DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 649

ANTIMONY DEPOSITS OF ALASKA

BY

ALFRED H. BROOKS

WASHINGTON
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By Alfred H. Brooks.

INTRODUCTION.

The publications of the United States Geological Survey on Alaska contain many references to the occurrence of antimony ore, but for the most part they make only brief mention of stibnite incidentally to the description of other metalliferous deposits. The present unusual demand for antimony has led to shipments of stibnite ore from Alaska. As a result there have been many inquiries regarding the occurrence of antimony in the Territory, and to meet this demand the present bulletin has been prepared.

The writer's field examination of stibnite lodes has been limited to those of the Fairbanks and Iditarod districts, which were examined in the summer of 1915. He had, however, in previous years made some observations on the occurrence of stibnite at Nome and acquired a general knowledge of the geology of the other mining districts mentioned in this bulletin. Much of the information here set forth has been compiled from the work of others, to which full references will be made. Some of the published descriptions of stibnite lodes have been amplified by a reexamination of the original field notes and specimens.

Though the presence of stibnite has been noted in 67 localities in Alaska, yet the aggregate knowledge of these occurrences is not large, for only a few have been studied in detail. Therefore this report must of necessity be ill balanced. The detailed descriptions of some localities serve only to emphasize the dearth of information about others that may be of even greater commercial or scientific importance. The first part of this report will be devoted to a general account, so far as the facts permit, of the geology of the stibnite lodes. At the risk of some repetition, this account of the geology will be followed by more detailed descriptions of the principal antimony-bearing districts. The Fairbanks district is the best known and also the one with which the writer is personally most familiar; hence it will be described in greater detail than any of the other antimony-bearing regions of the Territory.

MINING DEVELOPMENTS AND PRODUCTION.

It has long been known that stibnite, the sulphide of antimony and the principal source of that metal, is widely distributed in Alaska.[1] Until very recently the comparatively small consumption and low price of antimony and the relative inaccessibility of the Alaska stibnite deposits have not encouraged their development. However, in spite of these adverse conditions, some development work was done in past years on several Alaska antimony lodes, notably at the Sliscovich mine, near Nome, first opened in 1906. Some test shipments of stibnite ore were made from this property in 1907 and in succeeding years.

The recent revolutionary conditions of the antimony market, which have so stimulated the development of Alaska stibnite ores, have been summarized by Frank L. Hess in the following statement, issued by the United States Geological Survey on July 1, 1915:

Before the outbreak of the European war the leading brand of antimony, Cookson's, was quoted in New York at about 7 cents a pound, with other brands ranging from 5.30 upward. The outbreak of hostilities was followed by a rise in prices, and quotations for Cookson's soon rose above 20 cents. After some fluctuations the year closed with the quotations at 15 to 15.50 cents a pound, and other brands at 13 to 14.40 cents. The British Government placed an embargo on the shipment of antimony, and the price rose so that in May Cookson's was listed at 40 cents or more a pound, but in a few days quotations ceased, for the stock in this country was sold. Quotations for other European brands, Hallett's and Hungarian, ceased a little later, leaving the market to Chinese and Japanese (made from Chinese ore), which were quoted in the later part of June at 37 to 37.50 cents a pound.

The demand in this country for antimony for use in type metal, babbitt metal (for bearings), white metals used as a foundation for silver plate, and coffin trimmings is large and persistent and is not satisfied by the Chinese output, although that has been greatly increased.

These conditions have caused the American users to hunt the country over for antimony ores free from arsenic, lead, zinc, and copper. Prospectors have located or have begun to work deposits which have heretofore been unprofitable. The Chapman Smelting Co., of San Francisco, which smelted antimony a number of years ago, has resumed operations, and a new antimony smelter has been erected near San Pedro, which is reported to work upon ores from Wild Rose Canyon, near Ballarat, Cal. Antimony ores have been sold and shipped from Alaska, California, and Nevada.

It seems safe to predict that soon after the close of the war the price of antimony will again drop to or near its antebellum level. Most buyers of ores seem to be discounting heavily against this contingency, and many owners

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[1] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 91–92, 1911.

refuse to sell at the prices offered, which seem to range from 50 cents a unit (1 per cent of a short ton) for clean ores running 35 to 50 per cent antimony to $1 and $1.50 a unit for ores running above 50 per cent, f. o. b. railroad station near mine.

The permanent good which may be hoped for from the present abnormal situation is that the consequent exploitation may develop some mine with ore bodies rich and large enough to be worked at a profit even at the normal low prices.

The following statement relative to the production of antimony ore was issued by the Survey on January 24, 1916:

Antimony prices in 1915 were probably the highest known since the metal became a regular article of commerce. The high prices led to the largest production the United States has made and probably the same statement is true for the world's production.

According to preliminary figures collected for the United States Geological Survey by Frank L. Hess the production of antimony ores in the United States is estimated to have been about 5,000 tons, containing 2,000 tons of antimony, valued at about $325,000. The largest previous domestic production was in 1892, when 150 tons of metal was produced in San Francisco from Nevada ores and 380 tons of ore carrying 55 per cent of antimony was exported. Practically all operations of the past year were new, most were small, and they were widely scattered, so that it is difficult to obtain close figures immediately after the close of the year.

Antimony, which in July, 1914, had been down to a monthly average price of 7.11 cents for Cooksons, and from 5.44 upward for other brands, rose gradually, though unsteadily, to the end of 1915, when Chinese, Japanese, and American antimony were quoted at about 40 cents a pound.

Quotations for Cookson's antimony ceased in May, 1915, some time after an embargo had been declared against the shipment of antimony metal or ores from the British possessions, and 50 cents a pound is said to have been paid for it about June 1, when Chinese was selling for about 35 cents or less. In the fall American antimony appeared on the market for the first time in many years. At first it sold slightly below Chinese and Japanese but was soon quoted at the same price. Miners and smelters, apparently thinking that the high prices would be temporary, did not begin production as quickly as they otherwise might have done, but before the close of the year properties in Alaska, California, Idaho, Nevada, Oregon, Utah, and Washington were producing.

Prices for ores ranged from $1 to $2.10 per unit of antimony. At first, only ores carrying 50 per cent or more antimony were in demand, but before the close of the year 20 per cent ores were being shipped from Nevada.

As a consequence of these conditions the exploitation of the known stibnite ores of Alaska was begun in 1914 and active search was made for new deposits. In 1915 the production of antimony ores began at four mines in the Fairbanks and two in the Nome district, and there was much prospecting for stibnite in other parts of the Territory. All the operations were on a small scale, and at most of the mines they consisted principally in digging out rich ore shoots occurring near the surface by open cuts, together with breaking and hand sorting the ore. There is no record available of the ore mined, but the total shipments of antimony ore from Alaska in 1915 were

833 short tons. Exact information is lacking as to the antimony content of these shipments, but they probably averaged about 58 per cent metallic antimony. It is difficult from the information at hand to determine the value of this product, but the producer probably received from $1.25 to $1.75 a unit of antimony. The best information available indicates that this antimony ore sold at an average of about $86 a ton in San Francisco, where all the Alaska product was marketed. Therefore the total value of crude antimony ore shipped from Alaska during 1915 was probably about $74,000.

Though the antimony mines of Alaska that were productive in 1915 were all located in the Fairbanks and Nome districts, yet many stibnite deposits in other parts of the Territory were also prospected. Such development work is reported from the Nizina, Port Wells, Kantishna, and other districts. The outlook for profitable exploitation of Alaska antimony ores under normal conditions of the market is not very encouraging. It is possible, however, that the larger lodes which carry rich ore and are favorably located for transportation may furnish a field for permanent mining ventures.

GEOGRAPHIC DISTRIBUTION.

All the known localities of stibnite lodes in Alaska, as well as those in which the mineral occurs as an accessory or where it has been reported, are indicated on the accompanying map. (Pl. I, in pocket.) This map indicates the wide distribution of stibnite mineralization and augurs well for the discovery of other lodes.

The antimony lodes thus far found and about which definite information is available occur in the Fairbanks, Kantishna, Innoko, Iditarod, and Port Wells districts and on the Kenai and Seward peninsulas. Lodes have also been reported, however, in the Nizina and upper Tanana districts. Further search is likely to reveal lodes in the regions where thus far stibnite has been found only as an accessory mineral.

Stibnite has been found in only one vein in southeastern Alaska, and here it is only a sporadic occurrence as a minor accessory mineral. Southeastern Alaska is, therefore, not likely to yield any antimony ores. No stibnite occurs in the lodes of the Iliamna district, nor has it been reported in the gold ores of the Alaska Peninsula region. Fairbanks is the only mining district of the Yukon-Tanana region in which stibnite has been found.

With the exceptions noted stibnite occurs in nearly all of the gold-bearing areas of Alaska. As shown below, the stibnite mineralization appears to have taken place chiefly in Tertiary time, and this may account for its absence in those districts in which the latest metallization is of Mesozoic age.

GEOLOGY.[1]

OCCURRENCE OF THE ANTIMONY DEPOSITS.

Most of the Alaska antimony deposits occur in auriferous quartz lodes. In these lodes stibnite is found with other ore minerals in different proportions, but only those in which it is the dominating sulphide offer any promise as a source of antimony. Another phase of the siliceous auriferous antimony lodes is furnished by the stibnite-cinnabar lodes. A more distinct type is formed by the replacement deposits in limestone, where the stibnite is associated with galena.

The country rock of the stibnite lodes is sedimentary as a rule, but it differs greatly both as to age and lithology in the different districts. Some deposits have been found in highly metamorphosed schists of pre-Cambrian age. Others are found in little-altered clastics, as young as Upper Cretaceous. Practically all the antimony lodes occur in association with granular acidic intrusive rocks, among which the dominating lithologic types have been described as quartz diorite and monzonites. The formation of the stibnite lodes seems to have taken place principally in Tertiary time.

COUNTRY ROCK.

The lodes of the Fairbanks and Kantishna districts occur in mica and quartz schist known to be pre-Ordovician and probably of pre-Cambrian age. In the Seward Peninsula the siliceous stibnite lodes occur chiefly in feldspar schists which are infolded with limestones. The age of these rocks has not been determined, but they are either Lower Paleozoic or possibly pre-Cambrian. Galena-stibnite lodes also occur on the peninsula and these lie in Paleozoic limestones. Slates and graywackes form the principal country rock of the Prince William Sound region and Kenai Peninsula where stibnite has been found. These rocks are probably in part Mesozoic but some may be Paleozoic. The antimony lodes of the lower Yukon-Kuskokwim region occur in a belt of sandstones and slates of Mesozoic age and probably chiefly Upper Cretaceous. In the Nizina district the stibnite lodes occur in shales and slates of Upper Cretaceous age.

Wherever the geology of the Alaska stibnite deposits has been studied in detail they have been found in more or less close association with igneous intrusives. They occur as lodes in the igneous rocks themselves, but more often in the country rock not far from the intrusive. The antimony lodes, however, except possibly the stibnite-galena deposits, do not occur in zones of contact metamorphism, for the intrusives in most places appear to have produced but little

[1] The geology of some of the antimony-bearing districts is discussed in greater detail in the descriptions of localities (pp. 17–64).

alteration in the adjacent sediments. All the intrusives with which the antimony lodes are associated belong to the granitic family and in the different districts have been described as granites, diorites, quartz diorites, and monzonites or as porphyritic phases of those types. These intrusives occur as stocks and dikes. It will be shown below (pp. 14–17) that the age of many of these intrusives has not been established, but where determined it is Tertiary. In the Fairbanks and Seward Peninsula districts, where the principal development of antimony deposits has taken place, the intrusives with which they are associated are not older than Mesozoic and may be Tertiary.

ORE BODIES.

CLASSIFICATION.

The Alaska antimony deposits may be classed in three principal groups—siliceous gold-bearing stibnite lodes, stibnite-cinnabar lodes, and stibnite-galena lodes. Of these the first two can be further divided according to structure as fissure veins, shear-zone deposits, and stockworks.

SILICEOUS GOLD-BEARING STIBNITE LODES.

The auriferous quartz lodes that carry antimony comprise the only type of deposit which has thus far been developed on a commercial scale. They all occur along lines of fracturing. If the fracture is clean-cut, a fissure vein is formed. On the other hand, if the movement produced a sheeted zone in the country rock shear-zone or stringer-lead deposits are formed. In some places the fracturing has been of such a character that the lode has the form of a stockwork, but this type has not been recognized among the commercial ore bodies. There is no sharp line of demarcation between the fissure veins and the shear-zone deposits. A well-defined vein may widen out along the strike, include horses of country rock, and merge into a zone of mineralization, thus becoming a shear-zone deposit. Some of the shear zones show great persistency, are well defined, and are traceable for several thousand feet.

The siliceous antimony lodes that have been developed range in width from 2 to 5 feet. Some of the shear-zone deposits include a much greater width within the bounding walls, which may or may not be well defined. In general the antimony lodes differ greatly in width from place to place. A lode several feet wide may, in a distance of a hundred feet, pinch down to a foot or less.

So far as determined the distribution of the commercial antimony ore within the lode is irregular. In the deposits that have been explored the richer ore occurs in shoots or kidneys. These masses in some places occupy the full width of the lode, especially in the wider parts, and are connected by a narrower vein that carries ore of lower grade. In other places most of the stibnite occurs in rich lenses or pod-shaped shoots irregularly distributed through the lode matter, which is composed of quartz, stibnite, other sulphides, and fragments of country rock. At several properties in the Fairbanks district the larger stibnite shoots have roughly parallel axes diagonal to the general strike of the lode.

The mineralogy of the lodes that contain commercial ore bodies is simple. As the market demands are for antimony ore that contains only small quantities of lead or arsenic, the miners have sought lodes as free as possible from other sulphides than stibnite. However, most of the ores contain at least small amounts of galena and pyrite, and it appears that all carry more or less gold, grains of which are occasionally found embedded in the stibnite.

In the commercial ores the stibnite occurs most commonly in fine granular or in coarse or fine columnar aggregates. So far as observed, the fine-granular type seems to be the most common in the richest ores. Another type of ore is that made up of confused aggregates of acicular crystals, some of which show a radial grouping. Small acicular crystals are also seen in some of the granular aggregates.

Practically all the antimony ore, even where it appears to be made up of pure stibnite, carries more or less quartz, generally distributed in fine vitreous grains, some of which show crystal terminations. The ores of lower grade consist of an intergrowth of quartz and stibnite, and some of them carry other sulphides as accessory minerals. Such material constitutes in many places the principal lode filling, and here and there rich kidneys and shoots are distributed through it. Fragments and horses of mineralized country rock occur in some of the lodes, notably in the shear-zone deposits.

Quartz is the principal gangue mineral. That directly associated with the stibnite is generally vitreous, but some of the lodes contain an older or milky quartz that had been fractured and granulated before the stibnite was deposited. The reopening of an older series of quartz veins and the introduction of sulphides into them was specially noted in the Fairbanks district and is more fully described on page 27. Some feldspar is associated with the white quartz but none with the vitreous quartz, which is typical of the antimony ores. Calcite and some ferruginous carbonate is present in some of the ores.

The principal accessory minerals in the stibnite lodes besides the pyrite and galena previously mentioned are arsenopyrite and chalcopyrite, but none of these minerals are abundant in the ores as mined. Other sulphides that occur in the lodes at Fairbanks (pp. 23–24) may belong to the older epoch of mineralization, as is suggested by a specimen from Seward Peninsula, which shows the replacement of arsenopyrite by stibnite.

STIBNITE-CINNABAR LODES.

The development of the stibnite-cinnabar lodes, so far as undertaken at all, has been for their quicksilver content. They occur both as veins and in mineralized shear zones. The distribution of valuable metals probably occurs in shoots and kidneys, as in the types described above, but this has not been proved. Some of the veins of this type show a well-marked banding. Next to the vein walls are bands consisting of an intergrowth of idiomorphic quartz and cinnabar and these are separated by a band made up of stibnite and quartz. In these deposits the stibnite has been formed later than the cinnabar. On the other hand, Smith (pp. 45–46) at another locality found the cinnabar and stibnite in such relation as to show that their deposition was practically contemporaneous. The stibnite of this type of deposit occurs in bladed crystals, in columnar aggregates, and, apparently less commonly, in granular masses. Quartz, the only gangue mineral, is vitreous and commonly has idiomorphic development. Cavities lined with quartz crystals were seen in some of the deposits. Pyrite occurs as an accessory mineral but is not abundant. All these deposits are auriferous, and from the richness of the placers derived from them some must carry considerable gold. The abundance of scheelite in some of the placers which apparently derived their gold from these veins suggests that scheelite must occur in the stibnite-cinnabar lodes, but this has not been proved.

It appears from the information at hand that the origin of the stibnite-cinnabar deposits is essentially like that of the siliceous stibnite gold lodes. These lodes contain galena and arsenopyrite, which are not recognized in the stibnite-cinnabar deposits, and apparently in general a larger percentage of quartz. Gold occurs in both types of deposits, but it is probably more commonly abundant in the siliceous stibnite gold lodes than in the stibnite-cinnabar deposits. It is significant that lodes of the stibnite-cinnabar type have been found only in the Upper Cretaceous sediments, whereas the stibnite-gold lodes are more abundant in the rocks which must have been deeply buried at the time of the vein formation. This suggests that the stibnite-cinnabar lodes were formed at no great depth, a theory which is supported by what is known of the genesis of quicksilver deposits.

STIBNITE-GALENA DEPOSITS.

The stibnite-galena deposits appear to be replacements of crystalline limestone. This designation may be misleading, for it is not definitely established that the galena and stibnite found in close association were deposited during the same epoch of mineralization. Unfortunately there are no specimens at hand which illustrate this type of deposit. Unless there are shoots of stibnite in these deposits which are essentially free from galena, their value is not likely to be great as a source of antimony.

INFLUENCE OF COUNTRY ROCK.

There is no evidence that the mineralogy of the lodes has been affected by the composition of the country rock with the probable exception of the little known galena-stibnite lodes. On the other hand, as most of the antimony lodes occur in fractures, the physical character of the inclosing rocks has influenced the structure of the veins. The openings made by the deformation of the schists are more likely to have taken the form of irregular zones of fracture than are those in the more massive rocks. The form of the openings, however, depends on the space relations of the fractures that now contain the lodes to the original schistosity. If these two structures intersect at a considerable angle the fissure may be as clean-cut in the schists as in the more massive rocks. The best-defined fissures are those in the igneous rocks, but these, so far as observed, are narrow and usually are not traceable for any considerable distance. Less is known about the antimony lodes in the graywackes and slates, but to judge from the auriferous veins in the same class of rocks strong veins are likely to occur.

VERTICAL DISTRIBUTION OF ORES.

As the greatest depth to which any of the stibnite lodes have been developed is about 200 feet below the outcrop, there is no information available as to possible changes in the character of mineralization at greater depths. There is, however, no probability that any changes will occur near enough to the surface to affect the value of the antimony lodes. This view is supported by the fact that in several districts the stibnite lodes that outcrop in a vertical range of 1,000 feet or more show no difference in mineral character.

OXIDATION.

As a general rule the Alaska antimony deposits show but little oxidation. In the Fairbanks district stibnite ores have been found directly underneath the grass roots with less than one-fourth inch of incrustation of secondary minerals. (See pp. 26–27.) At these localities the subsoil was permanently frozen when the deposit was uncovered. In other places, where the ground was not frozen, some oxidation has been found at greater depth, but nowhere has it been sufficient to materially affect the character of the ore. The same conditions probably prevail in most of the occurrences of stibnite in the Yukon and Kuskokwim basins and on Seward Peninsula, where, as a rule, the ground is permanently frozen.

On Prince William Sound, on Kenai Peninsula, and in the Nizina district the recent profound glaciation has swept away any oxidized portion of the lodes which may have previously existed. Therefore in these districts, too, the massive unaltered stibnite is found close to the surface.

AGE OF MINERALIZATION.

Many of the Alaska stibnite deposits occur in districts in which the age of the mineralization has not been definitely determined. Nevertheless the evidence at hand indicates that most of the stibnite deposits were formed at a later time than the widespread epoch of Mesozoic mineralization to which so many of the gold deposits have been assigned. The evidence of age will be briefly summarized, taking up the districts in geographic order from south to north.

In southeastern Alaska, where the Mesozoic epoch of mineralization was specially pronounced, only a single occurrence of stibnite, even as an accessory mineral, is known. The same absence of stibnite is noticeable along the coast of British Columbia, where the only exceptions known are some stibnite veins in the Portland Canal district, described by McConnell.[1] It should be noted, however, that this district, though on tidewater, actually lies inside of the Coast Range batholith, where the character of the mineralization is very different from that of southeastern Alaska. This situation suggests that it may lie in different metallogenetic provinces from that of coastal Alaska and British Columbia.

The mineralization of the Nizina district, in the Copper River basin, where stibnite and gold-bearing veins have been found, is later than the intrusives which cut Upper Cretaceous sediments. There is no direct evidence of the age of the stibnite and gold-bearing veins of Prince William Sound and Kenai Peninsula, which lie 200 miles west of the Nizina district, though it has usually been regarded as Mesozoic. In the Iliamna region, still farther west, where the mineralization is connected with Mesozoic intrusives, no stibnite is present.

A stibnite vein has been found in the Willow Creek district, north of Cook Inlet. In this area the gold lodes, which so far as known carry no stibnite, are associated with quartz diorites that are believed to be of Mesozoic age. There are, however, some later dioritic intrusives that occur as dikes. Tertiary intrusives of similar type are found in adjacent areas. It is therefore quite possible that the

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[1] McConnell, R. G., Portions of Portland Canal and Skeena mining divisions, Skeena district, British Columbia: Canada Geol. Survey Mem. 32, pp. 17, 28, 45, 1913.

stibnite mineralization of the Willow Creek district may be connected with Tertiary intrusives.

The gold lodes of Unga Island, in southwestern Alaska, and some auriferous quartz stringers found on Unalaska Island, at the eastern end of the Aleutian chain, are probably of Tertiary age, but so far as known no stibnite has been found in any of these deposits. This is the only example of Tertiary metallization known in Alaska in which stibnite has not been found.

Some small stibnite lodes have been found in the Duncan district[1] and the Whitehorse district of the Canadian Yukon.[2] In neither of these districts is the age of the mineralization well established, though it has been generally regarded as Mesozoic.

Occurrences of antimony-bearing lodes in the Wheaton district have been described by Cairnes,[3] who, in discussing their age, states that "they therefor would seem to be all more recent than late Cretaceous and to antedate late Tertiary times." The same geologist has noted the occurrence of stibnite veins on Taku Arm of Lake Tagish, in the Atlin district of northern British Columbia.[4] These veins cut shales of Jura-Cretaceous age. The principal mineralization in this area is connected with Mesozoic intrusives, but Cairnes has made no definite statement as to the age of the stibnite lodes. The similarity of the geology of this district with that of the Wheaton district, referred to above, suggests that these stibnite veins may be of Tertiary age.

Though the quartz veins of the Klondike district have been examined in detail,[5] stibnite has not been found in any of them, even as an accessory mineral. Nor, save at Fairbanks, has stibnite been found in the placer camps of the Yukon-Tanana region, which can be regarded as a westerly extension of the Klondike auriferous zone. In this field the age of the auriferous mineralization is by no means definitely established. It is connected with granular intrusive rocks which are for the most part pre-Eocene, and the evidence in hand suggests their correlation with the great irruptive period of Jurassic or Cretaceous time. There is some evidence, however, of a later period of mineralization in the Fairbanks district (pp. 23–24), during which the stibnite was deposited, possibly in Tertiary time.

There is no direct evidence for determining the age of the antimony lodes in the Kantishna district. These lodes are probably

[1] MacLean, T. A., Lode mining in Yukon: Canada Dept. Mines, Mines Branch, p. 154, 1914.

[2] McConnell, R. G., The Whitehorse copper belt, Yukon Territory: Canada Geol. Survey, Dept. Mines, Pub. 1050, p. 28, 1909.

[3] Cairnes, D. D., Wheaton district, Yukon Territory: Canada Geol. Survey Mem. 31, p. 122, 1912.

[4] Cairnes, D. D., Portions of Atlin district, British Columbia: Canada Geol. Survey Mem. 37, p. 116, 1913.

[5] MacLean, T. A., Lode mining in Yukon; Canada Dept. Mines, Mines Branch, Pub. 222, 1914.

genetically related to granitic intrusive rocks which, to judge from what is known of adjacent areas, might be of early Tertiary or of Jurassic age.

The stibnite deposits of the Innoko-Iditarod and lower Kuskokwim region are all closely connected with intrusives that cut Upper Cretaceous rocks, which is also true of the stibnite found in the eastern part of the Norton Bay region (p. 64). There is no direct evidence of the age of the stibnite lodes of the Seward Peninsula, but these are for the most part associated with intrusives which are generally regarded as Mesozoic. It is not improbable that among these intrusives there may be some injected as late as Tertiary times. There are, however, in the peninsula several distinct phases of metallization, namely, the tin, tungsten, galena, gold, iron, and antimony, and the time relation of the deposition of these metals has not been determined. There is some evidence that the auriferous antimony-bearing veins are later than those which furnished much of the placer gold.

The above summary presents the known facts bearing on the age of the antimony mineralization. They do not prove that the stibnite has been everywhere introduced in Tertiary time, but it is true that where the age of the stibnite veins is known they are post-Mesozoic. Only one example (see p. 62) of the presence of stibnite in lodes of known Mesozoic age has been found, and in this place it occurs only as a minor accessory. It is also true that in many of the deposits stibnite can be shown to belong to the latest epoch of metallization. This does not mean, however, that its formation was separated from the older epoch of metallization by any considerable period of geologic time. The stibnite may merely represent the last of several stages in one general period of mineralization.

Formerly it was generally believed that nearly all the metalliferous deposits of Alaska were associated with Mesozoic intrusives.[1] It is only in recent years since the metalliferous deposits of the lower Yukon and Kuskokwim regions have been studied that the importance of the Tertiary period of mineralization has been recognized. Localities in this general province as widely separated as the lower Kuskokwim and northern British Columbia are now known to have been mineralized in Tertiary time, but between these localities there are mining districts in which the metallization is of Mesozoic age. Thus there seems to be here an overlapping of the two metallogenetic provinces. Like the Mesozoic mineralization, that of Tertiary age is genetically connected with granular acidic intrusive rocks, but the later intrusives seem to have been less widely distributed than

[1] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 56–58, 1911.

the earlier, which is believed to be due to certain features of the tectonic history that therefore merit brief mention.

In pre-Upper Cretaceous Mesozoic time most of Alaska was subject to pronounced recurrent deformation. The important feature of these movements, which are not here discussed, is that they were widespread. Accompanying and immediately following them there were injections of enormous masses of igneous rocks in connection with which there was widespread mineralization. It is by no means certain that there may not have been more than one epoch of Mesozoic mineralization.

The next important diastrophic event was the post-Kenai (Eocene) revolution, which was widespread, but the intensity of deformation differed greatly from place to place. In one area the Kenai rocks were intensely folded, but in an adjacent province they were only gently plicated, and it is only where sharp folding took place that igneous rocks were injected. As the mineralization is closely related to these intrusives, its action was also localized. Probably most of the irregularities in the distribution of the Tertiary metalliferous veins is thus accounted for.

It should be noted that though mineralization accompanied the Tertiary intrusives, no metalliferous lodes have been found in the Tertiary sediments. It appears that the conditions for the formation of the metalliferous veins necessitated a deeper cover than that furnished by these beds.

LOCALITIES.

FAIRBANKS DISTRICT.

DEVELOPMENT OF ANTIMONY DEPOSITS.

Stibnite was first found in the Fairbanks district during the early history of the camp in the concentrates from the placer mines on Cleary Creek. As the region became better known, especially after the development of the auriferous lodes, stibnite was found to be a common accessory mineral in some of the metalliferous deposits. Lodes were also discovered in which stibnite formed the principal metallic mineral, but they received little attention until the abnormally high price of antimony during the past two years made them available for commercial exploitation. In 1915 antimony ore was mined on four properties in the Fairbanks district—at the Scrafford, in Treasure Creek basin; the Stibnite, in Eva Creek basin; the Gilmer, in Vault Creek basin; and at Chatham Creek mine. All the operations were on a small scale and consisted chiefly of open cuts. The total shipments of stibnite from the district during 1915 were 685 tons, which probably averaged 58 per cent antimony.

Before describing the occurrences of stibnite it will be desirable to briefly review the geology of the Fairbanks district. This will make it possible to indicate the geologic associations of the stibnite deposits and to suggest something of their genesis. The sketch of the geology is largely abstracted from the reports of L. M. Prindle and F. J. Katz,[1] which have been amplified by the studies of the metalliferous veins by Philip S. Smith[1] and Theodore Chapin.[2] This material has been supplemented by the writer's own observations, made during numerous visits to the Fairbanks district.

GEOLOGY.

FORMATIONS.

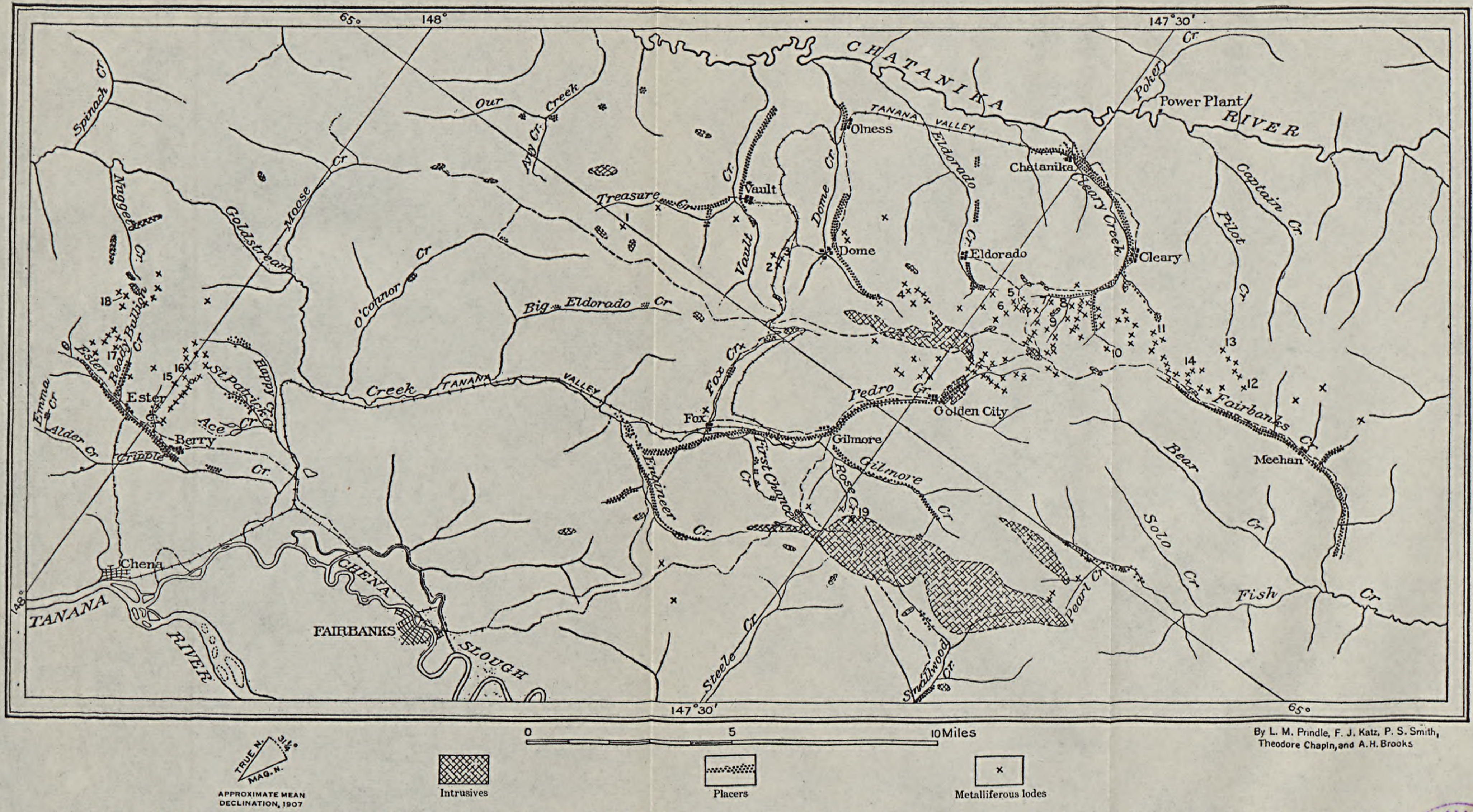
The larger features of the geology of the Fairbanks district are relatively simple, though the detailed structure and stratigraphy are so complex that in view of the scarcity of outcrops they almost defy analysis. Prindle and Katz[1] have shown that the dominating formation is made up of metamorphic rocks of sedimentary origin, consisting chiefly of quartzitic and quartz mica schist and some massive quartzites. With them occur some hornblende schists. These rocks have been grouped together under the name Birch Creek schist and are probably of pre-Cambrian age. The whole series has been rendered profoundly schistose. The schist area is also broken by some irregular belts of crystalline limestones and calcareous rocks, which have, for the most part, been much altered and in which the calcite has in many places been very largely replaced by secondary minerals. Some carbonaceous schists are associated with the limestones. The outcrops of these rocks are too few to make it possible to map them accurately, but their distribution, so far as known, suggests that they mark definite horizons in the metamorphic series.

The intrusive rocks of the area include a few belts of granite gneiss, which were intruded before the deformation which produced the schistosity. More important in this discussion are the extensive stocks of dioritic and granitic rocks (Pl. II) as well as dikes of the same composition. Prindle and Katz have recognized three epochs of intrusion. The earliest intrusive rock is quartz diorite, which is followed by porphyritic granite. These two types of intrusives occur both as stocks and dikes. Both are cut by acidic dikes which consist chiefly of quartz and feldspar.

There is no direct evidence of the age of the massive intrusives, but it seems certain that they are not older than the Mesozoic. Evi-

[1] Prindle, L. M., Katz, F. J., and Smith, P. S., A geologic reconnaissance of the Fairbanks quadrangle: U. S. Geol. Survey Bull. 525, 1913.

[2] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 222–335, 1914.



MAP SHOWING MINERAL RESOURCES OF FAIRBANKS DISTRICT AND LOCATION OF MINES AND PROSPECTS THAT CONTAIN MORE OR LESS STIBNITE.

1. Scrafford antimony mine.
2. Gilmer antimony lode.
3. Fredericks mine.
4. Spaulding claim.
5. Eldorado Creek Mining Co.
6. Newsboy mine.
7. Tolovana mine.
8. Rhoads & Hall mine.
9. North Star claim.
10. Chatham Creek gold and antimony mine.
11. Homestake mine.
12. Crites & Feldman mine.
13. Rob & Roy claim.
14. Mizpah mine.
15. Stibnite lode.
16. Jolly Rogers and Prometheus claims.
17. Hudson mine.
18. Jenny C. antimony claim.
19. Rose Creek claim.

dence is accumulating from some of the Yukon districts that all the massive intrusives are of Mesozoic or Eocene age. Monzonites have been found cutting Upper Cretaceous rocks in the western part of the Fairbanks and in the adjacent part of the Rampart quadrangle. The same period of intrusion is extensively represented in the Innoko-Iditarod region. In the Broad Pass region, 100 miles to the south of Fairbanks, granites and quartz monzonites cut Kenai (Eocene) sediments.[1] There are some conglomerates in Fairbanks district which include pebbles of massive granite.[2] These conglomerates are probably Tertiary, but may be post-Eocene, and hence this occurrence does not prove the pre-Eocene age of the granite.

The evidence in hand indicates that the intrusives are probably not older than Lower Cretaceous and some may be of late Upper Cretaceous or Eocene age.

STRUCTURE.

It has been pointed out that the distribution of the calcareous rocks indicates an original eastward-trending structure for the sedimentary rocks and that this structure has been modified by later profound deformation, which has rendered all the rocks schistose. Evidence from adjacent areas shows that this metamorphism and the accompanying schistosity were produced by movements which took place in pre-Paleozoic time. There is good reason to believe that the present complex structures are the end results of several periods of deformation, some of which took place in Paleozoic and some in Mesozoic time. There was also an epoch of deformation in Eocene times. The evidence for these periods of deformation will not be discussed here, but it will be noted that the Paleozoic rocks of the Yukon appear to have been deformed in pre-Mesozoic time and that there was also a well-marked period of deformation, accompanied by some metamorphism, which involved rocks as young as the Lower Cretaceous. The Eocene rocks of Yukon basin are also deformed. In the Fairbanks district these disturbances did not affect the massive granites, for since their intrusion the movements are recorded only as fissures, faults, and joints.

Prindle and Katz[3] have pointed out that the distribution of some of the calcareous beds suggests certain larger folds and that, superimposed on these folds are an infinite number of minor closed folds, chiefly overturned to the northwest. These minor folds were probably accompanied by dislocations, though the observed facts give little evidence of this. In the east half of the district the schistosity strikes east and northeast. To the west this trend gradually swings to the southwest. In the Ester Dome region the dominating trend of

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[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, 1915.
[2] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 66–67.
[3] Idem, pp. 75–76.

schistosity is north and northwest. This crescentic sweep of schistosity parallels the major structural features of central Alaska. This crescent, marked by the dominating structure, which is open toward the Pacific, is the result of folding in post-Kenai (Eocene) time, but these Eocene structures probably follow in part the tectonic lines of a Mesozoic epoch of deformation.

Though the average trends of schistosity lie in the directions noted above, there are many local variations. There are also systems of jointing which have not been studied in detail. The fissuring which marks the lode system will be discussed below.

The larger stocks of granite and quartz diorite trend from N. 70° E. to east. Therefore, they are intruded parallel to what is believed to be the original structure rather than to that of the foliation. Adjacent to the stocks, however, the foliation of the schists is, as a rule, parallel to the intrusives. Far more irregular is the strike of the acidic dikes, which in part follows the foliation and in part is parallel to the system of fissures occupied by the metalliferous veins.

LODE SYSTEMS.

Most of the developed metalliferous veins of the Fairbanks district group themselves into two areas, though some discoveries have been made in a third zone (fig. 1). The one marks a fairly well defined zone that stretches from Treasure Creek on the west to the lower part of Fairbanks Creek on the east, and includes the upper basin of Vault, Eldorado, Goldstream, and Cleary creeks (Pl. II, p. 18). It is not improbable that the placers found on Any Creek, which flows into Our Creek, a tributary of the Chatanika, and on O'Connor Creek, which flows into Goldstream Creek, may have derived their gold from a westward extension of the mineralized zone. The trend of the mineralized zone is about N. 70° E., which is roughly parallel to the limestone belts and to the major axis of the Pedro Dome quartz diorite intrusives.

As defined by lode discoveries, the belt has been traced about 20 miles and has an extreme width at the head of Cleary Creek of about 2 miles. It can be conveniently designated the Cleary mineralized zone. This zone is intruded by many dikes which appear to be specially abundant in the most strongly mineralized areas. The most abundant lodes of this zone are those that carry gold, and many of the richest placers of the district occur on the streams which traverse this zone. Stibnite deposits are also common but have thus far been found only in that part of the zone which lies north of the Pedro Dome quartz diorite stock. In other respects the mineralization on the two margins of the stock is the same, so far as determined. Some galena deposits have also been found in the Cleary lode system.

The second zone of metalliferous veins lies in the western part of the district and comprises a roughly circular area about $2\frac{1}{2}$ miles in diameter, approximately centered on Ester Dome (fig. 1). This area is drained by the northern tributaries of Ester Creek and by Nugget Creek, which flows into Goldstream Creek, and may be termed the Ester mineralized zone. It is cut by many dikes. Its metalliferous deposits are in general similar to those of the Cleary zone, and like

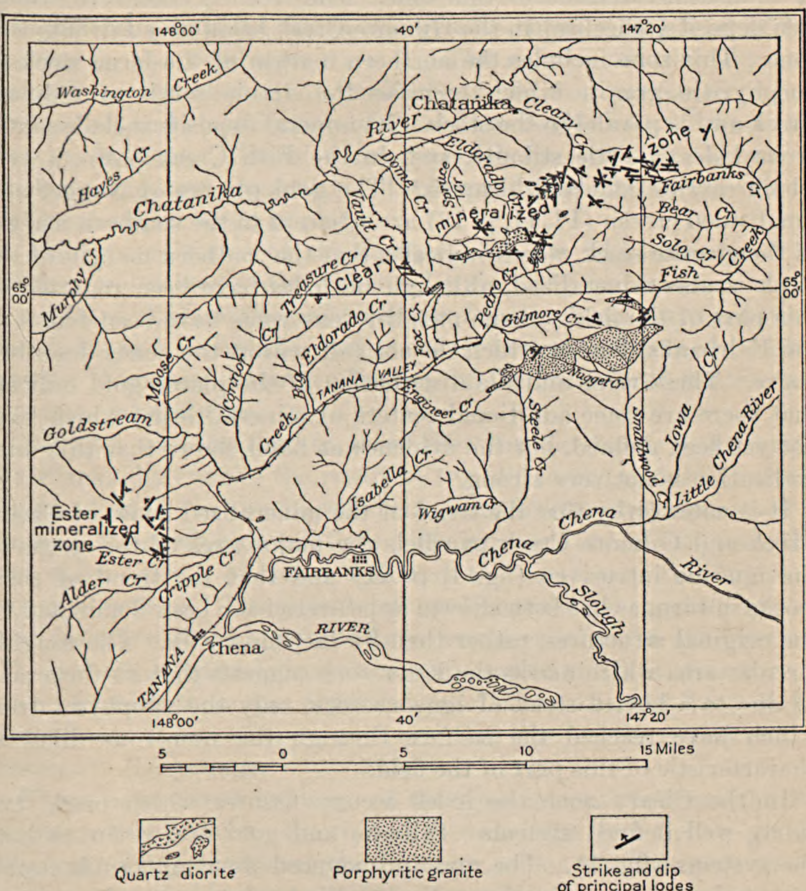

FIGURE 1.—Sketch map showing distribution of lodes, Fairbanks district.

them they include both antimony and gold ores and have yielded material for rich placers. Thus far galena has been found only as an accessory mineral in the deposits of this zone.

Though it is not impossible that the Cleary and Ester mineralized zones may form part of the same belt, there is no evidence of this relation. The arrangement of fissuring is different in the two zones, and there are some differences in the minerals of the vein matter.

Moreover, little or no evidence of mineralization has been found in the area which separates the two zones.

Some metalliferous deposits which are but little developed have been found in a third belt, which, so far as defined by present discoveries, stretches in a direction about N. 70° E. from a point near the mouth of Gilmore Creek into the Fish Creek basin. It is possible that the placers of Engineer Creek are derived from veins which lie in a western extension of this zone. The recently discovered tungsten deposit (scheelite) in the Gilmore Creek basin may fall into this zone. This zone includes the northern margin of the large stock of porphyritic granite which occupies the divide south of Gilmore Creek and is paralel to the stock. Its mineral deposits include auriferous lodes, a little stibnite, and, in the Fish Creek basin, a vein which carries gold and bismuth.[1] The gold placers of Nugget and Smallwood creeks (Pl. II, p. 18) are adjacent to the southern margin of the granite stock, which indicates that the southern margin of the stock is also mineralized, although no lodes have been reported in this part of the field. Some metalliferous veins have been found in the Fairbanks district which do not fall within the zones described above. These veins and the distribution of the placer gold indicate that there are some additional centers of mineralization which have not yet been defined, but the evidence at hand shows that this mineralization is not very strong.

It is noteworthy that the trend of the mineralized zones of Cleary Creek and Gilmore Creek parallels the major axes of the stocks of the igneous intrusives (fig. 1, p. 21) and that the trend of these stocks in turn, as has been shown, appears to have been dominated by the original structures, rather than by the schistosity. The roughly circular area which marks the Ester zone suggests that its form may be due to a buried stock of igneous rock, only the apophyses from which have reached the surface through the numerous dikes so characteristic of this part of the field.

In the Cleary zone the lodes occupy fissures which mark two fairly well defined systems. Stibnite and gold ores occur in both the systems (fig. 1). The most pronounced fissuring trends nearly east and west, ranging from N. 70° W. to due west. It is along this system that most of the rich lodes have been found. At about right angles to this trend lies another set of fissures in which some valuable stibnite and gold lodes have also been found. There are also some variations from these two general lines of trend, several veins having been found which strike N. 30°–60° E. The fissuring in the Ester zone shows far greater irregularity of direction, but the dominating trends fall into two systems, one striking N. 30°–60° E.

[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, p. 331, 1914.

and one N. 10°–40° W. Here the facts in hand suggest that the stibnite lodes fall chiefly in the northwesterly system, though this is by no means proved. The two systems of fissuring as a rule cut the foliation of the schists in both zones. Offshoots from the main lodes, however, penetrate the schists parallel to the foliation at several localities. There are also some small mineralized veins which follow the planes of foliation.

There has been considerable faulting since the formation of the metalliferous deposits, which has greatly enhanced the cost of lode mining in the Fairbanks district. The scarcity of rock exposure, as well as the absence of detailed studies, has prevented the coördination and classification of these later faults into a definite system or systems. Faults which parallel the veins are shown by slickensiding, and crosscutting displacements which cut the veins at different angles occur in places.

The time relations of the earth movements which produced the fissures and subsequently dislocated them is by no means clear. In the Cleary zone northward-trending veins crosscut eastward-trending veins and eastward-trending veins crosscut northward-trending veins. Moreover, the mineralization of the two sets of fissures is of the same general type.

Prindle[1] was the first to show that the auriferous lodes of the Fairbanks district are the result of two different periods of metallization; that is, that auriferous veins were fractured and enriched by impregnating sulphide solutions. The evidence in hand suggests that the older system of veins followed the same two trends as the younger systems. The second deformation, however, opened up some new fractures which appear to have been parallel to the old fractures. The end result was a lode system composed of two sets of fissures, in each of which there was a general parallelism of trend line. In the Ester zone there is some evidence that the northwesterly set of fissures is the younger.

There is no direct evidence of the time interval between the two tectonic disturbances. Smith has recorded the fact that a granite dike cuts a quartz vein at the Rainbow mine,[2] but this may be one of the systems of barren quartz stringers which are not uncommon in the schists and which appear to antedate the intrusion of the metallized veins. The close association between the granite stock and the mineralized zone south of Gilmore Creek might suggest that these belong to a different period of mineralization from that of the Cleary lode system, which is associated with the quartz diorite stock. This

[1] Prindle, L. M., Auriferous quartz veins of the Fairbanks district: U. S. Geol. Survey Bull. 442, pp. 218–220, 1910.

[2] Prindle, L. M., Katz, F. J., and Smith, P. S., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, p. 199, 1913.

view finds some support in certain differences of mineral contents of the veins as already noted.

The close association of the mineralization with the acidic dikes that represent the last period of igneous intrusion is supported by a large number of facts. No evidence has been found that the earlier auriferous mineralization and the later sulphide enrichment were separated by any considerable epoch, though they may have been thus separated. It will be shown that in many other districts where the age of the mineralization is known the antimony deposits are of Eocene age, and those in the Fairbanks district may be of the same age. If so, it appears necessary to assign a Tertiary age to most if not all the sulphide ores of the district, for, as will be shown, the stibnite lodes can not, on the basis of present information, be assigned to a different period of mineralization from the other sulphide deposits.

THE LODES.

Distribution.—Lodes in which stibnite forms the principal metallic mineral occur in both the Cleary and Ester mineralized zones. In both these zones stibnite is also found, as an accessory mineral with other sulphides in quartz veins that are principally valuable for their gold content. (See fig. 1, p. 21, and Pl. II, p. 18.) As already noted, in the Cleary zone the antimony deposits are found only north of the Pedro Dome quartz diorite stock. A little antimony ore has also been found on Rose Creek, which belongs to the Gilmore Creek mineralized zone.

Association.—Most of the stibnite deposits of the district occur in a country rock of mica schist or quartz schist. One deposit is known in small veins which cut porphyritic granite, and several lie at or close to the contact of the acidic dikes with the schists. No stibnite lodes have been found in the altered limestones of the district, but stibnite occurs as an accessory mineral in some of the gold ores which are associated with calcareous rocks. Chapin[1] reports the occurrence of lead sulphantimonite (jamesonite?) in association with galena deposits, which appear to be replacements of calcareous bands in the schist.

The present information indicates that the stibnite lodes which promise to be commercially valuable occur in the mica and quartz schists, where the physical conditions for fracturing seem to have been more favorable than in the massive intrusives; also that they occur in close association with the dikes that mark the latest epoch of intrusion.

Form of occurrence.—All the antimony deposits thus far found occur in zones of fracture. In some places the fracturing has resulted

[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, p. 324, 1914.

in open spacing, and these spaces are occupied by lodes of tabular type. More often the mineral-bearing solutions have permeated a sheet zone of fracture. There is, however, no sharp distinction between the two types of ore bodies as they merge into each other. A fissure may be traceable for some distance and then merge into a zone of fracture, and beyond open out again as a fissure.

Though many of the stibnite-bearing quartz veins maintain a fair degree of regularity, the stibnite lodes proper show great variation in width. The width observed ranged from a foot or less to 3 or 4 feet. Some sheet zones are reported as wide as 8 and 10 feet, but much of the material included between the walls of these zones is country rock.

Some of these veins are bounded by well-defined walls, marked by slickensides and gouge. In others only the hanging wall is slickensided, whereas on the footwall side the vein material is intermingled with country rock or penetrates it in small gash veins. Some of the deposits are said to have been followed for a long distance; one is reported to be traceable for 3,000 feet. The present developments indicate, however, that most of the lodes have not been traced more than a few hundred feet. This may, however, be due rather to the general scarcity of outcrop in the region than to lack of continuity of the deposits.

Prindle and Katz[1] have described the occurrence of stibnite in what appears to be small stockworks, in which the ore forms "a network of stibnite veins between fragments of brecciated schists." This type is probably not essentially different from the sheet zones described above.

The typical occurrence of stibnite is in shoots and kidneys, which are more or less irregularly distributed along the vein or sheet zone. These masses of ore, many of which are almost entirely pure, are separated by a mixture of quartz and stibnite and, in some places, by crushed and more or less mineralized country rock. The large ore shoots are generally lenticular or pod-shaped and have a well-defined pitch. So far as could be observed some of them have a parallel arrangement in the lode in a direction which may vary as much as 40° from the strike of the vein. Some ore shoots 40 feet in length and 4 to 6 feet wide have been found, but most of them are much smaller. Many of these shoots consist of almost pure stibnite, with only accessory quartz. Smaller shoots and kidneys of less regular form are more plentiful, and such masses of stibnite, weighing several hundred pounds, are not uncommon. The antimony ores mined in the district have all been taken from such shoots and kidneys. The material is broken up and concentrated by hand sorting. Most of

[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., p. 90.

the developed lodes lay close to the surface, and the deepest operations on antimony ores have gone down only about 200 feet.

Some shoots of antimony ore have been found in the auriferous quartz veins, but, so far as observed, this is rather exceptional, for most of the stibnite of the quartz veins occurs in disseminated particles or crystals with other sulphides. Some shoots and kidneys of stibnite are found in shear zones adjacent to auriferous quartz, where the vein forms one wall of the antimony lode. In other places the antimony lode cuts across the quartz vein and is clearly younger.

Minerals.—The lodes developed for antimony are largely composed of stibnite, and quartz is the only important gangue mineral, though some lodes contain a little calcite. The information at hand indicates that all the antimony ores are more or less auriferous. A few specks of gold can be seen in some of the stibnite.

The chief accessory minerals are pyrite, arsenopyrite, and galena. In the deposits that have been developed these accessory minerals are as a rule not abundant, partly no doubt because the miners have sought for lodes in which the antimony ores carry a minimum of impurities. In addition to the minerals noted above, sphalerite, chalcopyrite, tetrahedrite, and chalcocite have been noted in auriferous quartz veins which carry stibnite. Some of these quartz veins contain a small amount of albite and orthoclase. These accessory gangue minerals appear to be confined to the older period of mineralization and were not introduced with the sulphides. The feldspars, therefore, are believed not to occur in the stibnite deposits except where these are impregnations of the older epoch of mineralization.

The stibnite of the shoots and kidneys occurs in a variety of forms. Some of it is finely granular, with only here and there fibrous masses or acicular crystals. This form of the stibnite is probably the most common in the commercial ore bodies. Another type consists of a confused aggregate of acicular crystals, some of them showing a radial grouping. Again, the stibnite occurs in coarse and fine columnar form interspersed with fibrous and granular aggregates. In nearly all the specimens of stibnite that have been examined a little quartz was observed embedded in the mineral aggregate. This quartz has a vitreous character and occurs in fine grains, some of which show crystal terminations. Some of these crystal forms can be seen with the naked eye; others are visible only under strong magnification. This is probably the impurity which reduces the grade of the ore in the stibnite shoots and kidneys.

Most of the stibnite ore bodies that have been opened show oxidation products in larger or smaller amount. Chapin[1] has determined these secondary minerals to be chiefly cervantite, together with some

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[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, p. 325, 1914.

stibiconite. The oxidation products usually occur as a comparatively thin film, though in some places they form an incrustation one-fourth to one-half inch in thickness. There is no definite information as to the depth to which the oxidation extends, but it appears to be a rather superficial phenomenon. Even in stibnite masses which are directly beneath the soil the oxidation products may be less than a quarter of an inch thick, which is due, no doubt, to the fact that as a rule the subsoil is permanently frozen in the Fairbanks district. Exceptions to this rule are found at different localities, for example, on slopes which have a south exposure, especially those which have been burned over and the protecting coating of moss thus removed. This permanently frozen condition, which extends to bedrock, prevents the circulation of ground water. Nevertheless, some oxidation of pyrite has been found to the depth of the deepest gold mining in the district, which does not exceed about 300 feet. It appears that the zones of fracture are, in part at least, unfrozen to the present depth of mining. Little water has been encountered at depth. Many of the mine workings are dry, and the water of those that are not is probably of immediate surface derivation.

It is possible that some of the oxidation of sulphides may have taken place previous to the formation of the permanent ground frost. This frozen condition of the subsoil is interpreted as a survival of the climatic conditions that prevailed during the last glacial epoch. The thick blanket of moss has prevented the thawing out of this deep frost in spite of the milder climate of the present day. It has also greatly retarded erosion, and thus the oxidized parts of the veins may have been preserved since the last glacial epoch. It should be noted that the district is unglaciated, but the glaciers from the Alaska Range to the north reached within 40 or 50 miles of Fairbanks. There is no doubt that the climate of the Yukon basin was much colder during this ice advance than it is at present.

The quartz gangue of the stibnite lodes is white and vitreous. It occurs in small grains included in the stibnite and in larger masses between the ore bodies. Some of the grains within the ore masses show terminal faces, but as a rule the gangue quartz is allotriomorphic. In the stibnite-bearing auriferous veins druses which carry well-developed crystals are found here and there.

In many of these auriferous lodes two generations of quartz are observable. Some of the stibnite lodes proper also show an older quartz, which has been fractured and impregnated with sulphides accompanied by some quartz deposits. In these lodes thin films of stibnite separate fractured mosaics of quartz and are accompanied by some secondary quartz deposition. Where two generations of quartz are observed the older is white, the younger vitreous.

MINES AND PROSPECTS.

To present a complete account of all the occurrences of antimony in the Fairbanks district would be to duplicate a large part of the descriptions that have been published of the metalliferous veins, for many of these contain stibnite, at least as an accessory mineral. On the other hand, if only those stibnite lodes were described that have been developed on a commercial scale some promising ore lodes would be omitted. It therefore seems best to describe not only the four mines that have been productive, but also to refer briefly to the deposits in which stibnite has been found in association with other ores. The information is far from being complete, and there may be occurrences of antimony about which the Geological Survey has no information. The general distribution has already been noted. The deposits here to be described will be grouped according to the mineralized zone in which they fall. (See fig. 1, p. 21.)

CLEARY MINERALIZED ZONE.

Scrafford property.—An antimony lode has been developed on a claim located on Eagle Creek, a southwesterly tributary of Treasure Creek (Pl. II, p. 18). This claim is part of a group of locations, including the Chief, Sunrise, and other claims, of which Edward Quinn and others were owners and E. L. Scrafford the lessee in 1915. It is known as the Scrafford property or the Black Eagle mine.

Systematic development work was started in June, 1915, and about 25 men were employed during the summer. This force had been reduced to 20 men when the property was visited in September.

The country rock is quartz-mica schist. It is finely foliated, and the planes of schistosity strike about N. 60° E. and dip steeply to the northwest. No intrusive rocks were observed near the lode, but the extension of its strike to the east will bring it close to the dike which cuts the schist. The lode is marked by a shear zone which cuts the foliation of the schist and is readily traceable for several hundred feet at the mine openings. This shear zone strikes nearly east and dips 50°–70° S. The management reports that the zone of mineralization can be traced through two claims, a distance of about 3,000 feet, but the time available for the examination did not permit an examination of the extension of the deposit.

In the brief time devoted to the examination, especially in view of the lack of bedrock exposures, it was not possible to definitely determine the width of the shear zone. Where the lode had been opened the limits of ore deposition appeared to be within walls 3 to 4 feet apart. Here the hanging wall consists of a mass of iron-stained schist which has been much crushed. The schists were iron stained and fractured, however, for at least several feet beyond what was considered the hanging wall or lode. Moreover, the management reports the shear zone to be 10 feet wide in some places.

The richest ore occurs in shoots, which appear to be pod or lens shaped, whose longer axes have a trend that diverges 15° to 20° from the trend of the vein. The largest of these shoots measured about 40 feet in its longest dimension. The shoots are separated by an aggregate of quartz intergrown with stibnite and kidneys of stibnite, together with iron-stained fragments of the schist that forms the country rock. These fragments of schist included in the lode consist of quartz grains with films of sericite and have a parallel arrangement of minerals. They also include some vein quartz and sulphides. Stibnite is the only important metallic mineral in the lode, but a little free gold and galena are also present and probably pyrite, though this was not seen in unoxidized form. The management reports that the highest assay value obtained was $4 worth of gold and 8 ounces of silver to the ton, and only a trace of lead.

The stibnite occurs in finely fibrous and columnar form as well as in granular aggregates. The surface of the masses of stibnite shows considerable oxidation; secondary minerals form an incrustation half an inch or more in thickness. It appears that the subsoil at this locality was not permanently frozen, probably owing to the southern exposure of the locality where the lode has been opened. This situation has probably favored oxidation. The larger ore shoots, which appear to consist of almost pure stibnite, nearly all seem to contain some quartz, which in part occurs in visible aggregates, in part in fine grains only recognizable with a lens. This quartz is vitreous, as is also that which forms part of the matrix in which the shoots and kidneys are contained.

The deposit has been worked by an open cut along the vein which had been extended into the hill by an adit about 75 feet long in September, 1915. There are also some small stopes and a 20-foot shaft.

The ore is broken and sorted by hand. It is hoisted by an inclined cable-tram about 3,000 feet long to the top of the ridge, about 600 feet above the mine. Cars of 1-ton capacity are hoisted by a 15-horsepower gasoline engine. From the head of the tram the ore is hauled by teams to the railroad, a distance of about 4½ miles.

Gilmer lode.—Some antimony ore has been mined on the Gilmer lode, which is located on the east slope of Vault Creek. The series of open cuts and pits by which the lode has been traced crosses the Tanana Valley Railroad about a quarter of a mile south of the Fredericks gold mine.

The country rock of this lode is a silvery mica schist which strikes about N. 80° E. and dips 80° S. At the Fredericks mine there is a granite dike[1] and also some calcareous and graphitic schists, but rocks of this type were not observed near the stibnite deposit.

The antimony deposits occupy a zone of fracture in the schists, the strike of which ranges from N. 60° E. to due east and averages probably N. 70° E. Alois Frederichs, the owner of the lode, informed the writer that the Gilmer lode was parallel to that of the Fredericks gold vein, but this was not borne out by the field observations. P. S. Smith reports that the vein of the Fredericks gold mine strikes N. 70° W. The dip of the Gilmer lode is about 60°–70° NW. The lode has been traced from above the railroad and down the hill slope for about 600 or 700 feet. The open pits had in part caved in at the time of the examination, and there was no one on the property to furnish detailed information about the occurrence of the ore. Therefore, it is impossible to state definitely the character of the lode. It appears, however, to be a fracture zone, definitely traceable along the entire distance mentioned above, but it differs greatly in width. Probably the greatest width is 3 to 5 feet, and it seems to narrow in places to about a foot.

The stibnite occurs in shoots and kidneys along the shear zone, in part bounded by smooth walls, in part by zones of fractured schist. In places the fracture zone appears to have little ore in it; in others the ore occupies the entire zone. The owner reports that the widest ore shoot measures 4 feet in diameter. Between the shoots are quartz and mineralized schists and small kidneys of ore.

The stibnite forms finely granular and fibrous aggregates and shows only a thin film of oxidation products. Fine grains of vitreous quartz occur in the masses of stibnite. Some specimens taken from the dump showed a white quartz which had been fractured and was recemented by stibnite, which occurred in fibrous masses and acicular crystals. These specimens, when examined under the microscope, showed a granulation and recrystallization of vitreous quartz. The gangue also includes a little calcite intergrown with the quartz. Calcite is much more abundant as a gangue mineral in the gold ore of the Fredericks mine, which is close at hand, than in most lodes of the Fairbanks district. No analysis of the ore of the Gilmer lode was obtained, but it appears to carry a small quantity of galena.

The developments, which were all made during the summer of 1915, consist of some small shafts, open cuts, and pits, distributed along the lode for a couple of hundred yards below the railroad, and a few shallow pits above the railroad. A depth of 20 feet or more had probably been reached in some of the shafts.

Fredericks mine.—The Fredericks mine, located on the east slope of Vault Creek close to the railroad, has been developed on a large

[1] Smith, P. S., Lode mining near Fairbanks: U. S. Geol. Survey Bull. 525, p. 195, 1913.

scale. The vein strikes about N. 70° W. and dips north. Smith[1] has described this property in detail, and it is only necessary here to state that some stibnite, apparently in the form of kidneys, occurs in the ore. These masses of stibnite seem to be more abundant near the footwall side of the vein than near the hanging wall side. Specimens of stibnite from the mine in part show coarsely columnar, in part finely granular structure. A specimen of stibnite ore taken from the 100-foot level of the Fredericks mine showed much oxidation. In this specimen the unaltered stibnite is scattered through a mass of secondary minerals. This is the deepest level in which altered stibnite has been found in the Fairbanks district.

Spaulding claims.—Smith[2] has described the lode deposits that are contained in a group of claims located on the northern slope at the head of Dome Creek. (See Pl. II, p. 18.) At the time of his examination these claims belonged to the Reliance Mining Co., but this group is generally known as the Spaulding claims. It is not necessary to here quote his description of the auriferous quartz veins except in so far as it relates to the occurrence of stibnite, which is as follows:

> Sulphides form but a small part of the vein material. A small amount of stibnite occurs in many places and some large masses are reported; none were seen, however, and their relations to the vein were not determined. In addition to the more usual sulphides, the vein contains small quantities of tetrahedrite (sulphide of silver, copper, and antimony), with which some gold is intimately mixed, the two having been deposited contemporaneously. Copper sulphides are extremely rare.

The rich gold ore occurs in shoots along two veins that strike nearly east. The stibnite seems to occur in a similar way, though this has not been verified by actual observation. A specimen of stibnite from this locality consists of columnar and fibrous masses, together with fine granular aggregates. The oxidation products form a film about an eighth of an inch in thickness. In addition to the minerals mentioned above the ores from this property also carry a little galena, but it is not known whether this is associated with the stibnite. There are extensive developments on this group of claims, but these have been fully described by Smith[2] and by Chapin.[3]

Eldorado Creek Mining Co.—According to Smith[4] a shaft has been sunk on a claim of the Eldorado Creek Mining Co., located near the top of the ridge at the head of Cleary Creek. Here there appears to be an eastward-trending vein associated with limestones and calcareous rock. The vein filling, as far as could be determined, for the

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[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 195–196.

[2] Idem, pp. 190–194.

[3] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 343–345, 1914.

[4] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 186–187.

shaft was not accessible, is mainly quartz in which stibnite occurs as seams. This is one of the few localities in the district where stibnite has been found in association with calcareous rocks. According to recent reports a deposit of stibnite is being developed on this property. Near at hand is the Peter Steel adit, in which it is reported that some stibnite and pyrite-bearing veins occur in a zone of fracture.

Newsboy mine.—The Newsboy mine is located on the divide between Cleary and Last Chance creeks. (See Pl. II, p. 18.) It is one of the deepest mines in the district, the shaft having been sunk 315 feet below the surface. Detailed descriptions of this property are contained in Smith's[1] and Chapin's[2] reports, from which the information here given is taken. The vein trends N. 40° E. and dips 73° NW. In relation to the mineral contents of the vein Smith[3] says:

> Large amounts of sulphides occur in the vein, but the ore differs from that seen at any of the mines so far described, though it is more closely akin to that of the Tolovana than to that of the more eastern veins. The sulphides are mainly pyrite and stibnite, though arsenopyrite, a little chalcopyrite, and sphalerite have been recognized. Quartz, although the most abundant mineral, forms a rather smaller proportion of the vein material than in most of the other mines. Most of the quartz simulates that in the quartzite rather than that in the normal veins and has a fine granular texture. Schist horses are fairly numerous in the vein and are not sharply separated from the vein material.

There is no evidence from the information at hand that the antimony ores above described have commercial value. The presence of arsenopyrite and other impurities will probably not permit the utilization of the stibnite, even if it proves to be present in commercial ore bodies.

Mother Lode claim.—One of the first discoveries of a stibnite lode in the district was made at the time of the construction of the Cleary wagon road. The locality is about a mile northwest of the Summit road house. The deposit was staked under the name Mother Lode claim, but it has not been developed, and the claim is probably abandoned. Though no commercial ore bodies were found on this claim, the occurrence has considerable geologic interest. The stibnite seems to have been deposited in a horizontal vein at the contact of a dike of sericitized granite porphyry and mica schists. Prindle[4] has described this locality as follows:

> The schist had not only been intruded by the dike, but had apparently been fractured by it. Stibnite has been deposited on the surface of the dike and

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[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 187–189.

[2] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 340–341, 1914.

[3] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 187–188.

[4] Prindle, L. M., The auriferous quartz veins of the Fairbanks district: U. S. Geol. Survey Bull. 442, p. 221, 1910.

occurs as small veins and lenticular masses up to several pounds in weight in the schist. The stibnite at this locality is apparently in close genetic association with the granite porphyry. Assays of the stibnite have not shown a gold content of over $1 to the ton.

Specimens of ore from this deposit are made up of a granular aggregate of stibnite. The material has been much weathered, and the oxidation products form an incrustation half an inch to an inch in thickness. A little pyrite occurs with the stibnite. There are also some vitreous quartz grains buried in the stibnite, and some of these grains show crystal terminations.

Tolovana mine.—The Tolovana gold mine, which is located near the mouth of Willow Creek, a tributary of Upper Cleary Creek, has been operated on a productive basis. This property has been described by Smith[1] and Chapin.[2] Chapin's report has furnished the following items of information, which have more or less direct bearing on the occurrence of stibnite. The main lode strikes east and dips 60° S. Chapin describes it as composed of stringers of quartz which inclose lenses of schist. The quartz is dull and opaque and has few open cavities. A little feldspar (albite) has been found with the quartz and also a little calcite. The quartz appears to have been fractured and the fracture zones to have been impregnated by sulphides. In the vein material stibnite in acicular crystals is the principal sulphide, but some pyrite is associated with it. The included horses of schist are also mineralized, as is the wall rock adjacent to the vein. In the schist pyrite seems to be the dominating metallic mineral. The gold seems to be associated principally with the stibnite. Though this deposit, so far as known, can not be regarded as a commercial body of antimony ore, yet its description is included because it gives evidence of the close genetic association of the stibnite and the free gold.

Chapin[2] has described two other lodes on this property as follows:

Northeast of the Tolovana mill, on the Tolovana-Stibnite claim, another stibnite-bearing vein has recently been prospected. A shaft was sunk on an eastward-trending vein for 100 feet, and at the 50-foot level drifts were turned off to the east and west for 50 and 30 feet, respectively. A raise 24 feet west of the shaft connects the 50-foot level and the surface, and the block of ore thus outlined has been stoped out and milled. No further work has been done on this property, although the amount of gold obtained in the mill-run shows the lode to be workable ore. The vein is composed of quartz with considerable stibnite and lesser amounts of other sulphides. Yellow antimony oxide, in places stained red and brown by mixtures of other alteration products, is common.

The most promising vein on the property is one recently uncovered and at the time of visit just being opened. The vein strikes east and the surface dips

[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 183–185.
[2] Chapin, Theodore, op. cit., pp. 339–340.

50° S. It is nearly parallel to the main vein in the mine. It is being opened by a shaft from which drifts will be driven east and west to prospect the vein, and if results warrant it a crosscut will be run from the mine. The lode is a strong vein of quartz from 18 inches to 3 feet wide, with two well-defined walls separated from the vein by gouge seams. It thus differs notably from the stringer lode exposed in the mine.

The surface outcrops show considerable stibnite, occurring as irregular veinlets and masses consisting of needle-like crystals. Particles of visible gold are common in both stibnite and quartz. Assays on the surface portion, considered by the operators to be a fair sample of the vein, showed a high gold content.

A specimen of antimony ore from this property showed an irregular aggregate of acicular crystals of stibnite, some with radial arrangement. Some vitreous quartz grains are included in the mass. Another specimen showed stibnite in columnar form intergrown with quartz and pyrite.

Rhoads & Hall mine.—The Rhoads & Hall, the oldest and most productive gold mine in the district, is located near the junction of Bedrock and Cleary creeks. (See Pl. II, p. 18.) It has been fully described in the reports cited, and these statements will not here be repeated. The vein cuts the foliation of the schists, trends about N. 75° W., and dips about 55° S. It is considerably faulted, which makes the strike somewhat irregular. Some smaller veins parallel the main lode. As regards the mineral character of the ore Smith[1] says:

> Much of the gold is irregularly distributed through the vein material in visible particles uncombined with other elements. In some places the vein is richest immediately adjacent to its walls; in other places it is richest in its center. The ore is in large part free from sulphides, but here and there includes stibnite, some galena, and arsenopyrite, as well as lesser amounts of pyrite, copper pyrites, and sphalerite. These sulphide-rich portions of the vein also contain gold, and Prindle states that the gold, sulphides, and some quartz apparently have been introduced together at a period subsequent to that at which much of the quartz was formed. It therefore appears that the gold was introduced at two distinct times—first with the quartz and second with the sulphides. It is, however, by no means certain that the two events were separated by a long period.

During the early days of mining on this property some large masses of stibnite were found in close association with the quartz vein. The records of this occurrence are, however, not very definite. Mr. George L. Smith, manager of the Rhoads & Hall mine, is authority for the statement that a vein of antimony ore cuts across the main auriferous lode. This statement finds support in the fact that a northward-trending vein has been found on the Pauper's Dream and Texas claims, located a short distance to the northwest of the Rhoads & Hall mine.[2] This lead is heavily impregnated with sul-

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[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., p. 178.
[2] Idem, p. 181.

phides, which consist chiefly of arsenopyrite and stibnite. Cassiterite has been found in the weathered material associated with this lode.

Chatham Creek.—The North Star claim, located on Chatham Creek about a mile above its junction with Cleary Creek, forms one of a group belonging to the Pioneer Mining Co. on which considerable work has been done. Here a quartz vein, carrying free gold, which strikes northeast, is intersected at about right angles by a small vein carrying free gold, considerable stibnite and arsenopyrite, and some sphalerite and iron pyrite.[1] The material from this vein consists of quartz which has been fractured and permeated with sulphides. Some quartz of a second generation was also deposited with these sulphides. Close at hand is the B. & P. claim, on which there is a northwesterly striking auriferous shear zone which has been mineralized by pyrite, arsenopyrite, galena, sphalerite, and stibnite.

The Bobbie claim, west of Chatham Creek, is thus described by P. S. Smith:[2]

> On the Bobbie claim, west of the junction of Tamarack and Chatham creeks, at an elevation of 1,650 feet, several shallow pits have been sunk and a tunnel has been driven on a lode striking nearly north and south and dipping westward into the hill. No work has been done at this place recently, and most of the pits are too much caved to allow examination. Specimens of the ore, however, indicate that the vein belongs to the group having a high sulphide content. The ore consists mostly of stibnite and galena with other sulphides in smaller quantities. In the midst of the sulphides are numerous well-formed quartz crystals with uncorroded surfaces and random orientation. Several of the quartz crystals are more than an inch in length and a quarter of an inch in diameter.
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> In the short incline from the open cut on this claim is a narrow stringer of nearly pure galena. This vein shows well-marked banded structure near the walls, the center of the vein being completely filled with large crystals of galena.

The specimens from this locality indicate that the antimony ore occurs in kidneys made up of needle-like crystals of stibnite. In this mass the quartz crystals are embedded and some pyrite is included. The oxidation products form an incrustation one-fourth to one-half an inch in thickness.

The Chatham gold mine is located on the upper eastern slope of Chatham Creek, a tributary of Cleary Creek. (See Pl. II, p. 18.) It was worked for a number of years as a gold mine, but in 1915 shipments of antimony ore were made from this property. The mine has been described in some detail by Smith[3] and by Chapin,[4] from whose reports the data here given relating to the occurrence of antimony have been chiefly taken. The main lode strikes N. 60° W. and dips 65°–80° SW. Its mineral content consists of vitreous and

[1] Prindle, L. M., Auriferous quartz veins in Fairbanks district: U. S. Geol. Survey Bull. 442, p. 226, 1910.

[2] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., p. 177.

[3] Idem, pp. 172–173.

[4] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, pp. 335–336, 1914.

white quartz, in part in well-developed crystals, a little pyrite in cubical form, and some fine needle-like crystals of stibnite.

This lode is cut by a stibnite-bearing vein that strikes east and dips south. Chapin describes this as a narrow vein, but it was not well exposed at the time of his examination. Since then it has been opened up and J. W. Pomeroy, who had charge of this work, describes it as a zone of shearing 10 to 15 feet wide, traced on the surface for about 500 feet and bounded by slickensided walls. In this zone the stibnite is found along the shear zone in kidneys and shoots which range from a few inches to 10 and 12 feet in length. These ore shoots are described as running diagonally across the lode. The antimony ore has been mined to a depth of about 120 feet below the surface.

Mr. Pomeroy's description of this occurrence indicates that it is similar to those studied by the writer on the Scrafford and Gilmer properties. The fact that the main lode contains stibnite as well as the crosscutting vein suggests that there may have been two periods of antimony mineralization. It is quite possible, however, that the main lode was enriched by sulphides during the same period in which the crosscutting stibnite lode was formed.

Specimens from the antimony lode on this property showed a finely granular and fibrous aggregate of stibnite with but few, if any, impurities. The ore showed no alteration, but the specimens examined may have been taken from the central part of one of the ore shoots.

The Quemboe Bros. claim is located on the divide between Chatham and Wolf creeks, about one-half mile northwest of the Chatham mine. Here a quartz vein strikes N. 70° W. and dips south. It shows some banding and is much broken. The quartz is fractured and cemented by stibnite, pyrite, and arsenopyrite, and the deposit is reported by Smith to carry gold.[1]

Homestake mine.—The Homestake mine, which has been extensively developed, is located near the head of Wolf Creek, a tributary of Cleary Creek. According to Chapin[2] the property includes several veins which have an easterly trend and dip south. The vein that has been principally developed cuts some lenses of white quartz in the schist country rock. These lenses as a rule are barren, but some were mineralized apparently at the same time that the main lode was formed. Chapin has described the mineralogy of the vein as follows:[3]

> The vein matter is composed of iron-stained crystalline quartz with many open spaces. Sulphides are not abundant. Stibnite forms in isolated bunches in the vein, and pyrite and chalcocite, the black sulphide of copper, occur

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[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 171–172.
[2] Chapin, Theodore, op. cit., pp. 333–334.
[3] Idem, p. 334.

sparingly. Specimens taken from the dump show a parallel intergrowth of quartz and bladed crystals of chalcocite, giving the vein a granitic texture. Associated with the chalcocite are blue and green incrustations of copper carbonate, and throughout the vein are vugs and veinlets of limonite, oxidation products of the original vein minerals. The microscope shows a minute system of parallel fractures in the quartz resembling cleavage. Portions of the vein containing the copper minerals are said to be the richest in gold. Particles of visible gold occur in the quartz but are not numerous.

Fairbanks Creek.—Many of the gold lodes in the upper Fairbanks Creek basin carry more or less stibnite, but no antimony ores have been mined in this part of the district.

The Crites & Feldman mine, located near the mouth of Moose Creek, is one of the best developed properties in the district (Pl. II). The lode on which the principal developments have been made trends northwesterly to westerly, and this is the general direction of the other veins that have been opened up, though they do not seem to be exactly parallel. More detailed descriptions are contained in the reports of Smith [1] and Chapin.[2] The ore from the developed lode is composed of vitreous quartz that carries free gold, pyrite, sphalerite, galena, and arsenopyrite. Some of the quartz shows crystal terminations, and there are some druses which contain well-developed crystals. The stibnite occurs in fine needle-like crystals and the pyrite in small granular aggregates. The gold is intimately associated with the sulphides. Stibnite is reported to occur in shoots and kidneys, which lie adjacent to the quartz vein, but none of these were seen by the writer.

The so-called "big vein" on the same property trends about east and where exposed is about 18 inches to 2 feet wide. The mineral character of this vein appears to be similar to that of the developed lode, but it probably carries less gold. It includes, however, some shoots of stibnite which in places occupy the entire space between the walls of the lode. A specimen of ore from one of these shoots shows it to be made up of columnar aggregates of stibnite. The stibnite appears to be pure except for the inclusion of a few fine grains of quartz. Though taken from near the surface the specimen shows only a thin film of alteration products.

Smith [3] has described a lode which belonged at the time of his visit to Nars, Anderson, and Gibbs, located at the head of Too Much Gold Creek, and which he believes may be an extension of the Crites & Feldman lode. It has the same mineral character as the vein above described but where opened it carries less stibnite.

Still farther west are the Rob & Roy, Wolf, and Saucy claims, which are located on the head of Too Much Gold Creek. On these

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[1] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 156–159.
[2] Chapin, Theodore, op. cit., pp. 327–328.
[3] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., p. 159.

claims a shear zone has been found which trends about N. 60° W. and is about 30 feet wide. Within this shear zone occurs two mineralized zones that contain quartz, pyrite, gold, and stibnite. Some irregular shoots and kidneys of stibnite have been found here. Stibnite has been found on a number of other claims located on the north slope of the Fairbanks Creek valley and in adjacent parts of Too Much Gold Creek valley. The country rock in this region is chiefly schist but is intruded by many granite dikes. The stibnite is associated with galena and other sulphides in veins that have been opened for their gold content. Chapin[1] describes narrow veinlets of stibnite which cut vein quartz and schists on the Mizpah claim. Smith[2] notes the occurrence of stibnite and galena in ore from the Ohio and Mayflower claims and stibnite in a crushed and recemented quartz on the Kellen property. On the Excelsior claim[3] there is galena, arsenopyrite, and stibnite.

ESTER MINERALIZED ZONE.

Antimony ore has been mined at only one locality in the Ester mineralized zone (fig. 1, p. 21) but has been found at several other places. Here the country rock is schist but is intruded by many granitic dikes. The so-called Stibnite lode is located near the head of Eva Creek (Pl. II, p. 18), a northern tributary of Ester Creek, and is said to be owned by D. L. Thomas, J. Leach, James McCann, and Edward Hess. The lode occurs in a shear zone in the schist which strikes about N. 30° W. and dips 70°–90° N. An iron-stained quartz vein forms the hanging-wall side of the antimony lode, which has been definitely traced about 60 feet and is indicated by quartz float beyond. The wall of the lode next to the quartz vein is slickensided and is therefore well defined. The footwall of the deposit is not so well marked, for here the vein material intermingles somewhat with the schist which forms the country rock. There can be no question that the antimony lode was formed after the quartz vein had consolidated, and its position seems to have been determined by a zone of weakness, which marked one contact of the quartz vein. The shear zone has been traced for about 150 feet and is from a foot to 2½ feet wide. In this lode the antimony ore occurs as shoots, which are pod or lens shaped and pitch to the north. The largest of these shoots was about 40 feet long and had a maximum width of 2½ feet, but pinched out at the bottom. Most of the ore mined was taken from this shoot. Besides the antimony ore shoots the lode contains smaller kidneys of stibnite and quartz intermingled with mineralized fragments of the country rock.

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1 Chapin, Theodore, op. cit., p. 329.
2 Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 162–164.
3 Idem, p. 161.

The stibnite occurs in granular aggregates with some columnar masses. Some of it gives evidence of having been sheared. Some grains and well-developed crystals of glassy quartz are buried in the masses of stibnite. Oxidation products occur as a thin film on the masses of stibnite ore.

The gangue is white vitreous quartz, partly stained light green by the decomposition products of the stibnite. As already stated, part of the lode material consists of schist fragments which are more or less stained with iron. The iron stain suggests that some pyrite is present in the lode though none was recognized. This mineral undoubtedly occurs in the adjacent quartz vein together with some gold. It is not known whether the antimony lode carries gold, but the resemblance of this lode to other stibnite deposits of the district which are auriferous indicates that it probably does.

The developments on the property consist of open cuts and pits. All the ore shipped was hand broken and sorted. Returns from the first shipment showed that the ore contained 61.5 per cent antimony. The ore was hauled by wagon to Ester station, thence taken by rail to Fairbanks and by river and ocean steamers to San Francisco. It is reported by the operators that the cost of transportation from the mine to San Francisco, including the sacks in which the ore was shipped, was $30 a ton.

Chapin has described an occurrence of stibnite revealed in a shaft sunk on the junction of the Prometheus and Jolly Rogers claims, which are located near the stibnite lode described above. Of this he says:[1]

> The workings were not accessible, but samples taken from the dump show the ore to be white opaque quartz, badly crushed and containing angular fragments of clearer quartz. The microscope shows a fine aggregate of crystalline quartz containing fragments of an older quartzose rock. A still later phase in vein formation has been the sulphide metallization in the form of fine veinlets of stibnite. A coating of antimony oxide has given the rocks in places a greenish-yellow stain.

Some antimony ore has also been found in the upper basin of St. Patrick Creek. As elsewhere the stibnite in these deposits is associated with gold ores, but detailed information about the deposits is lacking.

Smith[2] has described an occurrence of stibnite in the Eva Creek basin as follows:

> Near the head of Eva Creek, at an elevation of 1,600 feet, Edward Hess and others have sunk a 60-foot shaft on a quartz vein carrying considerable stibnite and disseminated sulphides. The quartz is fine grained, is granular, and has

[1] Chapin, Theodore, Lode mining near Fairbanks: U. S. Geol. Survey Bull. 592, p. 355, 1914.

[2] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., p. 208.

a grayish color, due to the sulphides that occur throughout it. The vein matter is similar in appearance to that from many of the Cleary Creek prospects already described. Visible gold is reported to be fairly common.

Some stibnite has been found at the Hudson mine located on the ridge between Ready Bullion and Moose Gulch (Pl. II), both tributary to Ester Creek from the north. According to Chapin[1] the main lode strikes about N. 30° E. and dips 60° SW. The lode consists of stringers and lenses of quartz in a mass of mineralized schist. Underground workings have developed another lode which strikes about north and which may be a spur from the main lode or may be an older vein. The lode averages 4 inches in width and is "composed of dull opaque quartz with many open cavities into which well-formed quartz crystals project. Many of these crystals and some fractures are covered with a black coating of manganese oxide. Stibnite, the only sulphide detected, occurs sparingly."

About half a mile to the northeast of the Hudson mine is the Cottonblossom claim, which Smith[2] describes in part as follows:

A 70-foot shaft was put down at this place, but in following the lead it became so crooked that it was abandoned, and in 1912 a new vertical shaft had been started and sunk 60 feet. Some trouble was experienced with water, but the ground is not very wet, as less than 20 buckets of water collects in over 12 hours. No definite lead was found at this place, but there is a well-marked fault which is regarded as the footwall. Above the fault place is several inches of gouge made of the comminuted country rock. The shaft was started on this material, but as the dip of the gouge flattened sinking was continued on small fractures and quartz stringers. Stibnite occurs in bunches near the surface and at the bottom of the shaft and is scattered sparingly through the quartz stringers. In the rock are numerous cavities left by the decomposition of sulphides, which probably originally carried some of the gold. A part of the gold, however, occurs in the very narrow quartz stringers. So far as can be seen at present the mineralization corresponds in general to that at the Hudson property, half a mile to the south, on the same ridge, though apparently the ore is not so rich.

In the summer of 1915 an antimony-bearing lode was staked by R. W. McQueen on the ridge about a quarter of a mile west of Ester Dome. This claim was located under the name Jenny C. At the time of the writer's visit to this locality only a small pit had been opened on the lode and the character of the ore body could not be determined.

The strike appeared to be between 50° and 70° W. and the dip to be northerly. A slickenside, which probably marks the footwall, was noted. The lode matter so far as exposed consisted of iron-stained quartz and stibnite, and the stibnite occurs in shoots and kidneys. One irregular mass of stibnite had been dug out which

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[1] Chapin, Theodore, op. cit., pp. 350–352.

[2] Prindle, L. M., Katz, F. J., and Smith, P. S., op. cit., pp. 208–209.

weighed several hundred pounds. The stibnite consists of columnar and platy aggregates, and with it is intergrown some vitreous quartz, a part of which shows crystal faces. Though the ore examined was obtained directly beneath the moss cover, the oxidation products formed only a thin film on the stibnite.

Prindle[1] noted a stibnite-bearing vein near the point of the ridge, about a quarter of a mile south of the Jenny C. lode. At the time of his visit in 1908 a cut about 75 feet long, made on this vein, had caved so that the lode could not be examined. It appeared, however, from the size of the fragments that the vein is about 2 or 3 feet wide and the strike is about N. 60° E. The country rock is mica-quartz schist, whose foliation strikes about north and dips 30° W. The vein matter consists chiefly of quartz and stibnite. It appears that there has been no recent work at this locality.

MISCELLANEOUS LOCALITIES.

Stibnite has been found at several localities which are not definitely known to belong to either the Ester or the Cleary mineralized zones. Mr. Alois Frederichs stated to the writer that he found a promising prospect of antimony ore on the ridge which separates upper Spruce Creek from the Dome Creek valley. This location is near the northern margin of the Cleary mineralized zone. The writer saw some large pieces of antimony ore at Fairbanks which had been taken from a lode whose location was given rather indefinitely as near the Fairbanks-Cleary trail. It may have come from one of the lodes described which are located near the head of Fairbanks Creek. Chapin has described the occurrence of a little stibnite in the Rose Creek basin, a southern tributary of Gilmore Creek. This stibnite occurs in veins which cut a stock of porphyritic granite and is the only stibnite known in the Gilmore mineralized zone.

Near the dome on the ridge between the heads of the main forks of Rose Creek, at an elevation of 1,825 feet, a prospect hole has opened a lode 6 to 8 inches wide, striking N. 30° E. and dipping 70° NW., composed of quartz and feldspar. A 15-foot shaft and incline has been put down following the vein. A line of prospect pits at right angles to the strike of this vein has opened several other parallel veins. The only result of mineralization apparent is a small amount of stibnite in tiny veinlets. A number of other locations have been made on Rose Creek, some on lenses of bright glassy quartz showing no trace of metallization.[2]

KANTISHNA DISTRICT.

The Kantishna district embraces a gold-bearing area that lies about 30 miles north of Mount McKinley and drains to the Tanana by Kantishna River. (See Pl. I, in pocket.) Auriferous gravels were

[1] Prindle, L. M., unpublished notes.
[2] Chapin, Theodore, op. cit., p. 346.

first found in this district in 1905, since which time placer mining has been continued each season. Early in the history of the camp some auriferous quartz veins were found and also some that carry stibnite. The bedrock of the district is mostly mica schist, which is cut by some granite porphyry dikes.[1] The schists are similar to those of the Fairbanks district. They extend northeast and southwest and form a belt about 15 miles wide from north to south.

Prindle examined the district in 1906, and it has not since been visited by any Survey geologists. Meanwhile considerable work has been done on the lodes, including those which carry stibnite, but no detailed information in regard to this work is available to the writer. Prindle examined only one stibnite-bearing lode, which he describes as follows:[2]

> Stibnite (antimony sulphide) occurs in the wash of Caribou Creek, and a ledge containing this mineral has been located a short distance above the point where the creek emerges from the hills into the benched area of the lower valley. The creek forks at this locality, and on the southern fork, which has been named Last Chance, the ledge is exposed. The vein is about 4 feet thick, and the vein matter includes essentially quartz and stibnite. The quartz is partly massive and partly in the form of small crystals up to an inch in length. The antimony sulphide is in part a crystalline mass embedded in the spaces between the quartz crystals and in part a bluish-black, very fine grained massive variety. The ledge strikes northeastward and dips 75° N. The country rock is hornblende schist, to the structure of which the vein conforms. A short distance upstream the hornblende schist is structurally conformable to the quartzitic schist. A small amount of work was being done here in the hope that the ledge material would be found to carry values. Of three specimens from this locality assayed for the Survey, two contained silver at the rate of 4 and 2.76 ounces to the ton and the latter carried in addition 0.12 ounce of gold to the ton; the third specimen contained 0.12 ounce of gold, but no silver. Too little work had been done to give definite information regarding the proportion of the antimony sulphide in the vein, but pieces of nearly solid ore up to a foot in diameter were obtainable.

Stibnite lodes have since been reported from other localities in the district. Andrew W. Newberry informs the writer that stibnite occurs on Slate Creek, a westerly tributary of Eldorado Creek. Here there is a stibnite lode which cuts schistose rocks not far from a granite intrusion. Although considerable work had been done on this claim, the cuts had caved in at the time of Mr. Newberry's visit, so that he could not determine the character of the deposit. The dump, however, showed some large pieces of what seemed to be rather pure stibnite. It is reported that considerable work was done on this deposit during the winter of 1915–16.

Prindle found stibnite float in the placers of Eureka and Friday creeks, about 15 miles south of the locality on Caribou Creek. This

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[1] Prindle, L. M., The Bonnifield and Kantishna region: U. S. Geol. Survey Bull. 314, pp. 213–215, 1907.

[2] Idem, p. 219.

information indicates that antimony ores are rather widely distributed in the district.

The specimens collected by Prindle indicate that the lodes have the same mineral composition as those of Fairbanks. The stibnite ore occurs in both columnar and granular aggregates, and its only impurity appears to consist of grains of vitreous quartz, some of which have well-terminated crystals. Another type of ore consists of white vein quartz which has been fractured and impregnated with sulphides. In these specimens the sulphides appear to be chiefly pyrite and galena, and the stibnite is only accessory. The evidence of these specimens clearly shows two generations of quartz, but it remains to be determined whether the older is accompanied by any metallic minerals, like that at Fairbanks. The antimony ore appears to occur in shoots and kidneys, and to present a distinct form of occurrence from the lodes in which it is found only as an accessory mineral. As Prindle has shown, at least some of the antimony lodes are auriferous. He has furthermore noted the general similarity between the mineralization of the Kantishna to that of the Fairbanks district.[1]

LOWER YUKON AND KUSKOKWIM REGION.

DISTRIBUTION OF THE ANTIMONY DEPOSITS.

Some stibnite deposits have been found in a mineralized zone, marked by several gold placer districts, which stretches from the lower Kuskokwim River northeasterly to the northern part of the Innoko district. The metallization of this zone by no means extends throughout its length, but, as will be shown, is limited to certain centers determined by the intrusion of igneous rocks. As here defined it includes the antimony-bearing cinnabar prospects of the Kuskokwim and the Iditarod and Innoko gold-placer districts. It is reported that stibnite has been found in the Tuluksak-Aniak gold placer districts, still farther to the southwest, but this has not been verified. There has been no production of antimony in this region, and none of the lodes has been sufficiently prospected to prove its value. The wide distribution of stibnite-bearing veins is favorable to the discovery of workable antimony lodes. On the other hand, much of the region is now difficult of access, and it is at least an open question whether antimony ores could be mined in this region, even at the present high value of the metal. Some of the deposits are, however, favorably located for water transportation, notably those near or on Kuskokwim River. These deposits and some which are near Iditarod would seem to offer the best hope of development under the present conditions of transportation.

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[1] Prindle, L. M., op. cit., p. 220.

MODE OF OCCURRENCE.

The larger geologic features of the belt previously defined have been well determined by the work of several geologists. Maddren[1] has investigated the placer districts of the lower Kuskokwim and Smith[2] the geology of the central Kuskokwim Valley. Eakin[3] and Mertie and Harrington[4] have mapped the geology of the Iditarod, Innoko, and Ruby districts. The writer has made some supplementary investigations of the geology of the Iditarod district.

The results of these surveys indicate that a belt of sedimentary rocks stretches from the lower Kuskokwim through the Iditarod and Innoko districts. These rocks consist of dominating sandstones and shales or slates, together with some grit and conglomerate, and are probably in large part of Upper Cretaceous age. They are thrown up in broad open folds, though some of the structure is more complex. The Cretaceous rocks are in places interrupted by areas of older, more or less metamorphosed Paleozoic sediments. Some volcanics are also found in this belt. The Cretaceous sediments are cut by granitic stocks and dikes, chiefly monzonite. In addition there are some older basic rocks which have invaded the Cretaceous sediments partly as dikes and partly as surface flows.

All the mineralization of this area appears to be closely connected with monzonitic and porphyritic intrusives. Evidence of this relation is found in the distribution of the known placers, which all occur either near the contacts of the monzonitic stocks and the sediments or in areas that have been intruded by dikes. The lode deposits show a similar association. Mertie and Harrington[4] have indicated that this mineralization is probably of Tertiary age and have suggested that it represents a later period of metallization than that of the Ruby district to the north, which is believed to be Mesozoic. This view is supported by what is known of the general geology and by certain facts in regard to the mineral character of the metalliferous deposits in the two provinces, which need not here be discussed. On the basis of this classification, the stibnite deposits all fall in the Tertiary period of mineralization.

The stibnite deposits occur in fissure veins either near the contact of the monzonite and sediments or in close association with porphyry dikes. Two mineral types appear to be recognizable. In the one the stibnite occurs with auriferous quartz veins as the principal metallic mineral or as an accessory. In the other it is intimately

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[1] Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, pp. 292–360, 1915.

[2] Smith, P. S., Mineral resources of the Lake Clark-Iditarod region: U. S. Geol. Survey Bull. 622, pp. 247–271, 1915.

[3] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, 1914.

[4] Mertie, J. B., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 642, pp. — (in press).

associated with cinnabar. It is quite possible that these types represent different phases of the same epoch of mineralization.

PROSPECTS.

LOWER KUSKOKWIM.

The Parks cinnabar prospect, located on the Kuskokwim about 15 miles above Georgetown (Pl. I, in pocket), is the best known of the cinnabar-stibnite lodes. This deposit has been developed in a small way since 1906, and a little quicksilver has been produced. It has been studied by Smith,[1] and the following extracts, which relate more especially to the occurrence of the stibnite, are made from his report.

The country rock consists of Cretaceous sandstones and shales. Interlarded with these is an altered basic rock (diabase?), probably occurring as sills. Dikes of granitic or monzonitic character cut the sediments. The mineralization occurs along zones of brecciation in the shales adjacent to these dikes. These relations are shown in

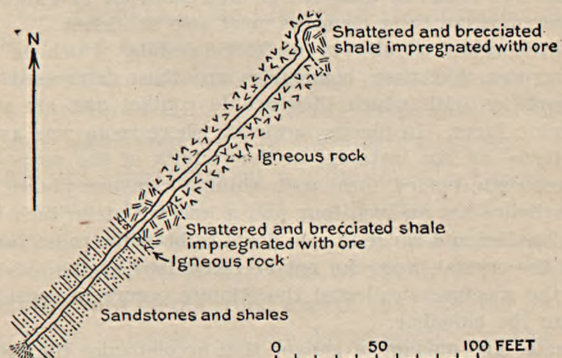

FIGURE 2.—Sketch map of the underground development at Parks quicksilver prospect.

figure 2, which is taken from Smith's report.[2] Smith's account of the mineralization is quoted in full, as it describes the occurrence of stibnite in this lode:

> The mineralization is closely related to the shattered and brecciated contact zone between the igneous dikes and the sediments. The metallic minerals are almost exclusively cinnabar and stibnite. Iron pyrite in narrow stringers, most of them less than one eighth of an inch wide, has been seen at a few places, but almost nowhere is it intermixed with other sulphides. In fact, it is so distinct that the impression gained in the field was that it had been introduced at an entirely different time than the ore minerals. Subsequent study in the laboratory, although affording no evidence in support of this view, has shown no facts that are opposed to it.
>
> In few places is a distinct veinlike form recognizable in the deposit. On the river bank a little west of the main opening a veinlike mass about a foot wide showing a somewhat banded structure has been traced for a short distance.

[1] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, pp. 274–280, 1915.

[2] Idem, p. 277.

Normally, however, the mineralization follows the irregular partings between the shattered fragments of country rock, and consequently forms a network of anastomosing stringers and lenses.

The ore near the surface is weathered to a rusty brown iron-stained color. In the more oxidized portions of the deposit the cinnabar is practically unrecognizable by inspection of the fragments, owing to the coating of iron oxides. In less decomposed parts the characteristic red of the cinnabar becomes more evident, until in the unaltered parts the blood-red cinnabar is very striking.

The cinnabar occurs principally in small particles intimately mixed with the well-formed crystal blades of stibnite, the sulphide of antimony. These two minerals were deposited almost contemporaneously, for the stibnite incloses and is inclosed by the cinnabar. So closely do the two minerals occur together that the mineral livingstonite—the sulphide of antimony and mercury—was reported to be the metallic sulphide other than cinnabar occurring in this deposit. Tests by R. C. Wells, of the chemical laboratory of the Geological Survey, failed to find this mineral and instead proved that the supposed quicksilver content of the stibnite was really derived from the minute particles of cinnabar that were intimately intergrown with the stibnite.

Tests were also made by Mr. Wells to determine whether any of the compounds of selenium or tellurium and mercury were present. Neither selenium nor tellurium was found in analyses of bulk samples, and therefore the compounds of mercury and these elements must also be absent.

The stibnite occurs usually in distinct crystals, which in places are so closely intergrown that their boundaries are those impressed upon them by the other particles with which they are in contact and are not the normal crystallographic faces. In places, however, where room was available for the crystals to form—as, for instance, in the vicinity of the vugs—the stibnite is in its characteristic bladed form with shining cleavage planes. Some of the crystals of stibnite are an inch long and a quarter of an inch wide, but most of them are smaller and range in size down to hair-like radiating aggregates so minute that the crystal faces can not be recognized by the aid of a hand lens. In most of the specimens collected the stibnite occurs in considerably greater amounts than the cinnabar.

The character and amount of gangue that accompanies the ore differ notably in different parts of the exposures. In places the sulphides are practically the only minerals in the deposits. Usually, however, considerable quartz and carbonate accompany the ore minerals. The carbonate consists of siderite or ferruginous dolomite and usually occurs in crystalline masses. Clearly in one specimen and apparently in others the carbonate has been traversed by narrow quartz stringers, associated with which are the bulk of the metallic minerals. The quartz in these narrow stringers near the contact with the carbonate is almost opaline, but farther away it is more crystalline, and in places where vugs have been formed small, perfectly terminated quartz crystals project into the cavities. In some of the vugs perfectly formed crystals of cinnabar have grown on the crystalline quartz.

In thus calling attention to a paragenetic arrangement that has been observed in some of the specimens the impression should not be gained that the ore is characterized by a well-marked banded appearance. Instead all the minerals were deposited so nearly at the same time that even the carbonate, which appears in places to be one of the earliest minerals formed, contains inclusions of the cinnabar, which appears usually to be one of the later minerals.[1]

[1] Smith, P. S., and Maddren, A. G., op. cit., pp. 278–280.

A deposit of stibnite is reported to occur in the Russian Mountains, which comprise an isolated group of rugged highlands that lies between the lower Kuskokwim and Yukon rivers. (See Pl. I, in pocket.) These mountains are 10 to 20 miles north of Kolmakof, an old Russian post on the Kuskokwim. Maddren[1] has described the geology of this area as consisting of a batholith of granitic rocks intruded in Cretaceous sediments. The occurrence of stibnite he describes as follows:

A deposit of gold-bearing antimony is reported to occur at or near the contact of the central igneous mass with the surrounding sedimentary rocks on the upper part of Mission Creek, in the southwestern part of the Russian Mountains. Prospects of placer gold are reported to be present in the gravels of Mission Creek below this locality, and the placer gold is presumed to be derived from the zone of stibnite mineralization. It is not improbable that there may be other occurrences of mineralization of the contact type about the borders of the intrusive igneous rocks.

IDITAROD DISTRICT.

Stibnite is common in the gold placers of the Iditarod district (see Pl. I, in pocket) and mostly occurs in the concentrates with cinnabar and in places with scheelite. Mining operations at a number of localities have uncovered stibnite-bearing veins and stringers, all of which are closely associated with monzonite intrusives.

A little work has been done on a stibnite lode, staked under the name Mohawk claim, located about a mile north of the settlement called Discovery on Otter Creek. The shaft and pits which exposed this lode were inaccessible at the time of the writer's visit, so that little information could be obtained except that yielded by the dump. Moreover, the claim is located on the flat summit, covered with moss and timber, between Glen Gulch and Slate Creek, where no bedrock is exposed. Monzonite occurs to the south in Glen Gulch and to the north lie the Cretaceous sandstones and slates, together with some basalt. Fragments of basaltic rock were seen on the ridge, so that probably this rock occurs close at hand. The lode is reported to occur at the contact of slate and "diorite" by those who have had access to the workings. The term "diorite" may refer to either the monzonite or the basalt. In any event, the deposit is not far from the margin of the monzonite stock.

The lode appears to trend northeastward, which is parallel to the major structure of the sediments. It dips about 45° SE. A shaft said to be 35 feet deep and a few pits are the only openings seen on the lode. The distribution of these workings indicates that the lode had been traced about 50 feet, but as no one was present on the

[1] Maddren, A. G., Gold placers of the lower Kuskokwim: U. S. Geol. Survey Bull. 622, p. 359, 1915.

property and the examination was hurried there are possibly other openings by which it may have been traced a greater distance. The width of the lode is reported to be 2 to 2½ feet. Though this statement could not be verified by observation, yet the size of the fragments of ore on the dump indicates that they came from a lode at least 1 to 2 feet wide.

The ore consists of an intergrowth of quartz and stibnite, and it is reported to contain gold values. The stibnite occurs chiefly as granular aggregates with some columnar masses. Vitreous quartz is rather evenly distributed among the stibnite in grains, in partly developed crystals, and in irregular aggregates. Some cavities lined with quartz crystals occur in the ore, and the heavy iron stains on some of this quartz suggest the oxidation of pyrite, though none of this mineral was actually observed. The stibnite itself shows very little oxidation.

In thin section the ore shows a mosaic of quartz in which some idiomorphic crystals are recognizable. The quartz has been in part fractured and granulated along margins. Subsequent to this granulation the stibnite has been deposited in part in irregular masses in the granulated areas, in part as thin films along the lines of fracture. This metallization appears to have been accompanied by some deposition of quartz. The noteworthy feature is that the deposition of the sulphide has taken place after the crystallization and deformation of most of the quartz.

The commercial value of the deposit as an antimony ore would seem to depend on the discovery of shoots of purer stibnite than most of that which was seen on the dump. However, some fairly pure specimens of stibnite from this lode were seen. In regard to its value as a gold ore the writer has no information other than that given above.

According to observations by Maddren,[1] some stibnite-bearing veins have been uncovered by placer mining on Glen Gulch and on Black Creek. Both these streams are tributary to Otter Creek from the south. The exact location by placer claims of these veins can not be given, but the occurrences on both streams are about 1,200 feet in air line from Otter Creek. It is probable that the Black Creek vein is on the Fraction claim below No. 3 below Discovery, and the Glen Gulch vein on No. 1 above Discovery.

Both veins strike about N. 60° E., and their relative position indicates that they may be on the same zone of fracture, but they are separated by a distance of about 500 feet in which the bedrock is not exposed. The Glen Gulch vein was exposed at the time of Maddren's visit for a distance of about 30 feet and the Black Creek vein for a

[1] Maddren, A. G., unpublished notes made in 1914.

somewhat shorter distance. They probably both stand nearly vertical, but as only the trace of the veins is exposed on the bedrock surface, and as no prospecting had been done on the deposits, their attitude could not be definitely determined. These veins occupy fissures in the monzonite which forms the bedrock of the creek. They are filled with quartz and range in thickness from 2 to 12 inches, probably averaging about 4 inches.

The vein filling is chiefly vitreous quartz, much of which shows crystalline outline, indicating the filling of open fissures at the time of deposition. Stibnite is the principal metallic mineral and appears to have been deposited after the quartz. A little cinnabar is associated with it and also some pyrite. The stibnite occurs in granular aggregates through which are scattered grains and crystals of vitreous quartz. Stibnite seems to be most abundant in the widest part of the vein, where it occurs as kidneys of irregular outline. Though the specimens were collected from the outcrop of the deposit, the stibnite shows very little oxidation, which may be due to the fact that the overburden was permanently frozen when first opened. As the alluvium that overlies these veins carries rich placers they may be auriferous. Scheelite occurs in the concentrates from the placers of these creeks but was not seen in the vein. So far as exposed the veins are not of sufficient width to permit development. Their description is here included because they indicate something of the mode of occurrence of the stibnite and because further prospecting might reveal larger ore bodies.

Maddren[1] also found a small stibnite-bearing vein on lower Slate Creek at a locality which lies approximately on the extension of the strike of the Glen Creek vein. Eakin[2] noted a small vein of stibnite associated with cinnabar at the head of Chicken Creek. This vein cuts a monzonite stock, and its mineral character is similar to those described above which occur on Glen Gulch and Black Creek. A specimen from this vein shows the deposition of quartz and cinnabar along both walls of the vein. Between these two siliceous parts of the vein lies an intergrowth of columnar and granular stibnite and vitreous quartz.

INNOKO DISTRICT.

Stibnite has been found in the concentrates of some of the placers of the Innoko district, but details regarding its distribution in the alluvium are lacking. According to Eakin[2] it occurs in a vein at a locality on Eldorado Creek about 1¼ miles from its junction with Ganes Creek. (See Pl. I, in pocket.) This lode is known as the

[1] Maddren, A. G., unpublished notes.
[2] Eakin, H. M., unpublished notes.

Katz prospect. It consists of a quartz vein which, where examined, is 8 to 10 feet in width, strikes N. 30° E., and dips 75° SE. This quartz vein, as described by Eakin, occupies a fissure that cuts sandstones, the extension of which is occupied by a rhyolite dike. The vein and dike can be traced for several thousand feet. Some specks of stibnite occur throughout the vein, but it is more abundant in a zone next the footwall, which is about a foot in thickness. Here granular aggregates of quartz and stibnite occur. The main lode is made up of sugary quartz, but the quartz associated with the stibnite is vitreous. A sample taken across the face of the vein on assay yielded only a trace of gold and silver.

According to Eakin a stibnite-bearing vein is reported to have been found in the Cripple Creek Mountains, in the northern part of the Innoko district. (See Pl. I, in pocket.) These mountains are formed by a monzonite stock which is intruded into Cretaceous sediments.[1] The vein is located near the head of Wyoming Creek and is reported to be about 30 inches thick. A specimen from this locality shows two bands, one of which is made up of quartz, some of it in crystals arranged at right angles to the banding, intergrown with cinnabar, and the other consists of coarse columnar stibnite associated with interstitial vitreous quartz. The longer axes of the stibnite crystals have a rough parallelism to the banding. The ore resembles that already described from Chicken Creek, in the Iditarod district.

SEWARD PENINSULA.

DISCOVERY AND DEVELOPMENT OF ANTIMONY DEPOSITS.

It is probable that the first discovery of stibnite on the Seward Peninsula was made many years ago at the Omalik mine, which was prospected as early as 1881.[2] An antimony lode occurs on this property, though it was developed for its silver-lead ores. Stibnite was found as an accessory mineral near Nome in 1900:

> The schists in the divide between Anvil and Glacier creeks are traversed by quartz veins containing arsenopyrite, chalcopyrite, pyrite, galena, a little stibnite, and visible gold.[3]

In 1905 a vein of stibnite was found on Manila Creek, and here developments were begun the following year.[4] This occurrence is now known as the Sliscovich mine. At about the same time stibnite was found at several other places in the Nome district.

[1] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pl. 3, 1914.

[2] Mendenhall, W. C., A reconnaissance in the Norton Bay region, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 214, 1901.

[3] Brooks, A. H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900: U. S. Geol. Survey Special Pub., p. 71, 1901.

[4] Smith, P. S., Investigations of mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, p. 244, 1908.

Some test shipments of ore were made from the Sliscovich mine in 1907 and in succeeding years, but there was no commercial output of antimony ore from Seward Peninsula until 1915. In that year antimony was produced from the Sliscovich mine and also from the Hed & Strand property, located a few miles to the north. There may have been some small shipments from other antimony lodes in the vicinity of Nome, but of this there is no record. It is not known how much antimony ore was mined during the year, but the actual shipments, according to the report of the deputy collector of the port of Nome, amounted to 148 short tons.

MODE OF OCCURRENCE.

At least two modes of occurrence have been recognized in the stibnite deposits of Seward Peninsula. The antimony ore that has been shipped has been taken from lodes which are essentially quartz veins that cut metamorphosed schists. A second type comprises the antimony which occurs in more or less close association with galena as replacement deposits in limestones. Mention should also be made of the occurrence of stibnite in association with fluorite in an altered rock, now largely composed of scapolite, in the Lost River basin of the York district.

In other parts of Alaska the stibnite-bearing quartz veins appear to be all genetically related to granitic intrusives. There is some evidence that this is also true in Seward Peninsula, but definite proof is not obtainable. The best known deposit is that at the Sliscovich mine, which occurs in schists that have been intruded by granite, though no granite crops out nearer than 3 miles from the lode. On the other hand, the Hed & Strand antimony lode lies near a granite intrusive, and on Lost River, in the York district, stibnite has been found in rocks that have been cut by quartz porphyry dikes. At the other localities the antimony occurs at some distance from the outcrops of any intrusive.

From what is known of the Fairbanks and other districts it is natural to expect a close relation between the bedrock source of the rich placers and the antimony lodes. Therefore the general distribution of auriferous lodes needs brief mention here. Though in the aggregate a good many auriferous veins have been found, but few of these have been opened up sufficiently to make it possible to determine their geologic relations.

The general distribution of the placer gold and what is known of the occurrence of auriferous quartz veins indicates that the contacts of the limestone and schist were favorable centers of mineralization.[1]

[1] Brooks, A. H., Geologic features of Alaskan metalliferous lodes: U. S. Geol. Survey Bull. 480, pp. 70–74, 1911.

Yet the auriferous mineralization was by no means confined to these contact zones.[1] The distribution of the antimony lodes bears out the same conclusion, for though the majority occur near the contacts of the limestone and schist, some have no such geologic relation.

It has long been known[2] that there were at least two periods of intrusion of quartz veins. The older system was intruded along the planes of foliation and was subsequently deformed; the younger system cut the older and has not been deformed. Both systems of veins carry gold and sulphides, but the mineralization seems to have been stronger in the younger. The stibnite-bearing fissure veins appear to belong with the younger crosscutting veins. Indeed, there is evidence that the antimony was introduced at a still later period of mineralization. It has been shown that no intimate relation has been established between the auriferous mineralization and the igneous intrusives. Smith[3] has, however, pointed out the genetic relation between some of the auriferous quartz of the peninsula and granitic intrusives and suggested that other bodies of the quartz may bear a similar relation to deeper masses of intrusives that do not outcrop. On the other hand, the mineralization that has been definitely connected with igneous intrusion comprises the tin and associated metalliferous deposits of the York region. These deposits, as shown by Knopf,[4] are of a different type from those here under discussion. It should be noted that one sporadic occurrence of stibnite has been found in the York district. This, however, is a different type of mineralization from that of other parts of the peninsula.

The quartz lodes that have been developed for antimony appear to carry but few metallic minerals except stibnite. They all contain some gold and generally a little pyrite and galena. Arsenopyrite is not an uncommon mineral in some of the auriferous lodes and has been found in at least one lode developed for its antimony. Quartz is the dominating gangue mineral in the stibnite lodes, in some places accompanied by a little calcite.

The antimony ore, so far as examined, consists in part of fine granular aggregates of pure stibnite, in which some glassy quartz grains are disseminated, and in part of an intergrowth of vitreous quartz and granular stibnite. Some specimens show an intergrowth of stibnite, pyrite, and quartz; others, an aggregate of needle-shaped

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[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, pp. 140–143, 1910.

[2] Collier, A. J., Hess, F. L., Smith, P. S., and Brooks, A. H., The gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, p. 118, 1908.

[3] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, p. 133, 1910.

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

crystals, which have a more or less radial arrangement and are distributed through a granular aggregate.

There is little information in regard to the mode of occurrence of the antimony ore within the lode, except that at the Sliscovich mine, which will be described below. There is some evidence that the stibnite ore, in part at least, occurs in shoots or kidneys. It is not known, however, whether these shoots are comparable in size to those found in the Fairbanks district. No general description will here be given of the stibnite that occurs in association with galena as replacement deposits in limestones. Only one example of this type—that of the Omalik mine—is definitely known on the peninsula, and this is described below.

MINES AND PROSPECTS.

Sliscovich mine.—The Sliscovich mine is located near the head of Manila Creek, at an elevation of 1,100 feet, and about 25 miles from Nome (fig. 3). Though the claim was staked in 1905, when developments were begun, it is only in recent years that the exploitation was undertaken on any considerable scale. Though the antimony of the lode was the chief feature which attracted the locator, yet until 1915 it was the gold that led to its development. Previous to 1915 only a few test shipments of stibnite were made, but in the past year the mine was worked largely for its antimony. Shipments of antimony were made during the open season of 1915. The Geological Survey has no records of the developments during 1914 and 1915, but the following statement, abstracted from a report by Chapin[1] shows the underground work accomplished up to the summer of 1913.

The vein, which strikes N. 60° E. and dips 45° NW., was traced on the surface for over half a mile, nearly across the basin of Manila Creek. Besides a number of prospect pits two openings have been made to develop the lode. A short distance below the point of discovery a 50-foot adit was driven to crosscut the lode, but no further work was done at this place. The main opening is at an elevation 100 feet lower. There an adit was driven 315 feet to the lode, which was opened by an inclined shaft for 100 feet.

The lode is composed essentially of dull, opaque quartz and stibnite, the sulphide of antimony, in approximately equal amounts, although slight variations in the proportions of the two minerals appear from place to place. Near the surface the antimony predominates, and in places nearly pure stibnite occurs in small bunches. A number of assays and analyses have been made on samples of the ore, all of which show rather constant antimony, gold, and silver. An analysis made on a small shipment of ore said by the owners to have been obtained by accurate sampling of the vein was submitted for chemical determination and showed the following:

[1] Chapin, Theodore, Lode developments on Seward Peninsula: U. S. Geol. Survey Bull. 592, pp. 403–404, 1914.

Gold and silver not published.

Antimony (Sb)[1]	35.05
Sulphur (S)	13.79
Silica (SiO_2)	48.80
Molybdenum (Mo)	None.
Qualitative arsenic (As)	None.
Wet lead	Trace.
	97.64

Lime and magnesia present but not determined quantitatively.

An analysis by the Tacoma Smelting Co., of Tacoma, Wash., showed:

Gold and silver not published.

Antimony[1]	36.40
Silica	49.00
Iron	5.10
	90.50

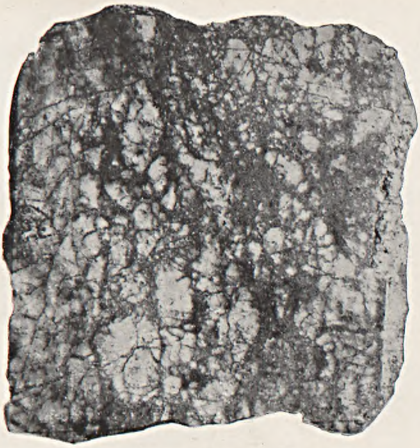
Although locally referred to as "the antimony mine," the property is being exploited (1913) solely for its content of gold and silver. The antimony appears to be of later origin than the quartz. Brecciated vein quartz has been healed by masses of stibnite that have inclosed quartz fragments and penetrated them as tiny veinlets of the sulphide.

The gold has two modes of occurrence. A part of it is free and may be seen readily in picked hand specimens. An examination of polished sections shows the greater part of the visible gold to be associated with the stibnite and to occur along the borders of the stibnite areas or in the connected cracks and veinlets which penetrate the quartz (Pl. III). It was probably introduced with the antimony. A small amount of the gold, however, has no apparent connection with the stibnite and may have been introduced with the quartz prior to the sulphide mineralization. The free gold is not evenly distributed throughout the vein but occurs in bunches and appears to be more plentiful in the surface portion of the vein. The greater part of the gold contained is invisible, occurring in a state of chemical combination with the stibnite. It may thus be seen that the lode owes its economic value to the sulphide mineralization, for most of the gold in both modes of occurrence was introduced through this agency. Locally the lode widens and narrows, varying in thickness from about 20 inches to 3 feet and appearing to widen and to become a little steeper with depth.

The country rock is dark-green chloritic schist composed mainly of quartz, chlorite, and colorless mica, in large part muscovite, with accessory amounts of calcite, epidote, hematite, and zircon. Bordering a seam of gouge that defines the footwall of the lode, about 15 inches of the wall rock has been altered to a mass of quartz and sericite with considerable white pyrite in small aggregate. The altered wall rock also contains small seams of gouge. The country rock long the hanging wall also has been silicified, but to a lesser extent.

Hed & Strand mine.—The Hed & Strand property is located on Dahl Gulch, a tributary of Lost Creek, which flows into Stewart River about 3 miles north of the Sliscovich mine (fig. 3). This

[1] These analyses of the ore presumably represent the average antimony content of samples taken from lode. No doubt the antimony ore actually shipped was concentrated by breaking and hand sorting, as is the practice at the Fairbanks mines.



A. NATURAL SIZE.

B. SAME SPECIMEN ENLARGED TWO DIAMETERS. SMALL BLACK SPECKS GOLD; GRAY MATERIAL STIBNITE.

ANTIMONY-GOLD ORE FROM SLISCOVICH MINE, NOME DISTRICT.

property was not visited by a Survey geologist, but the following information is obtained from sources which are believed to be reliable. The claim was located in 1909, and since that time considerable developments have been made. In 1915 some antimony ore was shipped.

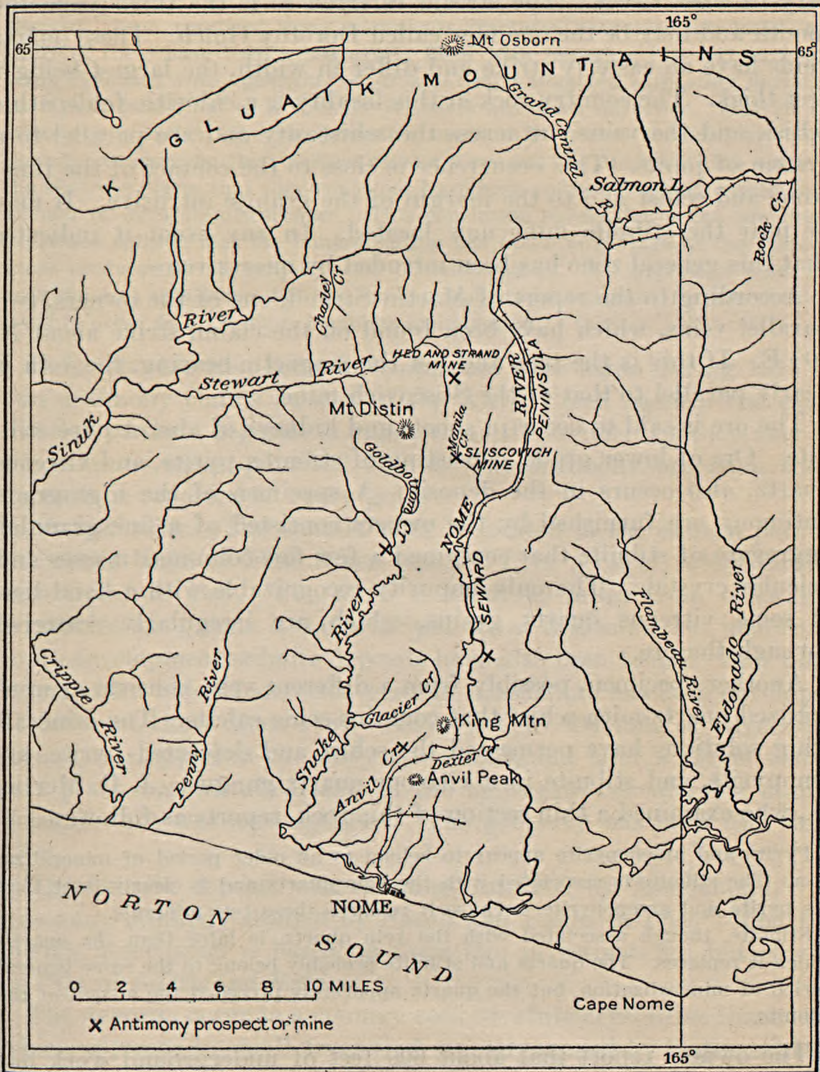


FIGURE 3.—Sketch map showing location of antimony deposits near Nome.

The available information does not permit a definite location of this property on the geologic map.[1] It appears to lie close to a contact of schist and limestone and not far from an intrusion of

[1] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, pl. 4, 1913.

granite. The rock adjacent to the lode has not been described. One of the specimens sent in from this property, however, is mineralized schist, and therefore schist probably forms the country rock of the deposit.

Some quartz veins have been noted by Moffit[1] on an easterly tributary of Lost Creek. The stream referred to is the third from the mouth and may be the one now called Dorothy Gulch. These quartz veins have an easterly strike and differ in width, the largest being 2 feet thick. The country rock at this locality is a chloritic feldspathic schist, and the veins cut across the schistosity and are parallel to a system of joints. This occurrence is close to the contact of the limestone and schist and to the margin of the granite intrusive. It may be near the stibnite mine now located. In any event it indicates that this general zone has been intruded by quartz veins.

According to the report of Martin Strand, one of the owners, two parallel veins, which have been found on the claim, strike about N. 70° E. If this is the true and not the magnetic bearing, the vein is nearly parallel to that of the Sliscovich mine.

The ore is said to occur in shoots and kidneys of almost pure stibnite. Ore of lower grade, consisting of stibnite, pyrite, and vitreous quartz, also occurs in the deposit. A specimen of the high-grade antimony ore furnished by the owners consisted of a fine granular aggregate of stibnite that contained a few fine columnar masses and acicular crystals. The only impurity recognizable with a hand lens is some vitreous quartz grains, which are irregularly scattered through the ore.

Another specimen, possibly from a different vein, consists of mineralized quartz-mica schist that contains some calcite. The mineralizing solutions have permeated the schist and deposited pyrite, arsenopyrite, and stibnite in a vitreous quartz gangue. J. B. Mertie, jr., who examined a thin section of this rock, reports as follows:

> Pyrite and arsenopyrite appear to belong to an older period of mineralization. The stibnite is associated with the vein quartz and is clearly later than the pyrite and arsenopyrite, because it replaces these two minerals.
>
> Stibnite, though associated with the vein quartz, is later than the quartz, which it replaces. The quartz and stibnite probably belong to the same general period of mineralization, but the quartz apparently preceded the advent of the stibnite.

The owners report that about 600 feet of underground work has been done on this mine. This work includes adits, drifts, crosscuts, raises, and a 40-foot shaft.

Anvil Creek.—A stibnite deposit on the west side of Anvil Creek, near Specimen Gulch (fig. 3, p. 55), was prospected by several pits in 1908. The country rock at this locality is schist which has been

[1] Moffit, F. H., unpublished notes.

much fractured and sheared. The observations made by Smith[1] in 1908 on this occurrence are as follows:

A short distance above Specimen Gulch, on the western slope of the Anvil Creek Valley, at an elevation of 25 to 30 feet above the stream, several holes have been sunk on a vein carrying a considerable amount of stibnite, or antimony sulphide. The rocks in this part of the valley are much dislocated and sheared. As a result of these movements fractures have been produced, and many of them have been subsequently filled with minerals. In certain places veins 18 inches wide, consisting of stibnite nearly unmixed with other minerals, have been found, but as a rule the stringers are much narrower. Most of the stibnite is in rather massive aggregates, but in a few places radiating groups of the mineral show by their perfect crystal form and the unbroken lath shape of the separate plates that they could not have been subjected to any considerable amount of dynamic disturbance. This conclusion substantiates the previously expressed opinion that the mineralization has taken advantage of the fracture zones produced by an earlier period of diastrophism. No systematic work has been done at this place, but the surface indications warrant further development in order to allow more complete examination.

It is reported that some developments were made during 1915 on two antimony claims located in the Anvil Creek basin. The exact location of these deposits is unknown to the writer, but they may be the same as those described above. The antimony ore from these deposits is reported to carry gold.

Omalik mine.—The Omalik mine is located in the eastern part of the upper basin of Fish River (see Pl. I, in pocket), which drains into Golofnin Bay. The mine is about 40 miles from tidewater. Argentiferous galena is the principal ore at this mine, but incidental to its development stibnite deposits have also been found. This mine is one of the oldest lode discoveries in Alaska and has been developed at different times since 1881. About 300 to 400 tons of silver-lead ores were shipped in the early operations, and later a rather elaborate plant was installed, and in the aggregate considerable underground work was accomplished. The property has been idle since 1908.

The Omalik deposit was examined in 1900 by Mendenhall.[2] It was more minutely studied by Smith and Eakin in 1909.[3] The following description is based on these two investigations, but chiefly on that of Smith and Eakin.

The deposits occur in a country rock of white crystalline limestone, which outcrops in small areas that are surrounded by biotite schists. According to Smith and Eakin, the limestone is probably older and

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[1] Smith, P. S., Recent developments in southern Seward Peninsula: U. S. Geol. Survey Bull. 379, pp. 282–283, 1909.

[2] Mendenhall, W. C., A reconnaissance of the Norton Bay region, Alaska: U. S. Geol. Survey Special Pub., pp. 213–214, 1901.

[3] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 131–133, 1911.

is infolded with the schists. A belt of greenstone—a sheared igneous rock, which is probably an intrusive in the limestone—occurs near the mine. This rock appears to have been intruded before the deposition of the galena and stibnite. Although the principal ore body is said to lie at the contact of the limestone and greenstone,[1] this could not be verified by Smith and Eakin, for the main workings were inaccessible at the time of their examination. They found, however, evidence of mineralization within the limestone at some distance from the greenstone contact. The most reliable information at hand indicates that the galena occurs in irregular pockets or kidneys, probably along zones of fracture which have given opportunity for the mineral-bearing solutions to circulate.

Two kinds of ore minerals are found in this deposit—argentiferous galena and stibnite. So far no interrelation between the two has been shown, but it is believed that both were introduced at essentially the same time. It should be noted that the deposits containing the galena seem to be topographically above those with stibnite.

From the reports of others—as it was not possible to see the underground workings personally—it was learned that "no continuous vein of galena ore existed, the ore being found only in irregular and disconnected pockets." None of the pockets were of large size and the better ones occurred entirely within the limestone. Some of the ore was thickly covered with products of oxidation, mostly lead carbonate.

About 400 paces south of the galena shaft there are a shaft and an incline which were used to explore the stibnite leads. The limestone is much fractured and the ore occurs in thin streaks in the shattered zone. None of the veins seen by the writers are of sufficient size to warrant mining. The stibnite is well crystallized, the thicker stringers apparently occupying fault planes and sending small offshoots into the limestone, which, near the ore, is abnormally granular and sugary.[2]

These ores are evidently replacement deposits in the limestone, and it is natural to connect their genesis with the intrusion of igneous rocks. No such rocks have, however, been found near the mine except the greenstone, which, as Smith and Eakin have pointed out, was intruded before the limestone was sheared. Granites intrusive in the metamorphic sediment occur about 10 miles east of the mine, and it is possible that a detailed study of the region may reveal some closer at hand.

Miscellaneous localities.—In 1907 a stibnite-bearing ledge was reported to have been found east of Nome River, on the divide between Mineral Creek and Osborn Creek. Smith[3] describes this and some other occurrences as follows:

The lead is reported to be rather flat lying and is much contorted, the ore occurring in lenses and kidneys. A piece of ore 6 inches wide, 8 inches thick, and a foot long from this vein was examined and found to consist of almost

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[1] Mendenhall, W. C., op. cit., p. 214.

[2] Smith, P. S., and Eakin, H. M., op. cit., p. 131.

[3] Smith, P. S., Investigations of the mineral deposits of Seward Peninsula: U. S. Geol. Survey Bull. 345, p. 245, 1908.

pure stibnite. The ore, in addition to antimony, carries more or less gold. Near the gold lode on Goldbottom Creek also some auriferous antimony ore has been reported, but the prospect was not visited by members of the survey. On Last Chance Creek a vein which is said to be 5 feet wide has been discovered, but exploration has not proceeded far enough to show the value of the property. Picked samples, however, are reported to yield high assays in both gold and antimony. Near the mouth of Goldbottom Creek on Snake River some stibnite has been found and it was proposed to ship some of the ore, but it is not known whether this was done or not.

Smith[1] has also noted that stibnite occurs with other sulphides in some of the quartz veins of the Solomon-Casadepaga region. So far as known, no antimony lodes have been found in this part of the peninsula.

Knopf[2] has made record of the occurrence of stibnite in the York district, which comprises the western part of the Seward Peninsula. Of this he says: "Some float stibnite associated with purple fluorite was found in the saddle at the head of Tin Creek by H. E. Angstadt, of the survey party." Tin Creek is an easterly tributary of Lost River, which flows into Bering Sea about 12 miles west of Port Clarence. (See Pl. I, in pocket.) The bedrock is limestone, which is cut by porphyritic dikes. Tin ores are found in association with these dikes. Near the locality of the stibnite float Knopf[3] found an altered rock which carried stibnite. The stibnite occurs in fine granular aggregates in association with fluorite. No primary minerals are recognizable in the rock, which consists chiefly of a dense aggregate of scapolite and is probably a contact-metamorphic phase of the limestone.

A specimen of stibnite, said to have been taken from a tunnel on the west side of Brooks Mountain (see Pl. I, in pocket) in the York district, has been presented to the Survey by George Jamme. This specimen is made up of coarse columnar aggregates of stibnite. Scattered through the ore are some irregular masses of vitreous quartz. Nothing is known about the lode from which this specimen was taken. Knopf[4] has, however, described a galena deposit in the same general locality, which occurs in a coarsely crystalline limestone close to the contact with a granite intrusive.

PRINCE WILLIAM SOUND AND KENAI PENINSULA.

Some of the siliceous gold ores of Prince William Sound contain stibnite as an accessory mineral.[5] These ores occur as fissure veins

[1] Smith, P. S., Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 433, p. 93, 1910.

[2] Knopf, Adolph, Geology of the Seward Peninsula tin deposits: U. S. Geol. Survey Bull. 358, p. 17, 1908.

[3] Knopf, Adolph, unpublished notes.

[4] Knopf, Adolph, op. cit., p. 42.

[5] Johnson, B. L., The gold and copper deposits of the Port Valdez district: U. S. Geol. Survey Bull. 622, pp. 157, 179, 185, 1915; The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 217, 228, 229, 230, 1914.

that cut a country rock of slate and graywacke. Though igneous intrusives are not very common, some granite and quartz diorite, both in the form of stocks and dikes, have been found, and Johnson has shown that the metalliferous veins are probably genetically related to these intrusives.[1]

The lodes are essentially quartz veins, carrying gold, pyrite, and galena, some stibnite, pyrrhotite, sphalerite, arsenopyrite, and chalcopyrite. Quartz is the dominating gangue mineral, and calcite and albite have also been found.

The auriferous quartz veins of Kenai Peninsula[2] are of very much the same type, but Johnson found no stibnite in them. There are, however, in both the Prince William Sound region and on Kenai Peninsula, some lodes in which stibnite is the dominating metallic mineral.

In the past little heed has been given by the miners to the antimony ores of this province. The general awakening of interest in antimony mining during 1915, however, led to considerable prospecting for stibnite deposits, though, so far as known, no antimony ore was shipped from Kenai Peninsula or Prince William Sound. Current reports indicate that some antimony lodes have been opened up, but information in regard to these is lacking at this writing. It is also reported that a stibnite lode has been found on Bear Creek in Kenai Peninsula. However, attention will be directed to certain deposits, long known, but which at the time of examination were practically undeveloped. These deposits were first studied by U. S. Grant, to whose reports reference will be made.

Stibnite lodes have been found at two places on Barry Arm (Pl. I, in pocket), in the Port Wells district. The exact location of one of these lodes is unknown; the other is described by Grant and Higgins[3] as follows:

On the east side of the bay of Port Wells, in which is the Barry Glacier, about 1½ miles south of the front of this glacier, is an antimony prospect. Near the shore there are exposures of graywacke striking N. 28° E. and dipping 45° to 60° W. Back (northeast) from the shore about 200 yards and 100 feet above the sea a few small strippings have been made on the north side of a small stream. The rocks here are black slates and graywackes, sheared and fractured. The strippings are along a zone of highly sheared rock. This zone is 6 to 8 feet in thickness, strikes N. 68° E., dips 45° to 65° N., and is the breccia along a thrust fault. The rock of this zone is black slate cemented by quartz. On the footwall side of the zone there is 3 to 4 inches of black gouge, and on the hanging wall one-half inch to 2 inches of the same material. Next to the hanging wall, but in the sheared zone, is a layer, 1 to 8 inches thick, of

[1] Johnson, B. L., The gold and copper deposits of the Port Valdez district: U. S. Geol. Survey Bull. 622, p. 158, 1915; The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, p. 217, 1914.

[2] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, pp. 131–142, 1915.

[3] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 78, 1910.

quartz holding less rock than usual. This layer contains stibnite (sulphide of antimony), which is closely associated with the quartz and in some places fills little vugs in the quartz. Some movement has taken place along the fault since the deposition of the quartz and stibnite, as indicated by slickensided surfaces. The samples of this layer collected here have one-tenth to one-third of their mass stibnite. This layer is reported to have been 2 feet thick in places and to have carried much more stibnite than noted above. About 1,000 pounds of antimony ore is said to have been taken from this place.

In 1913 Johnson also visited this locality, but the prospect holes had by that time caved, and he was unable to add anything to Grant's description. Specimens collected by him show the stibnite to occur in finely columnar and granular masses with which are associated some acicular crystals. Included within the masses of stibnite are grains of vitreous quartz, some of which show crystal terminations. Ferruginous carbonate is also intimately associated with the stibnite. These specimens also indicate that a quartz vein was shattered and subsequently intruded by the stibnite-bearing solutions. The original vein quartz is white, and in it are included some angular fragments of the country rock. Some cavities in the white quartz are filled with limonite, which suggests that the original quartz may have carried some sulphides before the introduction of the stibnite.

This is the only stibnite lode on Prince William Sound about which any definite information is available. It is reported, however, that stibnite veins have been found near Point Doran, at the entrance to Harriman Fiord, on Portage Bay, and on Coghill River, a tributary to College Fiord. All these localities are in the Port Wells district.

In the Valdez district a small vein of stibnite has been reported on McAllister Creek, a tributary of Shoup Bay. (See Pl. I, in pocket.) Johnson has noted the occurrence of stibnite as an accessory mineral in the auriferous quartz vein of the Silver Gem claim[1] and of the Gold King mine,[2] both in Port Valdez district. In Port Wells[3] district it has been found in the gold ores of the Reiter & Olson claims. According to Johnson[4] the stibnite at this locality occurs in large crystals in the central part of the vein, whereas near the walls pyrite and sphalerite are found. The quartz of the central part of the vein contains some cavities lined with quartz crystals and these cavities are filled with stibnite and iron-bearing calcium carbonate. Stibnite has also been reported by Johnson[3] in gold ore from the claims of the Sweepstake Co. and from the Granite mine. In the Granite mine it occurs as small acicular

[1] Johnson, B. L., The gold and copper deposits of the Port Valdez district: U. S. Geol. Survey Bull. 622, p. 179, 1915.

[2] Johnson, B. L., Idem, p. 185; The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 228–230, 1914.

[3] Johnson, B. L., The Port Wells gold-lode district: U. S. Geol. Survey Bull. 592, pp. 228–230, 1914.

[4] Johnson, B. L., oral communication.

crystals. According to Johnson[1] the evidence would seem to indicate that the stibnite of Prince William Sound region was deposited with an iron-bearing carbonate and possibly some quartz during the last stage of a single general period of mineralization. This view, he thinks, finds support in the presence of stibnite in the gold ores.

Only one occurrence of stibnite is definitely known on the Kenai Peninsula. (See Pl. I, in pocket.) This was first described by Grant and Higgins,[2] but the following account of this occurrence is by Johnson:[3]

> An antimony prospect is reported about three-quarters of a mile north of Kenai Lake and about a mile east of Quartz Creek. The country rock is slate cut by a dike 6 to 8 feet wide. Specimens from this prospect show a fine-grained, sheared, acidic dike rock containing stringers and disseminated particles of stibnite (sulphide of antimony). One specimen showed a small quartz vein that included needles of stibnite. Assays of the antimony ore are reported to show neither gold nor silver.

MISCELLANEOUS LOCALITIES.

All the districts containing stibnite deposits sufficiently well known to indicate their possible commercial value have been described above. Stibnite has been found, however, at a number of other localities in Alaska. At some of these localities, so far as known, the stibnite occurs only as an accessory mineral, and in others commercial ore bodies have been reported, but this has not been verified by field examination. A description of these localities is given in geographic order from south to north.

SOUTHEASTERN ALASKA.

Although southeastern Alaska has been more carefully prospected than any other part of the Territory, no stibnite lodes have been discovered. Spencer[4] has, indeed, reported the occurrence of stibnite at the Queen mine, in Juneau district (see Pl. I, in pocket), as "minute radiating needles inclosed in calcite." This occurrence, however, appears to be spasmodic, as this mineral has not been found in any of the other gold ores of southeastern Alaska, though tetrahedrite, the copper-antimony sulphide, is not an uncommon mineral in the gold quartz veins of that region.

NIZINA DISTRICT.

The Nizina placer district (see Pl. I, in pocket) lies in the upper basin of Chitina River, an easterly tributary of Copper River. Here

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[1] Johnson, B. L., oral communication.

[2] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U. S. Geol. Survey Bull. 442, p. 178, 1910.

[3] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, p. 179, 1915.

[4] Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, p. 36, 1906.

placer gold has long been mined, and stibnite has been found in the concentrates. On Chititu Creek[1] the concentrates, in addition to the gold and stibnite, include copper, silver, pyrite, galena, barite, and lead. The source of the gold has been traced to small quartz veins carrying pyrite, native gold, and some molybdenite and reported to carry stibnite.[2]

These veins cut black shales, formerly believed to be Triassic but now definitely assigned to the Upper Cretaceous. They are intimately associated with quartz diorite porphyry dikes. It is reported that in 1915 a stibnite-bearing lode was found in this district. The region is readily accessible from the coast by the railway which runs inland from Cordova.

WILLOW CREEK DISTRICT.

The Willow Creek gold district lies about 30 miles north of Knik (see Pl. I, in pocket), with which it is connected by wagon road, and will be made still more accessible by the Government railroad under construction. The auriferous quartz veins of this district have been productive for a number of years and occur in a quartz diorite stock intruded into schists. This intrusion took place during Mesozoic or possibly Tertiary time. Capps[3] reports the occurrence of stibnite in this district. He has informed the writer that he did not see any stibnite in place and that this mineral does not occur in the typical gold ores of the district.[4] However, he saw some specimens of a quartz vein carrying stibnite which came from the district, though the exact locality of the occurrence is unknown.

UPPER TANANA REGION.

Through the courtesy of Abraham Stein, of Fairbanks, the writer was enabled to examine a report by Albert Johnson on an occurrence of stibnite in the upper Tanana basin and also specimens from this locality. This occurrence is about 30 miles south of Tanana River, on Stibnite Creek (see Pl. I, in pocket), a northwesterly tributary of Tok River, and is about 15 miles north of Mentasta Pass. The deposit was found in 1914 and is reported to consist of banded quartz and stibnite which occupies a mineralized zone in mica schist country rock. The walls of the lode are said to be well defined by gouges, and the surface features to indicate a considerable body of ore. Specimens from this locality show the stibnite to occur in a fine granular aggregate that contains some acicular crystals. Fine grains of quartz are scattered through the stibnite ore.

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[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 105, 1911.

[2] Idem, pp. 98–99.

[3] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, p. 59, 1915.

[4] Capps, S. R., oral communication.

KOYUKUK-CHANDALAR REGION.

The gold deposits of the Koyukuk and Chandalar districts occur in a belt of mica schists which skirts the southern foot of the Endicott Mountains north of the Yukon. It appears that the placer gold is derived from areas that have been intruded by granites and diorites. Placer mining has long been carried on in the Koyukuk district where there has also been a little prospecting of auriferous veins. A little gold has been won from the placers of the Chandalar district (see Pl. I, in pocket), and much prospecting done on some quartz veins. These auriferous quartz veins of the Chandalar occur in mica schist near the margin of intrusive diorites,[1] and in addition to free gold carry much sphalerite and arsenopyrite, with which occur smaller amounts of stibnite and galena and a little pyrite and chalcopyrite. So far as known, the stibnite of this district occurs only as a minor accessory mineral. No stibnite has been found in the quartz veins of the Koyukuk district, but this mineral has been recognized in some of the concentrates from placer mines, notably on Gold Creek, an easterly tributary of the Middle Fork of the Koyukuk. Schrader[2] reports that pebbles and angular fragments of stibnite were found in the alluvium of this stream.

NORTON BAY REGION.

Smith and Eakin[3] found float stibnite in the gravels of Bonanza Creek, a tributary of Ungalik River, which flows into Norton Bay from the east. (See Pl. I, in pocket.) Gold placers were mined on this creek for several years. The bedrock of the creek consists of slates, probably of Cretaceous age, which are cut by granitic dikes. Prospectors also report the occurrence of stibnite float on the slope of Christmas Mountain, which is a dioritic stock intruded in Cretaceous sediments about 4 miles east of Bonanza Creek.

NOATAK REGION.

A gold-bearing quartz vein is reported to occur on the divide between Alatna and Noatak rivers. One specimen examined by Schrader[4] from this locality consisted of pyrite and quartz with chalcopyrite and a little bornite and malachite, and another consisted chiefly of stibnite. The meager description of the locality from which the above specimens were obtained makes it impossible to indicate it on a map.

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[1] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 110–115, 1913.

[2] Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne, in 1901: U. S. Geol. Survey Prof. Paper 20, p. 105, 1914.

[3] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 106–107, 1911.

[4] Schrader, F. C., op. cit., p. 103.

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MAP OF
ALASKA
SHOWING DISTRIBUTION OF ANTIMONY DEPOSITS
Compiled by Alfred H. Brooks
1916
Scale 1/5,000,000
Approximately 80 miles to 1 inch
50 0 50 100 150 200 Miles
50 0 50 100 150 200 Kilometers
Antimony (stibnite) lodes
Localities where stibnite occurs as an accessory mineral or has been reported to occur
LOCALITIES
1 Fairbanks district
2 Kantishna district
3 Cripple Creek Mountains
4 Katz prospect, Innoko district
5 Iditarod district
6 Parks prospect, lower Kuskokwim River
7 Russian Mountains, lower Kuskokwim River
8 Bonanza Creek, Norton Bay
9 Nome district
10 Omalik mine, eastern Seward Peninsula
11 Tin Creek, York district
12 Brooks Mountain, York district
13 Koyukuk district
14 Chandalar district
15 Tok River, upper Tanana River
16 Willow Creek district, Susitna River basin
17 Kenai Lake, Kenai Peninsula
18 Port Wells district, Prince William Sound
19 Valdez district, Prince William Sound
20 Nizina district, Copper River
21 Juneau district, southeastern Alaska
ARCTIC OCEAN
BERING SEA
PACIFIC OCEAN
GULF OF ALASKA
BRISTOL BAY
NORTON SOUND
ENDICOTT RANGE
ALASKA RANGE
CHUGACH MOUNTAINS
WRANGELL MOUNTAINS
ALEUTIAN ISLANDS
West of Greenwich