 6, older granite 3, and other igneous rock 4.

LOCATION OF ORES WITH REFERENCE TO GRANITE.

Most of the tin ores of the world are within the granites. Bateman and Ferguson found that in 26 localities the cassiterite occurs almost exclusively in the granite, in 8 it is divided between the granite and the invaded rock, and only in 4 is it preponderantly in the invaded rock.

So far as known the tin in the York region occurs mostly in the invaded rocks, chiefly slate, as indicated both by placers and by occurrences in place. The granites themselves have been the direct source of very little placer tin. The only commercially important placer deposits are derived from slate at Potato Mountain. The invaded rocks influence the shape of the tin deposits formed within them. In limestone, because of its tendency to react with tin-bearing solutions, the tin deposits usually take the form of irregular replacement deposits; in slate and quartzite the tin deposits are more commonly in the form of fissure veins.

AGE OF TIN DEPOSITS.

In age the tin deposits of the world range from Archean to late Tertiary. Most of them appear to be late Carboniferous or Mesozoic. The granites of the York region are probably Mesozoic. The youngest rocks known to be penetrated by them are of Mississippian age. The gap between the Mississippian and the Pleistocene is not known to be represented by sediments, hence the age of the intrusions can not be determined more precisely.

CLASSIFICATION OF TIN DEPOSITS.

Ferguson and Bateman have compiled the frequency of occurrence of certain types of tin deposits of the world as follows: Normal lodes, 27; pegmatite lodes, 7; stockworks, 12; pipes, 2; segregations, 2.

They define normal lodes as including both veins and tabular ore bodies formed by a series of parallel, closely spaced fissure veins, with the intervening country rock more or less replaced by ore. Cornwall, the Zinnwald district, Tasmania, New South Wales, and Bolivia have deposits of this type.

Pegmatite lodes are pegmatite veins containing cassiterite. Deposits of this kind are known in North and South Carolina, the Black Hills, the Vegetable Creek district, New South Wales, and Swaziland.

Stockwork deposits consist of a network of veins and impregnated country rock. They are represented by deposits in the Erzgebirge, New South Wales, Tasmania, and South Africa.

Pipes are unique cylindrical deposits, composed of a central core of altered granite with disseminated cassiterite which is surrounded by zones of cassiterite and tourmaline. They have been found in Transvaal and New South Wales.

Segregations are interpreted as portions of the original granite magma containing unusual amounts of cassiterite. In the Mergui district, Bolivia, massive segregations of quartz at the outskirts of the granite contain wolframite, chalcopyrite, and cassiterite. A segregation of tin-bearing magnetite in granite gneiss is said to occur at Ross-shire, Scotland.

Some of the tin deposits of the York region can be classed with certain groups established by Ferguson and Bateman, and some represent other types. The classes recognized are fissure veins and replacement deposits. The latter are not mentioned as such in the above classification. The fissure veins are found at Cassiterite Creek in the limestone and in the Ida Bell dike. Distinct veins of this type are practically absent from the Cassiterite dike. In these veins cassiterite is associated with quartz, topaz, zinnwaldite, fluorite, tourmaline, wolframite, and albite. Quartz-cassiterite fissure veins also occur in the granite at Cape Mountain and in the slate at Potato Mountain. Quartz veins locally form a stockwork as Potato Mountin but generally do not carry cassiterite in amounts visible to the eye.

The replacement deposits include limestone contact-metamorphic deposits in limestone, deposits formed by the replacement of brecciated border phases of granite, known in the Empire Mining Co.'s tunnel at Cape Mountain, and the replacement deposits of the Cassiterite dike and Greenstone lode. In the limestone contact-metamorphic deposits the cassiterite occurs as an irregular replacement of marble and is associated with secondary tourmaline, axinite, fluorite, paigeite, hulsite, hornblende, pyroxene, vesuvianite, humite, serpentine, danburite, zinnwaldite, phlogopite, green mica, chondrodite, grossularite, stannite, wolframite, chalcopyrite, pyrrhotite, arsenopyrite, pyrite, galena, sphalerite, molybdenite, and stibnite.

The brecciated zones in the granite of Cape Mountain show cassiterite-bearing replacement deposits only a few inches wide. The cassiterite is associated with secondary quartz, tourmaline, colorless mica, and sulphides of iron.

The tin-bearing portion of the Cassiterite dike is almost entirely replaced by sericite, fluorite, and zinnwaldite, with scattered cassiterite, wolframite, tourmaline, topaz, humite, arsenopyrite, pyrite, molybdenite, and stibnite. Similar replacement deposits were noted in the Greenstone lode. Locally quartz is an abundant replacing mineral and is associated with wolframite, sericite, and cassiterite.

ROCK ALTERATIONS ASSOCIATED WITH TIN DEPOSITS.

The contact metamorphism of limestone, slate, and other rocks adjacent to tin-bearing granite shows phases due to recrystallization which do not differ from contact alterations caused by granite that is not tin bearing. It seems that tin has rarely been introduced as a contact mineral. In the York region, however, there have been at the limestone contacts, except the one at Black Mountain, marked accessions of tin, boron, fluorine, and sulphur bearing minerals, such

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as fluorite, tourmaline, axinite, cassiterite, paigeite, hulsite, chalcopyrite, pyrrhotite, and galena.

The alteration of the granites and dikes effected by tin-bearing solutions is very much like that generally caused by hydrothermal solution on acidic igneous rocks, consisting of silicification and sericitization. In the Cassiterite dike sericitization is far more prominent than silicification. In all phases of alteration of the granites and dikes in the York region there is a marked introduction of fluorite, tourmaline, and sulphides. This is characteristic of the alteration of similar rocks by tin-bearing solutions in other parts of the world.

ORIGIN OF THE TIN DEPOSITS OF THE YORK REGION.

TIN DEPOSITS ASSOCIATED WITH GRANITE.

Inferences as to the origin of the tin deposits of the York region must take cognizance of their constant association with granite stocks. The tin minerals occur in the border phases of granite, quartz veins, porphyry dikes, and in limestone near granite intrusions.

TIN MINERALS DEPOSITED FROM SOLUTIONS AFTER SOLIDIFICATION OF GRANITE.

With one exception all known occurrences of tin in the granites of the York region are in fractured zones. The tin in the form of cassiterite replaces with other minerals the feldspars of the granite. The secondary minerals that were introduced with the cassiterite include quartz, sericite, tourmaline, topaz, fluorite, arsenopyrite, and pyrite. These facts imply that the cassiterite did not crystallize with the feldspars and other minerals of the granite but was introduced after the granite had solidified. An unimportant exception to this statement is seen at Ear Mountain, where a white muscovite granite dike was found to contain microscopic crystals of cassiterite embedded in muscovite. The muscovite is abundant and with minor amounts of topaz and fluorite constitutes the groundmass in which an earlier generation of quartz and feldspar phenocrysts are embedded. Several samples of this rock were examined, but only one found by Knopf showed cassiterite.

Whether the tin that replaces rock material adjacent to the granite was deposited after the granite had solidified can not be stated as confidently as in the case of the tin occurring in the granite. The cassiterite in the rocks adjacent to the granites has the same mineral associates as the cassiterite of the granite. This implies similarity in the composition and temperature of the solutions that deposited both. The fact that the two occurrences of cassiterite resemble each other closely and are near each other undoubtedly means that they came from the same source.

CHARACTER AND SOURCE OF SOLUTIONS.

It is apparent from the chemical composition of the tin minerals and their occurrence as vein material and as irregular replacement deposits, that the solutions which carried and deposited the tin transported a variety of elements—silicon, aluminum, iron, magnesium, sodium, potassium, lithium, fluorine, chlorine, sulphur, tungsten, and other metals. It is improbable that all these elements came from the same source, however. The silica, aluminum, iron, magnesium, sodium, and potassium may have been derived partly or wholly from the limestones and dikes which the solutions traversed. Certain other elements which the solutions carried, such as fluorine, lithium, chlorine, sulphur, tin, and tungsten, may have been present in minute quantities in the original limestones and dikes, but their abundance in the solutions can not be accounted for from this source. Their close association with igneous intrusions points to their having an igneous source.

The solutions that deposited the tin and the secondary minerals closely associated with it were hot solutions of deep-seated origin. This is inferred from the close association, both as to time and place, of such minerals as tourmaline, topaz, danburite, axinite, and scapolite with igneous activity. These minerals are not known to be formed under surface conditions. The list of known minerals deposited by the tin-bearing solutions includes cassiterite, quartz, fluorite, tourmaline, topaz, scapolite, danburite, a green mica, muscovite, zinnwaldite, phlogopite, wolframite, calcic and sodic plagioclase, hornblende, pyroxene, vesuvianite, magnestite, humite, chondrodite, serpentine, arsenopyrite, pyrite, stannite, and probably pyrrohotite, galena, sphalerite, molybdenite, and stibnite. Some of the minerals named were deposited from the solutions in cavities, fissures, and other openings. Others replaced previously existing minerals. Some of them were probably formed by the interaction of the solutions with rock materials. Quartz, fluorite, tourmaline, topaz, danburite, muscovite, zinnwaldite, wolframite, and plagioclase occur as minerals deposited directly from solutions in fissures. This same group of minerals and in addition hornblende, magnetite, chondrodite, serpentine, phlogopite, arsenopyrite, pyrite, and stannite are known to replace previously existing rock materials. It is probable that considerable amounts of the fluorite and hornblende found in the tin-bearing limestone were formed by the interaction of the solutions with the original constituents of the limestone. The calcium in both the fluorite and the hornblende may have been derived from the limestone, and the aluminum, magnesium, and some of the iron in the hornblende may also have come from the limestone. Certain dense, compact alternating laminae of grossularite, vesuvianite, and colorless to light-green pyroxene replacing limestone adjacent to the granite contacts are not regarded as having been caused by the introduction of materials in solution, for the laminae are parallel to the bedding and show great regularity. They are ascribed to the expulsion of the carbon dioxide of the limestone and the recrystallization of the remaining limestone materials. The occurrence of vesuvianite and pyroxene in concentric rings, as at Tin Creek, is ascribed to the action of solutions. Tremolite occurs as a product of regional metamorphism of the limestone. Its distribution parallel to the bedding and in association with fine-grained clayey layers indicates its development was influenced by the original composition of the limestone.

SEQUENCE OF THE TIN-BEARING SOLUTIONS.

In some tin districts of the world a sequence of deposition of the tin and its associates has been inferred. Except at the Cassiterite Creek deposits the opportunities for study of the deposits in the York region have not been favorable enough to determine a sequence of deposition. The limestone that crops out in the creek at the Cassiterite Creek tin prospect shows two stages of mineralization, represented by (1) irregular, crisscrossing replacement veins, consisting mainly of fluorite, hornblende, and calcic plagioclase; (2) fissure veins containing chiefly quartz, topaz, tourmaline, albite, wolframite, cassiterite, and zinnwaldite. No sequence of deposition was noted in minerals replacing the dikes of Cassiterite Creek.

SUGGESTIONS ON LODE TIN PROSPECTING IN THE YORK REGION.

The following suggestions on tin prospecting in the York region apply to deposits in place and not to placers. All the known tin deposits of the world are either in granite or closely associated with granite. A few apparent exceptions are associated with rhyolite or similar rocks closely related to granite. Tin prospecting in the York region can therefore be limited to granite areas, to the rocks adjacent to granite, and to places where granite is inferred to lie at a shallow depth below the surface and which can be recognized by the contact metamorphism which the surface rocks have suffered.

In the granite tin may be looked for in quartz veins or in any altered portion of the granite. The alterations of the granite associated with tin are either a sericitization or a silicification. Both alterations may be accompanied by tourmalinization. The sericitized portions of the granite commonly contain sulphides and fluorite. The quartz veins and silicified masses stand out on weathering and usually are easily found. The sericitized granite, being soft, does not form prominent outcrops but is generally covered by débris.

It is useless to start underground exploration in fresh, unaltered granite. Subsurface work is justified only where there is some probability of finding a large tonnage of one of the types of deposits enumerated. Tin deposits, in order to pay, must be capable of yielding a considerable tonnage, for they all have a low tin content, usually less than 3 per cent.

Tin in the rocks adjacent to the granite occurs as a replacement of quartz porphyry dikes and limestone and in quartz veins cutting dikes, limestone, and slate. So far, the best-developed deposit in this region is a dike in which cassiterite occurs as a disseminated replacement mineral in soft sericitized and locally in silicified portions of the dike. The chief alteration is sericitization of the dike, which is therefore very soft and is commonly covered at the surface by débris.

Dikes of this kind in limestone are not promising unless the limestone adjacent to them has undergone severe contact metamorphism resulting in the development of many hard resistant silicates, which cause such deposit to stand out in prominent outcrops that are easily distinguished from the soft unaltered limestone. The metamorphosed limestone breaks down into large blocks several feet in diameter, but the unaltered limestone breaks down to small chips.

Slate adjacent to a tin-bearing dike may be expected to be hard, brown, and compact and to show very little slaty structure. Tin has not been found in place in dikes cutting slate, but large amounts of tin could hardly be expected in a dike unless the rocks associated with it showed considerable contact metamorphism.

Tin as a replacement of limestone can generally be located without difficulty. Such deposits occur in very hard, resistant limestone which makes conspicuous outcrops. Siliceous vein deposits, whether in limestone, slate, or dikes, are also readily found as outcrops or in float.

In a rugged open country nearly free from vegetation and alluvial deposits, like the York region, tunneling and shaft sinking ought to be resorted to only when surface work has shown the presence of deposits. At almost any place in the region it is possible to get down to bedrock by means of pits or trenches. Such surface work gives just as much information as underground work and is generally accomplished in less time and at a lower cost. The nature of tin deposits is such that the tin content at the surface is very much like that which may be expected below the surface. Hence deep exploration is generally uncalled for in advance of thorough surface examination.

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