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OCCURRENCES OF MOLYBDENUM MINERALS IN ALASKA

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By Phillip S. Smith

ABSTRACT

In the accompanying report reference is made to all of the deposits in Alaska in which molybdenum minerals have been definitely recognized and reported. None of the deposits have been mined commercially, and none of them have been prospected thoroughly enough to afford quantitative estimates as to their tenor and potential reserves; in fact, at only a few of the localities has there been more than surficial testing. Forty-one separate and distinct localities where molybdenum minerals occur are listed, and the available information on factors of geologic significance regarding each occurrence is given. A small-scale map of Alaska on which the various localities are indicated forms part of the bulletin, and in the text are extensive references to the various published reports and records of the Survey upon which the statements are based. In spite of the widespread distribution of molybdenum mineralization in Alaska, the remoteness of many of the localities, their handicap through dearth of transportation facilities and labor supplies, and the already well-supplied condition of the American market for molybdenum ores discourage the early development of any of the known deposits or search for them in unsurveyed areas. These draw-backs will doubtless become less important factors as the settlement and development of Alaska as a whole takes place. It is, therefore, with a view to the future that one must consider these deposits, and from that standpoint it becomes evident that some of them merit watchful consideration.

INTRODUCTION

During the many years that the Geological Survey has been conducting mineral investigations in Alaska it has accumulated a large amount of data regarding all of the known mineral deposits of the Territory and has published most of the essential facts resulting therefrom. However, many of the records and descriptions, especially of the less-developed deposits and of the less-used materials are not now readily accessible, because they are widely, and often obscurely, scattered through the many volumes that have been published. It has therefore seemed desirable from time to time to assemble and bring together in one place all the available records regarding the known occurrences of individual mineral commodities. Such a compilation regarding the known occurrences of molybdenum minerals in Alaska is afforded by this volume.

In thus focusing attention on the molybdenum deposits the writer wishes to disclaim specifically any implication that the deposits discussed are likely to have a significant effect on supplying molybdenum ores to the Nation or to the world trade in the near future. At the present time the United States within its own borders exclusive of Alaska, is well supplied with developed molybdenum deposits, and those deposits now furnish more than 90 percent of all the molybdenum that is produced in the world. As a consequence, there is now little incentive to hunt for or to try to develop molybdenum deposits in remote parts of Alaska, which necessarily have the present disadvantages of greater distance from markets and supplies, lack of established facilities, and uncertainty as to the geologic factors that will be involved in their successful operation.

Many of the Alaska localities recorded are little more than points at which molybdenum minerals have been identified, and none of them afford specific quantitative information as to the potential resources at that place or in the neighborhood. On the other hand, the localities recorded indicate the minimum number of places where molybdenum minerals have been found, because they include only those that are specifically known to the Geological Survey and exclude those known only on the basis of unconfirmed reports from prospectors and others. Furthermore, it should be realized that less than half of Alaska has been examined by the Geological Survey; consequently, about 300,000 square miles, or an area approximately twice as large as the entire State of California, is as yet unsurveyed even by the most hasty explorations.

In spite of these limitations and imperfections in the available records, the assembling of the records regarding the occurrence of molybdenum minerals in Alaska serves to emphasize certain broad features of distribution or of geologic relationships and to make available the older records in such form as will save future inquirers time and effort in advancing any investigations they may undertake.

In collecting the data here set down the writer has assumed the role mainly of compiler. He has had the constant help and advice of his present associates in the Alaskan Branch, who in turn have availed themselves of the results of the work of the many geologists and engineers who in the past have carried on their field investigations under the administration of that branch. References to the specific contributions of each investigator have been made at appropriate points in later pages of the text, and grateful acknowledgment is made here of the general assistance freely rendered at all times throughout the preparation of the manuscript by F. H. Moffit, J. B. Mertie, Jr., and J. C. Reed.

CHARACTERISTICS OF MOLYBDENUM MINERALS IN ALASKA DEPOSITS

Although a number of compounds of molybdenum and other elements occur in nature, the only primary molybdenum mineral that has been recognized in Alaska deposits is molybdenite, a sulfide of molybdenum, whose chemical composition is 40 percent sulfur and 60 percent molybdenum and is indicated by the formula MoS_2. Usually this mineral occurs in plates or scales, which on casual examination resemble graphite. Molybdenite, however, differs from graphite in that it leaves a brown or bluish-gray streak on paper or other material rather than the black of graphite. The mineral also shows a somewhat bluish cast rather than the pure black of graphite. Chemical tests readily serve to differentiate the two, because molybdenite gives off sulfur fumes when heated and shows characteristic reactions for molybdenum when treated with acids, whereas graphite, consisting solely of carbon, shows no such reactions. Molybdenite is much heavier than graphite, having a specific gravity of about 4.7 as against 2.1 for graphite. Molybdenite is very soft, having a hardness of 1 to 1.5 on the scale customarily used by geologists, which ranges from 1 (very soft) to 10 (very hard). The plates or scales in which the mineral usually occurs can readily be bent, but they are not elastic and hence do not spring back into their original position. In these respects molybdenite resembles graphite and differs from the micas, for which, in small particles, it might be mistaken, as the ordinary micas are highly elastic.

In a few of the Alaska deposits the mineral wulfenite, which should not be confused with the mineral wolframite, has been reported. Wulfenite is a lead molybdate, which contains about 39 percent of molybdic trioxide and 61 percent of lead oxide and has the chemical formula $PbMoO_4$. It appears to occur only as a secondary product resulting from the weathering of original molybdenum minerals whereby solutions were formed that interacted with nearby lead-bearing minerals. This mineral usually forms in squarish tabular crystals, whose colors range from nearly white to deep red, but which, on being crushed, yield white powder or streak. Wulfenite is very heavy, having a specific gravity of 6.7 to 7. It is rather soft, having a hardness of 2.75 to 3, about that of calcite.

DESCRIPTION OF ALASKA OCCURRENCES

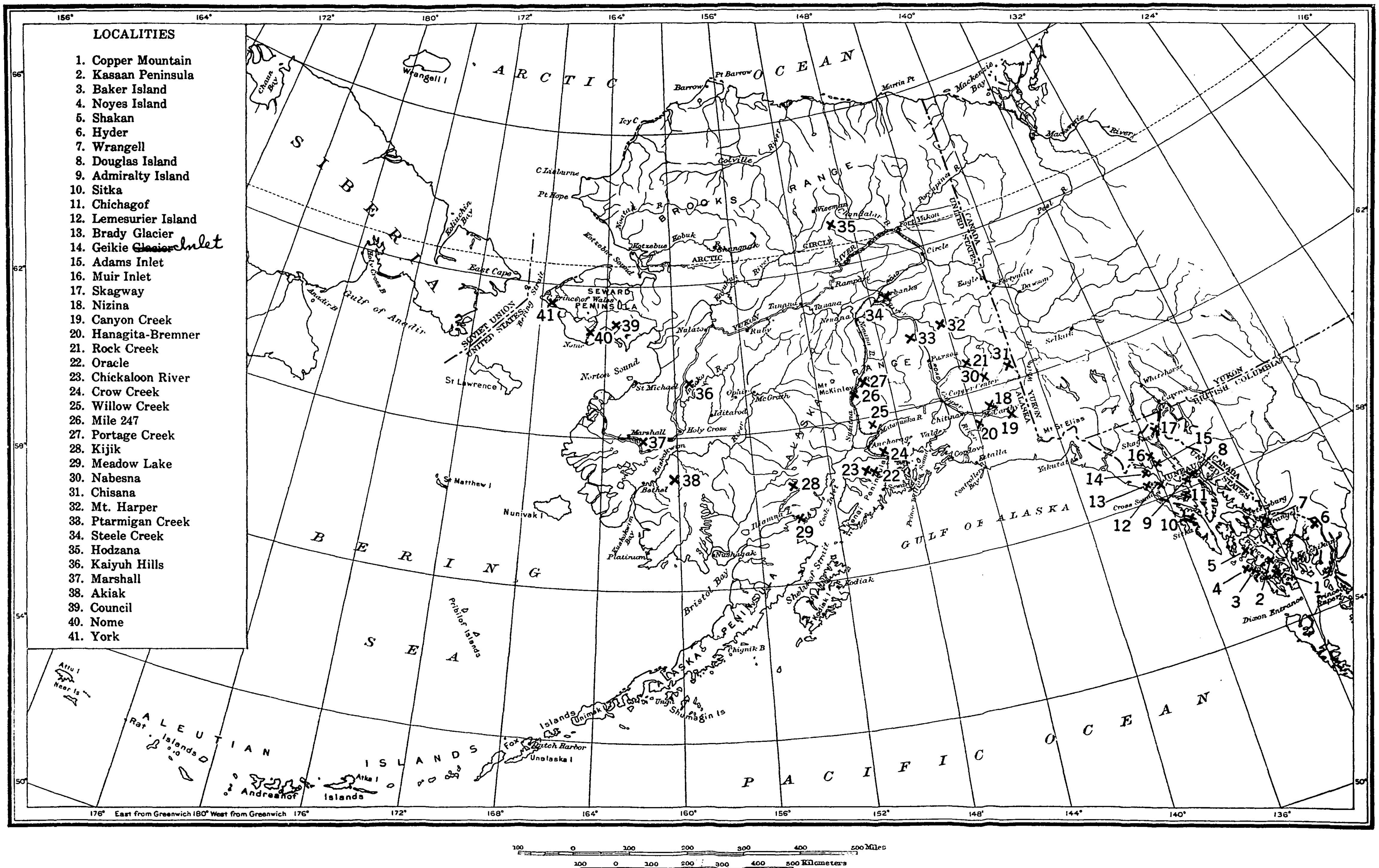
GENERAL DISTRIBUTION

At the present time some 41 separate Alaska localities are known at which molybdenum minerals occur. These localities are widely dispersed from near the extreme southern part of southeastern

Alaska to the extreme northwestern part, in Seward Peninsula. The order that has been adopted in describing these different localities in the main follows their geographic sequence from south to northwest. Following the usual practice of the Geological Survey, the largest geographic divisions of Alaska are called regions, the next smaller subdivisions are called districts, and the districts are broken down into smaller tracts, which are generally called areas or are named from individual mines or other distinguishing local features. The localities where molybdenum minerals occur are indicated on the accompanying map (pl. 12) and are numbered in sequence from the southeasternmost to the northwesternmost part of the Territory.

It should be clearly recognized that the adoption of a geographic order for the description of the occurrences of the minerals has the merit of avoiding any appearance of listing them in the order of their presumed economic importance. This is highly desirable, because the data on which to draw valid judgments as to the relative value of the various deposits are not now available. In fact, as yet few serious attempts to develop any of the Alaska molybdenum deposits have been made. Indeed, except for the work that has been done on the deposits at Shakan and on Lemesurier and Baker Islands, in southeastern Alaska, and on Rock Creek, in the Copper River region, none of the occurrences have been actively prospected with the sole aim of determining the feasibility of developing their molybdenum content.

The adoption of the various geographic divisions should not be regarded as other than a convenient method of arranging the various descriptions. If adequate information had been available it would have been far better to adopt a scheme in which the geologic relationships were more clearly emphasized. Then the reader would be aware of the role that certain geologic processes had in the formation of the deposits and would be aided in recognizing comparable areas in which search for molybdenum mineralization might be more profitably conducted than in places not having a favorable environment. To remedy this obvious defect an attempt has been made in a later section of this report to summarize some of the main points of geologic significance that come out of the individual descriptions that follow. For the present purpose it will perhaps suffice to urge the reader to regard the adoption of geographic divisions as merely a convenient method of description rather than as rigidly defining the extent of the mineralization referred to. In other words, the areas mentioned are to be regarded only as places at which the certain type of mineralization has actually been found, so that if similar geologic conditions prevail beyond that area it is probable that comparable mineralization also occurs there, though it may not yet have been discovered or reported.



MAP OF ALASKA SHOWING LOCALITIES WHERE MOLYBDENUM MINERALS HAVE BEEN FOUND.

SOUTHEASTERN ALASKA

In southeastern Alaska there are eight districts in which molybdenum minerals have been found, namely, Prince of Wales Island and vicinity, Hyder, Wrangell, Juneau, Sitka, Chichagof, Glacier Bay, and Skagway. In some of these districts the molybdenum minerals have been found at several rather widely separated places, which appear to be sufficiently distinct from one another to be described as separate areas. The records regarding each of these will be reviewed in the following pages.

PRINCE OF WALES ISLAND AND VICINITY

In five areas on Prince of Wales Island and in its vicinity occurrences of molybdenum minerals have been reported. These are at Copper Mountain, Kasaan Peninsula, Baker Island, Noyes Island, and near Shakan. General discussion of these occurrences, as well as of others in southeastern Alaska, is contained in a report by Buddington and Chapin,[1] which has been fully used, together with other more specific information, in the preparation of the present report.

COPPER MOUNTAIN AREA

Copper Mountain is the name of a prominent landmark about 45 miles northwest of the southern tip of Prince of Wales Island. In the main the higher parts of the mountain have for their bedrock granitic intrusives of Mesozoic age that have been injected into metamorphic schists and limestones of Paleozoic or later age. Near the contacts of the granitic rocks with the schists and limestones there has been considerable alteration, forming zones in some of which ore bodies have been found. In the past, several of these ore bodies yielded considerable copper ore that was mined commercially. The geology of this area, as well as of a nearby tract to the north, on Kasaan Peninsula, has been described in considerable detail by the Wrights.[2] From this report[3] it is learned that the molybdenite occurs in the contact deposits, usually in small flakes, or in the altered granitic rock near these deposits. At one of the mining claims, the Jumbo No. 4, the molybdenite is associated with such minerals as garnet, calcite, diopside, and chalcopyrite. An analysis of the altered diorite from the Jumbo mine[4] showed a content of 0.78 percent MoS_2. The altered diorite at the contact with the diopside-garnet-calcite rock is described as having lost all its free quartz and most of its

[1] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, pp. 329–330, 347–348, 1929.

[2] Wright, F. E. and C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula: U. S. Geol. Survey Prof. Paper 87, 110 pp., 1915.

[3] Idem, p. 49.

[4] Wright, F. E. and C. W., op. cit., p. 106.

plagioclase and as having in place of these abundant calcite, considerable garnet, and much diopside. Small patches of molybdenite accompanied the calcite, and to the Wrights it seemed clear that the molybdenite had been introduced, because it was abundant in the adjacent contact rock. They expressed the following conclusions: "The first development of the diorite was evidently accompanied by the deposition of pyrite, pyrrhotite, and molybdenite. Diopside seems to occur where pyrite is present, and calcite with hornblende accompanies the molybdenite and magnetite." A photograph of a characteristic specimen of the ore containing molybdenite is shown on plate 7, *D*, of the Wright report. The amount of molybdenite seen in the entire area, however, was small, and the Wrights[5] definitely state that "It is not found in the Copper Mountain area in commercial quantities."

KASAAN PENINSULA AREA

Kasaan Peninsula is a long promontory jutting out about midway on the eastern coast of Prince of Wales Island, some 25 miles northeast of Copper Mountain. In the main its geologic features are closely comparable with those of the Copper Mountain area in that large bodies of granitic intrusives have been injected into older sedimentary rocks having the composition of graywacke, quartzite, conglomerate, and limestone, which are regarded as dominantly of Devonian(?) age. A number of ore deposits occur in the area, the Wrights differentiating four distinctive types as defined by their mineral composition or by their mode of occurrence. In only one of these types, namely, the contact metamorphic deposits, do the Wrights[6] report the presence of molybdenite. They do not give details as to the mode of occurrence or of the quantity present. It is apparent, however, that they regard the origin as comparable with that at Copper Mountain, though it seems probable that the amount of this mineral actually seen in the Kasaan area was somewhat less. There are, however, large tracts of contact rock in the area, so that doubtless there are many places where molybdenite might be found if carefully searched for.

BAKER ISLAND AREA

Baker Island is about 16 miles long by 10 miles wide, lying about midway off the west coast of Prince of Wales Island. The general bedrock of the island as mapped by Buddington and Chapin[7] consists of a mass of quartz diorite, which occupies much of the southern part of the island and intrudes sediments that are mainly Middle

[5] Wright, F. E. and C. W., op. cit., p. 49.
[6] Wright, F. E. and C. W., op. cit., p. 87.
[7] Buddington, A. F., and Chapin, Theodore, op. cit., pl. 1.

Devonian. The northern part of the island is composed mainly of Middle Devonian andesitic lavas, breccia, and conglomerate. Apparently none of the Geological Survey geologists have examined the reported molybdenite deposits of the island, though the writer [8] stated that in 1930 a company had been formed to undertake their development. The following statements therefore rest on a report made June 8, 1931, by M. M. Reese, mining engineer, to J. G. Galvin of Seattle, a copy of which was courteously furnished to the Geological Survey. The property in question is that of the San Antonio Metals Co. and is said to embrace 26 claims, which cover most of the eastern part of the island south of Harbor Creek, San Antonio Bay. According to Mr. Reese, in the slates close to the contact with the main granitic mass are several fissures, which contain sugary quartz associated with molybdenite, pyrite, and pyrrhotite. In places the molybdenite appears as thick incrustations on the walls of the fissures, as well as enclosed in the quartz and in the altered granite. Samples taken by Mr. Reese were regarded by him as carrying on the average about 0.276 percent of MoS_2, as well as considerable amounts of gold, though he states that a number of samples carried several percent of MoS_2 and one carried 7.25 percent. Using his estimated average assay content and his estimate that 100,000 tons of such ore occurs above drainage level as a basis for computation, he concluded that the molybdenite and gold in the surficial part of the deposit alone would defray all anticipated costs of operation and leave a margin of profit. In spite of his encouraging report the property has not yet been brought into successful production and in fact has been the scene of only little actual exploration.

NOYES ISLAND AREA

Noyes Island is a small island lying off the west coast of Prince of Wales Island, a few miles northwest of the north coast of Baker Island. Very little is known about the occurrence of molybdenum minerals at this place, though Buddington [9] definitely notes the occurrence of molybdenite on the north coast of this island and states that it is found there in schist. The geologic map accompanying Buddington's report shows that the rocks exposed on the north coast of the island are in the main Middle Devonian slates and limestones with interbedded andesitic volcanics. No granitic intrusives are indicated on his map in the vicinity of the north coast or elsewhere on the entire island, but Wright [10] refers to the fact that "chalcopyrite associated with pyrrhotite has been discovered at the

[8] Smith, P. S., Mineral industry of Alaska in 1930: U. S. Geol. Survey Bull. 836, p. 81, 1933.

[9] Buddington, A. F., and Chapin, Theodore, op. cit., p. 329.

[10] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 80, 1908.

granitic contact on the north end of Noyes Island * * *." It seems probable, therefore, that the molybdenite may have been introduced into the schists at this place by the igneous activity attendant on the injection of granitic rocks, which are the same or comparable to those reported by Wright.

SHAKAN AREA

Shakan is a small settlement on Kosciusko Island, not far from the extreme northern point of Prince of Wales Island. The geology of the area is complex, a great variety of different kinds of sediments of early Paleozoic age having been intruded by a granite and dioritic stock 6 to 8 miles in diameter. A mineral that was supposed to be lead but that subsequently proved to be molybdenite, had long been known to occur near Shakan, and claims had been taken up to include the better showings. These claims were subsequently allowed to lapse but were relocated for the molybdenite showings in 1917 and the property bonded to the Alaska Treadwell Mining Co. At that time the price of molybdenite was approximately $2 a pound, and the entire production of metallic molybdenum from deposits throughout the world appears to have been less than 1,000 tons a year.[11] The opportunity of establishing a significant mining enterprise appeared attractive, and the company started and carried on extensive prospecting and development work until late in 1918, when the ending of the war, with the attendant collapse in the price of molybdenum, and the extensive opening up of large deposits in the States so altered conditions that the company no longer felt justified in continuing the Shakan project. During the time that work was in progress at this property many items regarding the acomplishments were recorded in various Geological survey reports, the more significant of which appeared in publications by Chapin,[12] Mertie,[13] and Hess.[14] Several informative articles regarding this deposit also appeared in the technical press. Of these, that by Bradley [15] is the most comprehensive and authoritative.

Recently through the courtesy of the Alaska Juneau Gold Mining Co. the Geological Survey has been permited to consult a report [16] made to the company by its geologist, Livingston Wernecke, at the

[11] World Atlas of Commercial Geology, pt. 1, Distribution of mineral production, p. 38, U. S. Geol. Survey, 1921.

[12] Chapin, Theodore, Mining developments in the Ketchikan district: U. S. Geol. Survey Bull. 692, p. 89, 1919.

[13] Mertie, J. B., Jr., Lode mining in the Juneau and Ketchikan districts: U. S. Geol. Survey Bull. 714, pp. 118–119, 1921.

[14] Hess, F. L., Molybdenite deposits, a short review: U. S. Geol. Survey Bull. 761, pp. 14–15, 1924.

[15] Bradley, F. W., Min. and Sci. Press, vol. 118, p. 48, 1918.

[16] Wernecke, Livingston, Geology of Shakan molybdenite deposit, Treadwell, Alaska, December 28, 1917 (unpublished report).

time exploration of the property was most active. As that report gives especially full details as to the geology and other characteristics of the ore occurrence, it forms the source from which all the following statements have been abstracted.

The claims forming this property were known as the Alaska Chief group and were situated one-third of a mile or more southeast of Shakan village. In the vicinity of Shakan the bedrock consists of a Lower Devonian limestone about 2,000 feet thick, striking N. 5° to 15° W. and dipping 70° W. This limestone grades upward into greenstone composed of fine volcanic tuffs, in places banded with black argillite. Lying to the east and cutting all of these older rocks is a large intrusive mass of diorite, whose contact with these older rocks is doubtless irregular in detail but broadly follows a crescentic course from near Shakan to Calder Bay. The diorite contains considerable hornblende and in places approaches the composition of gabbro. The molybdenite-bearing material is a quartz-albite vein in the diorite, about 1,000 feet from the contact of that rock with the argillite. This vein had been traced by surface cuts and a tunnel for a linear distance of 520 feet, and in that distance it had been found to range in width from 2 feet to more than 6 feet, with an average width of 4.1 feet. The vein usually is separated from the diorite on the footwall by a layer of gouge, and this condition is occasionally true for the hanging wall contact, though more commonly the vein and the diorite on that wall are "frozen" together. The course of the vein is exceedingly variable. In different places it strikes from N. 60° W. to N. 65° E. Its dip, however, is fairly uniform, at from 20° to 30° S.

The deposit, according to Mr. Wernecke, clearly was formed by circulating thermal waters, which deposited quartz, albite, orthoclase, phrenite, epidote, biotite, chlorite, and some sericite as gangue and pyrrhotite, pyrite, chalcopyrite, and molybdenite as metallic sulfides. In places these metallic sulfides form as much as 30 to 40 percent of the vein filling, and in the order of their relative abundance are usually about as follows: pyrrhotite 50 percent, pyrite 40 percent, chalcopyrite 6 percent, and molybdenite 4 percent. The amount of molybdenite in different parts of the vein varies widely. Apparently it is most abundant in those places where the gangue consists of about 30 percent of quartz, 40 percent of albite, and 20 percent of orthoclase. Molybdenite is also especially abundant in those places where numerous fragments of the altered wall rock diorite form inclusions in the vein. The third place that appears favorable for the formation of molybdenite is where quartz is absent, or present only in small amounts, and pyrite is abundant. In these places the pyrite is cut by many small veinlets, one-sixteenth to one-fourth inch wide, which contain considerable amounts of molybdenite.

Obviously the deposit is genetically connected with the intrusion of the hornblende diorite and was formed after the wall rocks had solidified sufficiently to fracture and were comparatively cool. The relation of the molybdenite to other vein minerals indicated to Mr. Wernecke that there were two stages during which the molybdenite was deposited. One of these was at a fairly early stage, while the temperature was relatively high; the other was at a much later time, when the temperature was considerably lower. Most of the molybdenite was deposited during this later stage, when the temperature had probably fallen below 300° C. Evidence of the lateness of its deposition is afforded by the fact that the molybdenite coats all the other sulfides and is the latest deposit on the walls of cavities.

Thirteen samples taken at fairly regular intervals along the vein as exposed in the tunnel showed molybdenite content ranging from 0.27 percent to 2.32 percent, with an average of 0.95 percent of MoS_2. Six other assays that had been made of samples cut during earlier operations of the company averaged 0.69 percent of MoS_2. The average for all 19 of these assays gave 0.86 percent of MoS_2. Obviously, parts of the vein would show a much higher tenor, but the foregoing was the average for the entire 520 feet. On the basis of an average width of slightly more than 4 feet, the estimated tonnage of this one vein would probably not exceed 100,000 tons, but there was expectation that as exploration progressed extensions of the principal vein or new veins might be found. As planned at that time, mining would be carried on at a rate sufficient to supply a mill capable of handling about 100 tons in 24 hours. Apparently the various ore-dressing and metallurgical procedures were never carried out, and no ore or concentrates were produced for sale. As noted above, the collapse of metal prices following the Armistice led to suspension of further prospecting and development work at the Shakan property, and so far as the Geological Survey is informed no further work has been done there.

In some of the early analyses of the ore from the Shakan property a considerable amount of vanadium pentoxide was reported, one analysis showing 0.52 percent of this material. This was so much more than was expected or apparent from microscopic examinations that F. L. Hess, at that time the Survey specialist on the rare minerals, took the matter up with F. W. Bradley, the president of the company that was carrying on the exploration. In a letter to Mr. Hess, dated February 21, 1919, Mr. Bradley discussed the matter and stated his belief that the amount of vanadium shown by this earlier analysis was erroneous, and he then cited the results of an especially thorough, new analysis that had been made by Mr. Wernecke to test this particular point. This later analysis showed vanadium pentoxide as only 0.04 percent of V_2O_5. Mr. Bradley quoted Mr. Wernecke to the effect "It verifies my conclusion that vanadium is present in only very small quantities."

HYDER DISTRICT

In the Hyder district, which embraces the country adjacent to the international boundary at the head of the Portland Canal, in the extreme eastern part of southeastern Alaska, considerable detailed work has been done by Buddington. As a result of his studies in the district he states:[17]

> Molybdenite has not been found in the normal vein deposits. It is abundant in an aplite dike associated with the Texas Creek granodiorite on the banks of Fish Creek, on Fish Creek No. 2 claim of the Mountain View property. In the vicinity of the head of the West Fork many of the thin quartz veinlets facing fractures in the Texas Creek quartz diorite carry pyrite and molybdenite. In the vicinity of Greenpoint Glacier fractures in the Hyder quartz monzonite adjacent to the contact with the graywacke and slate are coated at some places with molybdenite.

On plate 2 accompanying Buddington's report these various intrusive igneous rocks are shown as different units that go to make up the great Coast Range batholith and are known as the Coast Range intrusives and are assigned to the Jurassic or Cretaceous. The Texas Creek granodiorite is regarded as having been formed somewhat earlier than the Hyder monzonite. The sedimentary rocks mentioned are considered to be members of the Hazelton group, which is assigned to the Jurassic (?). The molybdenum mineralization at the head of the West Fork appears to have been especially noted on claims held by Frank Blasher and to have been exposed in an adit at an elevation of 2,700 feet. Concerning this place Buddington[18] notes "The adit starts in argillite which contains quartz veins with disseminated molybdenite."

Apparently molybdenum mineralization may be expected at many places near the border zone of the Coast Range batholith. W. B. Jewell, who assisted Buddington in the surveys near Hyder, made a reconnaissance along the Chickamin River, which cuts across a considerable section of the range. One of the results of that reconnaissance was to demonstrate that a few glassy quartz veins near the contact of the Coast Range batholith with the metamorphic complex on the southwest contain small amounts of pyrite and molybdenite. One specific locality of this type is mentioned by Buddington[19] on

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[17] Buddington, A. F., Geology of Hyder and vicinity, southeastern Alaska: U. S. Geol. Survey Bull. 807, p. 50, 1929.

[18] Buddington, A. F., op. cit., p. 100.

[19] Buddington, A. F., op. cit., p. 120.

a group of claims situated on the north side of Chickamin River, about 4 miles east of Behm Canal. At this place there is a glassy quartz vein about 8 feet wide in the granodiorite, striking N. 30° W. and dipping 60° NE. This vein is slightly mineralized with pyrite and molybdenite on the hanging wall. No development of the property appears to have been in progress for many years.

In a recent report from Frank Blasher regarding his prospecting ventures in 1940 the following information is given. A vein 4 feet wide showing molybdenite mineralization was discovered on the Blasher group of claims on Texas Creek. The molybdenite occurs in a quartz vein in the granodiorite formations. An open cut about 20 feet long was driven to open up and test the deposit, but so far as known no shipments of ore or concentrates have been made.

WRANGELL DISTRICT

Evidence of the occurrence of molybdenum minerals in the vicinity of Wrangell is not very definite. The writer [20] noted that "During 1930 interest was revived in the deposits containing molybdenite that are found in veins in the Ground Hog Basin near Wrangell * * *." The Wrights,[21] however, who had specifically described the mines and prospects in this basin and neighboring areas in an earlier report made no definite mention of the occurrence of molybdenite there, though in another part of their report [22] they do state "Flakes of molybdenite, molybdenum sulfide, are found in some of the quartz veinlets occurring in the metamorphic schists and schists and intrusives of the mainland." This very indefinite location might well fit the conditions in the Ground Hog Basin, as it is on the mainland and is traversed by a narrow belt of Coast Range intrusives which is bordered both to the northeast and southwest by metamorphic schists that have been considerably mineralized near their contacts with the igneous rocks. Obviously this occurrence is among the least well-substantiated occurrences in the Territory, and many other localities might fit equally well the descriptions given.

JUNEAU DISTRICT

DOUGLAS ISLAND AREA

Douglas Island is a small island lying immediately close to and west of Juneau. It is the site of what was for many years the principal producing lode-gold mines of the Territory, notably the Treadwell group of properties. The geology of this area, as well as of

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[20] Smith, P. S., Mineral industry of Alaska in 1930: U. S. Geol. Survey Bull. 836, p. 81, 1933.

[21] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 188–190, 1908.

[22] Idem, p. 89.

other parts of the so-called Juneau gold belt, was intensively studied by Spencer,[23] assisted by C. W. Wright, during 1903 and 1904, and in the report resulting from that work the occurrence of molybdenite is frequently mentioned. The Treadwell properties lie some 5 to 6 miles west of the main western boundary of the Coast Range batholith in this part of Alaska. In the intervening area are metamorphic schists, slates, and greenstones that have been intruded by the Coast Range diorite and dikes that appear to have been associated with that intrusion. In the immediate vicinity of the mines are alternating schists, slates, and greenstones that in general dip eastward at angles of as much as 75°. All these rocks have been intruded and greatly altered and contain considerable amounts of minerals that have been introduced either in the form of fracture fillings or as impregnations of the rock masses. The following specific comments by Spencer [24] give the significant facts regarding the occurrence of the molybdenite:

"It [molybdenite] has not been observed in the quartz veins at large but occurs in certain zones of sheeting in the diorites of the region and has been found in all parts of the Treadwell ore bodies. When present in amounts notable to the unaided eye it is said to indicate an increase in the value of the ore but no constant relations between molybdenite and the gold of the ores have been established."

He further states,[25] "Molybdenite is frequently noted, though it is irregularly distributed," and again [26] "Molybdenite can hardly be an important carrier of gold, because it seems to be somewhat limited in distribution, though its presence in visible quantities is said to indicate high values." However, he specifically states [27] that the ore-bearing solutions that introduced the valuable gold-bearing minerals were hot ascending solutions that contained among other elements molybdenum, and that they laid down at least part of their mineral constituents at considerable depths below what was then the surface of the earth. The origin of these ore-bearing solutions Spencer [28] concludes was from a magmatic source connected with the emplacement of the great Coast Range batholith. The molybdenite appears to have been formed relatively late in the general sequence of mineral formation, as Spencer [29] lists it among the group which he refers to as "secondary minerals."

[23] Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, 161 pp., 1906.
[24] Spencer, A. C., op. cit., p. 36.
[25] Spencer, A. C., op. cit., p. 109.
[26] Spencer, A. C., op. cit., p. 111.
[27] Spencer, A. C., op. cit., p. 29.
[28] Spencer, A. C., op. cit., p. 30.
[29] Spencer, A. C., op. cit., p. 101.

From the foregoing descriptions it is evident that although molybdenite was fairly common in the Treadwell mine it did not occur there in masses of sufficient concentration to have attracted attention as a resource that merited being mined separately.

ADMIRALTY ISLAND AREA

It is with considerable hestitation and doubt that the possible occurrence of molybdenite in the vicinity of Admiralty Island is recorded. The only justification for listing this area among those in which molybdenite has been reported rests on the fact that a specimen of molybdenite was received by the Geological Survey from one of the principal mining operators on the island. The identification of the mineral was reported in a letter from the Geological Survey to W. S. Pekovich, of Funter Bay, under date of March 22, 1932. No definite information was obtained as to the source of the specimen, and it is therefore a pure assumption that it came from near the address of the sender. In fact, J. C. Reed, who has made the most extensive examinations of the island of any of the present Geological Survey geologists, has stated his firm conviction that molybdenite has not been recognized in any of the deposits of the island. The fact that parts of Admiralty Island lie only 10 to 20 miles distant from the Douglas Island locality and in certain respects present somewhat comparable relations to intrusives correlated with those of the Coast Range lends some color to the possibility of molybdenite occurring on Admiralty Island.

SITKA DISTRICT

An occurrence of molybdenite in the Sitka district was examined by J. C. Reed in the course of his field work during the season of 1941, and he makes the following statements regarding it:

The molybdenite mineralization occurs on claims held by C. E. Deining, on one of the smaller of the Magoun Islands, a group of islands near the southern end of Krestof Sound between Krusof and Krestof Islands, about 12 miles northwest of Sitka.

On inspection of hand specimens and outcrops in the field, the country rock at the prospect appears to be biotite quartz diorite. The rock is massive and locally is slightly foliated. The extent of the quartz diorite has not been determined, but presumably it does not occupy a very large tract, as the principal country rock of the neighborhood is graywacke, thought to be of Cretaceous age, into which the quartz diorite is probably intrusive.

At the prospect a quartz veinlet is exposed for a few feet on the beach between salt water and the cover of vegetable debris that elsewhere hides the bedrock. The veinlet, which stands nearly vertical and trends about N. 60° E., attains a maximum width of about 6 inches and locally appears to have pegmatitic borders. In addition to the veinlet mentioned, the rock nearby is cut by several much smaller, branching veinlets.

Chalcopyrite is distributed rather sparsely throughout the larger veinlet. Molybdenite, in plates as much as one-half inch or more in diameter, is present in the veinlet but is concentrated near and on the veinlet walls. Some molybdenite is present in the quarz diorite walls close to the veinlet. In the part of the veinlet exposed, the molybdenite is more abundant on the southeast than on the northwest wall.

CHICHAGOF DISTRICT

An occurrence of molybdenum mineralization on the east coast of Chichagof Island was examined by J. C. Reed in the course of his field work during the season of 1941, and the following observations were made by him.

In May 1941 a mining claim, called the 3 J claim, was staked by Joe Stannard and Jim Martin on a molybdenite showing on the north shore of Tenakee Inlet, Chichagof Island, about 5½ miles east of the village of Tenakee.

The country rock is coarse-grained biotite-hornblende quartz diorite. The rock is massive, but locally it is slightly and obscurely foliated. Rounded, dark, richly biotitic inclusions or segregations are sprinkled through the diorite. At and near the discovery post of the claim the coarse-grained country rock is cut by dikes of finer-grained, lighter-colored, intrusive rock, which, in the absence of microscopic evidence, is called aplite. The dikes appear irregular and branching, but they are not sufficiently exposed over a large enough area to yield a clear picture of their pattern. A dike at the discovery post is at least 20 feet wide, and its boundaries are partly obscured. The contacts between the dikes and the coarser-grained quartz diorite are generally rather sharp, but they are "frozen," slightly wavy, and locally are gradational over short distances.

Molybdenite in small flakes is conspicuously present in the aplite, but some of the aplite may be barren of this mineral. Molybdenite, apparently in smaller amounts, is disseminated in the quartz diorite, but it may be more abundant there than is realized because it is fine grained and difficult to identify in the micaceous quartz diorite.

The molybdenite is closely associated with chalcopyrite. The chalcopyrite seems more widespread than the molybdenite in the quartz diorite, whereas the reverse may be true in the aplite.

A rather crude chip sample cut over a length of 5 feet in a random direction in the aplite at the discovery post of the claim contained 0.01 percent of molybdenum and 0.07 percent of copper. A similar sample from the quartz diorite about 75 feet northeast of the discovery post contained less than 0.01 percent of molybdenum and 0.01 percent of copper. The low molybdenum content of the samples, particularly of the one cut in the quartz diorite, indicates that the material exposed now on the 3 J claim is probably not of commercial significance.

GLACIER BAY DISTRICT

The Glacier Bay district, as its name implies, embraces a large tract of country adjacent to Glacier Bay, which lies some 80 or more miles northwest of Juneau. The occurrence of molybdenite has been resported at five separate localities in this district. These, for convenience, will be described as the Lemesurier Island, Brady Glacier, Geikie Inlet, Adams Inlet, and Muir Inlet areas.

LEMESURIER ISLAND AREA

Lemesurier Island is a small island about 5 miles long, lying just south and west of the entrance to Glacier Bay. The geology and ore deposits of this locality were examined and described by Buddington,[30] from whose report the following abstract has been made. The principal showings of molybdenite mineralization on the island are on the headland on the southern coast, about midway between Iceberg and Willoughby Coves. The development at this place at the time of Buddington's visit consisted of a tunnel about 78 feet long and a 25-foot crosscut at an elevation of about 50 feet above sea level. At this place massive contact rock and hornstone are exposed at the contact between limestone and diorite for a width of about 30 feet. The contact rock consists dominantly of red-brown garnet and associated metamorphic minerals, of which the most common is green pyroxene. The tunnel was started near the contact between the limestone and the contact rock. Farther in, the tunnel cuts banded hornstone and quartzite beds, but at the face it is in diorite. Several pockets of garnet rock occur at intervals along the walls of the tunnel, but the best exposures are at the surface. The molybdenite occurs as facings along small gash fractures in the contact rock and to a lesser extent in disseminated form. Although the quantity of molybdenite in general is sparse, Buddington noted that at places there were small pockets in which molybdenite formed as much as several percent of the rock. Reed, who made a brief visit to the property in 1936, states that at the time of his visit work on the property appeared to have been abandoned for a long time, though the two claims, the Christmas and the Enterprise, which had been patented, were still held in the name of G. H. Whitney. Reed's observations agree with those made by Buddington, and he added little new information to that which had been published, except to

[30] Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 783, pp. 55–56, 1926.

give a somewhat more detailed petrographic description of some of the rocks and to state specifically that this contact deposit was probably formed at high temperature. From informal discussion with Reed the writer has gained the impression that he regards the showings he saw as justifying a much more intensive examination of the property as a possible source of molybdenite, although he realizes that the commercial development of such a deposit involves many factors lying outside the field of geology. A brief statement regarding some of Reed's observations[31] at this place was published in 1938.

In addition to the molybdenite mineralization shown on the Whitney property, Buddington also stated that he had been informed by J. P. Ibach that small vein stringers with variable mineralization had been recognized on the headland southwest of Willoughby Cove, on the southern coast of Lemesurier Island. These stringers were reported to consist of quartz with garnet and molybdenite; epidote with bornite along the fractures; pyroxene with molybdenite; and quartz heavily metallized with chalcopyrite. This locality has not been examined by any of the Survey geologists, and no further details regarding the occurrence are now available.

BRADY GLACIER AREA

About 20 miles west of the entrance to Glacier Bay is the front of Brady Glacier, one of the large streams of ice that heads in the high mountain range that extends southeastward from Mount Fairweather. Most of the country tributary to Brady Glacier is unexplored, but its general relation to known areas indicates that its geologic formations are broadly comparable to those occurring in parts of Chichagof Island to the south and of the Glacier Bay area on the east. In other words it is probable that large tracts in it are occupied by igneous rocks correlated with certain outlying units of the great series of intrusives of the Coast Range. These igneous rocks intruded Paleozoic and Mesozoic sediments and volcanics that have a wide range in lithologic facies. Buddington[32] records the fact that "Very fine specimens of molybdenite quartz veins have been brought from float on Brady Glazier." Obviously, being aware of the hundreds of square miles tributary to this glacier, it is entirely impracticable to surmise as to the precise locality from which the molybdenite float may have come. However, it seems certain that it came from within the limits of the present basin of the glacier and that doubtless its source was in or close to the contact zone of some of the igneous intrusives with the sedi-

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[31] Reed, J. C., Some mineral deposits of Glacier Bay and vicinity, Alaska: Econ. Geology, vol. 33, pp. 74, 79, 1938.

[32] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, pp. 329–330, 1929.

mentary rocks. That there are many such places in the area is abundantly indicated by the available information, so that search for the source from which the specific float came would probably be extremely difficult; in that search, however, it is not at all unlikely that other occurrences of molybdenum mineralization might be disclosed.

GEIKIE INLET AREA

Geikie Inlet indents the western coast line of Glacier Bay, about 20 miles northwest of the entrance to the bay. Buddington [33] notes that "Very fine specimens of molybdenite quartz veins have been brought from float * * * from Geikie Inlet, Glacier Bay." This statement is confirmed by Reed, who has seen and examined specimens from this area. According to Reed, this molybdenite mineralization occurs in a tactite that appears to be similar to that in which the molybdenite occurs on Lemesurier Island. A local prospector, Mr. Koby, has some claims near the head of Geikie Inlet at a rather high elevation, and it is from these that the rich specimens seen by Reed are understood to have been taken. Some of the speciments showed considerable molybdenite in rather large flakes in the midst of brown-red garnet. The claims from which these specimens came are not now being actively developed.[34]

ADAMS INLET AREA

About 15 miles northeast of the entrance to Geikie Inlet and on the northeastern shore of Glacier Bay is a reentrant, now beyond the terminus of Adams Glacier, known as Adams Inlet. To the south of the inlet the country rock is composed dominantly of Paleozoic slates, quartzites, and graywacke. To the north is an isolated knob composed of granitic igneous rocks, which intrude sediments similar to those south of the Inlet. Buddington [35] reports that molybdenite occurs facing fractures in the metamorphic rocks on the north side of the inlet, near the entrance. Evidently the occurrence at this locality belongs to the same general type of contact metamorphic deposits as those already mentioned on Lemesurier Island and probably at other points in this district. So far as known no serious development work aimed at opening up the deposits for their molybdenite content has been undertaken.

MUIR INLET AREA

A few miles north of the molybdenite showings near Adams Inlet, near the head of Muir Inlet, a Geological Survey party in charge of J. C. Reed in 1941 found extensive outcrops of molybdenite-bearing

[33] Buddington, A. F., and Chapin, Theodore, op. cit., pp. 329–330.
[34] Reed, J. C., oral communications.
[35] Buddington, A. F., and Chapin, Theodore, op. cit., p. 330.

rock. In the brief time that was spent there, the party saw no evidence of any mining claim markers. However, it was later reported that the body had been discovered previously and was covered by claims at the time of the examination by the Survey party. John Johnson is said to be one of the claimants, but the names of others, if any, are not known.

The mineralized body occupies a considerable amount of the northwest part of a small mountain, about 1,150 feet high, which lies between Muir Inlet on the west and a large field of stagnant ice, formerly part of Muir Glacier, on the east.

The mountain was climbed from the south by Reed [36] in 1936, when the locality where the better molybdenite showings seen in 1941 were much less accessible, because the ice of Muir Glacier then lay against the western and northwestern base of the mountain. Molybdenite was not recognized in 1936.

Practically the whole mountain appears to be in a contact zone between intrusive granitic rock and limestone. Such contact zones are common in the Glacier Bay area. According to Reed,[37] "The country rock is principally hornfels; its general strike is N. 40° E. and its dip about 50° NW. * * *. Granitic dikes up to more than 100 feet thick are common in the hornfels and are particularly abundant near the top of the mountain."

The two days available for work in the vicinity in 1941 were not enough to permit the distribution of the molybdenite deposits to be determined in any but the most general fashion. The following statements, therefore, reflect field impressions that were fairly definite but which, without further work, cannot be accepted as final.

An intensely contact-metamorphosed zone several hundred feet wide crosses the mountain diagonally in a direction about N. 30 E. from Muir Inlet to the field of stagnant ice. This zone is now made up almost entirely of quartz, which has replaced the earlier rock materials. Both northwest and southeast of this siliceous zone the metamorphism is less intense, or at least the replacement is less complete, and the rock consists of hornfels, largely epidote and quartz, cut by an intricate net of small quartz veinlets. Still farther from the highly siliceous central zone the quartz veinlets decrease in abundance, and garnet, as well as epidote and quartz, becomes a noticeable constituent of the hornfels.

Molybdenite is present as joint facings, in veinlets, and in irregular patches throughout the contact-metamorphosed zone from the central siliceous zone outward at least as far as the outer part of the zone in which the network of small quartz veinlets is conspicuous. Much

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[36] Reed, J. C., Some mineral deposits of Glacier Bay and vicinity, Alaska: Econ. Geol., vol. 33, No. 1, pp. 56, 57, Jan.–Feb., 1938.

[37] Reed, J. C., op. cit.

of the molybdenite lies along the edges of the quartz veinlets between the quartz and the hornfels remnants. The molybdenite is much less abundant toward and in the central siliceous zone, but some is present throughout. Chalcopyrite in small amounts is locally associated with the molybdenite, but, unlike molybdenite, the chalcopyrite, together with some pyrite, appears to be more abundant in the central siliceous zone.

The molybdenite-bearing zone is probably more than a thousand feet wide and is several thousand feet long. To the southwest, the zone is concealed by the waters of Muir Inlet and to the northeast it disappears under the stagnant ice field. Whether or not the zone appears farther southwest across Muir Inlet or farther northeast on the other side of the ice field is not known. A siliceous zone lean in molybdenite extends through the middle of the molybdenite-bearing zone.

The determination of even the order of magnitude of the molybdenite content of the zone would involve a large amount of sampling. The amount of molybdenite readily apparent in the rock is large enough to indicate that such sampling should be done, particularly in view of the large tonnage of material in sight.

SKAGWAY DISTRICT

In the extreme northern part of southeastern Alaska is the old settlement of Skagway, which is situated within the area occupied by granitic rocks that form the main body of the Coast Range batholith in this part of Alaska. The western limit of that body passes in a northwesterly direction from points about 20 miles either south or west of Skagway. In this district, near Clifton, a station on the White Pass & Yukon route, about 8 miles north of Skagway, molybdenite mineralization has long been known. The presence of molybdenite there appears to have been recognized as early as 1915, and claims were staked on the showings by Joseph Guyot and C. L. Cartwright. The deposit was examined in 1917 by J. B. Mertie, Jr., and it is from his unpublished notes that the following abstract has been made. The principal development at the time of his visit consisted of a shaft about 15 feet deep, just east of the track and about 1,000 feet north of Clifton. About 80 feet south of the shaft, on the west side of the track, a tunnel about 30 feet long had been driven S. 55° E. along the strike of a prominent joint plane. The molybdenite, according to Mertie, appears to be present in a rock varying in composition from alaskite to granite and differing chiefly from the general intrusive rock of the neighborhood in that it contains no black minerals. The molybdenite is distributed in patches throughout the granitic rock, and an estimate made by Mertie from merely visual inspection indicated that it formed about 1 percent of the rock. The granite is extensively sheeted horizontally and is also cut by prominent joint planes, which strike N. 50° W. and dip 72° SW. According to Mr. Cartwright, one of the owners of the claim, the same zone that was being prospected on the claims near Clifton can be traced on the south side of the mountain northward to and beyond Denver Creek, a distance of a mile or so from the tunnel described above.

In an early report of the Geological Survey, Chapin [38] noted and described briefly an occurrence of molybdenite near the Denver station, and in a later report Brooks [39] indicated that this locality was at a point said to be about 25 miles north of Skagway. The description of the locality coincides so closely with all of the principal features noted above for the deposit near Clifton that the writer feels no doubt of the identity of the two and believes that the stated distance of 25 miles was based on the somewhat erroneous information then available as to its distance from Skagway.

COPPER RIVER REGION

The Copper River and its tributaries form one of the major river systems of Alaska, the drainage basin embracing all of the tract south of the Alaska Range between approximately meridian 147 on the west and the international boundary on the east and extending southward to the Pacific Ocean, except where the narrow belt of coastal mountains west of Mount St. Elias drain directly to the sea. Most of the central part of this area has been examined with a fair degree of thoroughness, but many of the mountain fastnesses that limit the region on the north and south have received at best but scanty study, and vast tracts in them have probably never been traversed at all. Consequently there are extensive areas for which information as to their potential molybdenite occurences are either entirely lacking or inadequate. The conjectured geology of some of these unknown or little-known areas suggests that they may well mark the continuation of some of the already described features of southeastern Alaska that have proved to be associated with molybdenum mineralization. Such speculations, especially in view of the inaccessibility of these tracts, are hardly pertinent to the present consideration of localities where molybdenum minerals are known to occur and may be dismissed with the bald statement that at present only three localities within the entire Copper River drain-

[38] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 100, 1916.

[39] Brooks, A. H., The Alaskan mining industry in 1916: U. S. Geol. Survey Bull. 662, p. 25, 1918.

age basin are known to contain molybdenum minerals. These are an occurrence on Canyon Creek, in the Nizina district, indefinitely located showings in the Hanagita-Bremner district, and one on Rock Creek, a tributary of Tanada Creek, near the Gulkana-Nabesna highway.

NIZINA DISTRICT

In his general description of the Chitina Valley Moffit[40] notes the fact that in the Nizina district the Lower Cretaceous shales at many places are cut by numerous conspicuous dikes and sills of quartz diorite porphyry. Some of these dikes and sills are associated with veins carrying pyrite and free gold, as well as a number of other minerals, among which he mentions molybdenite. Moffit gives no references to specific points at which he observed such molybdenite mineralization, but from informal communications with him it is understood that he regarded the presence of this mineral in such veins as a rather common phenomena, and he recalled such showings on Dan Creek and near McCarthy. The amount of molybdenite in these places, however, he regarded as of no commercial significance.

CANYON CREEK AREA

About 25 miles west of the head of Chitina River and about the same distance southeast of the settlement of McCarthy is the valley of Canyon Creek, a tributary of Chitina River from the north. Considerable tracts within the basin of Canyon Creek have not been surveyed by members of the Geological Survey, but parts are shown on the geologic map accompanying Moffit's report.[41] According to this map, much of the headward and eastward parts of this valley as mapped have for their bedrock a thick series of basaltic lavas and associated rocks, which are members of the Nikolai greenstone. The western part of the valley, as well as considerable tracts near its southern part, are formed dominantly of Lower Cretaceous shales, sandstones, and conglomerates, with smaller areas of Triassic shales and Carboniferous chert and argillites. It is understood, however, that in the unmapped area, especially near the head of the large glacier-filled tributary that enters Canyon Creek from the northeast, about 12 miles north of the junction with Chitina River, there is a considerable area occupied by a stock of granitic rocks. It is in proximity to this intrusive mass that the reported occurrence of strong molybdenite mineralization is said to have been found. This locality has not been examined by any members of the Geological Survey staff, and the following statements are based on information furnished to

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[40] Moffit, F. H., Geology of the Chitina Valley and adjacent areas, Alaska: U. S. Geol. Survey Bull. 894, p. 117, 1938.

[41] Moffit, F. H., op. cit., pl. 2.

Hess by one of the former owners, Mr. Rowe,[42] and from Moffit's report,[43] and from late information obtained by Moffit from Mr. Sullivan,[44] who has lately been active at the property. The vein occurs at a high elevation, cutting across the steep, bare mountainside. In places the vein is said to be 8 feet wide, and throughout a width of 1 foot, near one of the walls, the concentration of molybdenite is greatest. Stringers and bunches of molybdenite are scattered through the rest of the vein material. The country rock is described as a granite, which is in contact with an igneous rock of porphyritic texture. The location of the deposits is such as to make the early development rather difficult. At the elevation at which they are situated the ground is free from snow and ice for only a very short season each year, so that surface prospecting is hampered. The nearest source of timber is some 8 miles distant, and the difference in elevation between that point and the mine is several thousand feet. There is no available site for the development of water power within a radius of 10 or 12 miles of the property. In spite of these draw-backs it is the opinion of those who have examined specimens of the ore that is of sufficiently high grade to warrant a much more intensive examination of the resources of the deposit before regarding these drawbacks as insuperable obstacles to development. It is obvious that these handicaps are much more serious in the initial stages of development than they would be for an operating mine provided with adequate facilities for overcoming the seasonal and transportational difficulties.

HANAGITA-BREMNER DISTRICT

South of the Chitina River and east of the Copper River is a large tract of country referred to in Survey reports as the Hanagita-Bremner district, named from the two large streams, Hanagita River and Bremner River, which, with their tributaries, traverse a large part of the area. According to Moffit,[45] who has made the most extensive geologic surveys of the district, an extensive belt of slates and graywackes traverse it from east to west. This belt has been intruded by light-colored dioritic dikes and is cut by numerous quartz veins. "The veins commonly contain a small proportion of metallic sulphides, among which pyrite is predominant and galena and molybdenite are found."[46] No specific mention is made of the localities at which such molybdenite mineralization was actually seen, but from informal discussion with Moffit, it was learned that the statement related to the veins in general throughout the district.

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[42] Rowe, J. A., letter dated November 27, 1915.

[43] Moffit, F. H., Upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, p. 79, 1918.

[44] Sullivan, Robert, oral communication, 1940.

[45] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, 56 pp., 1914.

[46] Moffit, op. cit., p. 44.

GULKANA DISTRICT

ROCK CREEK AREA

According to Moffit[47] the natives of the country adjacent to the old settlement of Batzulnetas have long recognized the occurrence of molybdenite at several places in the neighborhood. At only one of these, however, has a serious attempt been made to test the extent of the surface showings. This place is near the head of Rock Creek, a tributary of Tanada Creek, which joins Copper River near Batzulnetas. The nearest point to the mine from the highway that connects Gulkana and Nabesna is at mile 84. The rocks in the vicinity of the prospect consist of a stock of granitic intrusives, which cuts bedded volcanic rocks, including altered tuffs and lava flows of Permian age. The molybdenum mineralization occurs on the borders of the intrusive mass, about 4 miles from the highway and about 2,000 feet above it, its elevation above sea level being about 5,100 feet. The molybdenite has been exposed in several surface cuts and near the portal of a prospecting tunnel. The igneous rock has been petrographically determined to have the composition of diorite. In general it is fine-grained, but coarse-grained, rusty-weathering, and gneissic phases and pegmatites occur. Near the prospecting tunnel the bedrock shows gneissic phases and dark micaceous banding that simulates bedding. The molybdenite occurs in flakes, blebs, and veinlets in the shattered light-colored fine-grained intrusives and pegmatites. It is much more abundant in the more-shattered parts of the rock than in the gneissic part. No conclusive evidence was obtained as to whether the mineralization follows distinct fault or shear planes or represents a border phase of the intrusion. No molybdenite was found in the part of the diorite traversed by the prospecting tunnel. The general history of the development at this place, as sketched by Moffit,[48] indicates that in 1936 G. B. Todd, William Frame, Vernon Horn, and Lawrence DeWitt staked six claims, known as the Todd claims or Discovery group. Assays of specimens collected at that time are said to have shown as much as 4 percent MoS_2, and their average was estimated to be as high as 3 percent. In 1937 an arrangement was made with the Kennecott Copper Corporation[49] to carry on a prospecting program to test the showings. As a result, during the winter of 1937–38 the driving of a prospecting tunnel into the diorite was undertaken. After having reached a distance of 160 feet in the tunnel further work was discontinued, as no molybdenite was disclosed. Since that time no active development work has been

[47] Moffit, F. H. Geology of the Upper Tetling River district: U. S. Geol. Survey Bull. 917–B, pp. 150–153, 1941.

[48] Moffit, F. H., op. cit., p. 152, 1941.

[49] Moffit, F. H., in Smith, P. S., Mineral industry of Alaska in 1937: U. S. Geol. Survey Bull. 910–A, p. 105, 1939.

done on the property, and Moffit suggests that much more thorough prospecting of the surface should be carried on before further expensive underground exploration is justified.

COOK INLET-SUSITNA REGION

The occurrence of molybdenum minerals has been reported from eight widely separated areas in the Cook Inlet-Susitna region, which embraces all of south-central Alaska south and east of the Alaska Range to the Prince William Sound Region on the south and the Copper River Region on the east. So far as known no serious attempts have as yet been made to prospect the molybdenum deposits at any of these localities, and so far at none of the deposits has sufficient molybdenum mineralization yet been disclosed to warrant intensive search for potential commercial deposits. Possibly an exception to this rather sweeping statement should be made in the case of the reported deposit on Portage Creek, which has not been seen by any of the geologists of the Geological Survey or, so far as known, by other disinterested persons who have made the results of their findings public.

In many respects the geology of this part of Alaska resembles that in the contiguous parts already discussed, but, as it embraces an enormous extent of country, the formations and structures in different parts show wide diversities in detail. It is therefore impracticticable to summarize briefly the major geologic features of the region. Instead, the significant facts regarding the various localities will be given under the appropriate smaller subdivisions.

KENAI DISTRICT

Kenai Peninsula is a large southward-projecting part of south-central Alaska, lying between Prince William Sound on the east and Cook Inlet on the west. Much of its area is occupied by the Kenai Mountains, which form a backbone some 150 miles long. Many of the higher peaks rise to elevations of more than 5,000 feet. By far the larger part of the mountain belt has for its bedrock argillites and graywackes that in part at least are of Cretaceous age. Intruding these sediments in a few places are granitic igneous rocks that are mainly of Mesozoic age but possibly are in part of Tertiary age. Fairly common in the sediments are small acidic dikes that in general are fine-grained and have a composition rather closely related to the quartz diorites, though remote areally from any of the granitic stocks. Capps,[50] summarizing the general geology of the peninsula, states that a number of veins have been found. In these veins he

[50] Capps, S. R., Geology of The Alaska Railroad region: U. S. Geol. Survey Bull. 907, p. 173, 1940.

mentions as the commonest valuable metallic minerals gold and certain specified sulfides, and he adds "more rarely molybdenite and pyrrhotite." He does not mention any specific localities at which such molybdenite mineralization occurs.

ORACLE AREA

About 15 miles northwest of the Moose Pass station, on The Alaska Railroad, is the Alaska Oracle mine or prospect. This property is situated on Summit Creek, the northernmost tributary of Quartz Creek, which discharges into Kenai Lake near its western end. Tuck,[51] who examined all of the mines in the northern part of the entire district, makes specific mention of the recognition of molybdenite in specimens from this mine, though he gives no detailed description as to its occurrence. In his general description of the property he states [52] that the vein on which mining has been done strikes N. 15° E. and has an average dip of 60° W. In width it ranges from a few inches to 3 feet, and it occupies a fracture along which movement had taken place before the deposition of the ore. No igneous rocks are known in the immediate vicinity of the Oracle ore body, but a narrow acidic dike, which has been traced continuously for about 10 miles, lies about a quarter of a mile to the west of the mine. The dike itself is sufficiently mineralized so that attempts have been made to mine it for its content of gold, but so far without much success. Tuck [53] interprets the formation of the veins of the district as attendant on the same processes as those giving rise to the mineralized dikes and attributes both to the presence, at the time of their formation, to an underlying magmatic reservoir, which gave off the ore-bearing solutions.

It is not unlikely that molybdenite was recognized in parts of the area other than at the Oracle, for Tuck [54] states that it has been reported "from several localities," though he does not give further identification of the places.

CHICKALOON RIVER AREA

Chickaloon River rises on the western slopes of the Kenai Mountains and after a very circuitous course discharges into Chickaloon Bay, near the entrance of Turnagain Arm. It should not be confused with the Chickaloon River, that is a tributary of Matanuska River, about 80 miles to the northeast. Johnson,[55] in describing the central and northern parts of Kenai Peninsula, states that molybde-

[51] Tuck, Ralph, The Moose Pass-Hope district: U. S. Geol. Survey Bull. 849–I, p. 509, 1933.
[52] Tuck, Ralph, op. cit., pp. 507–508.
[53] Tuck, Ralph, op. cit., p. 493.
[54] Tuck, Ralph, op. cit., p. 491.
[55] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, p. 37, 1915.

nite is one of the rarer metallic minerals of the region. He does, however, refer to less specific identification of that mineral "near the head of Chickaloon River, where small flakes of molybdenite occur in quartz ledges." It is not possible now to identify more definitely the locality to which Johnson referred. On the map that accompanied his report [56] the bedrock geology of practically none of the drainage area of Chickaloon River is shown, and there are no symbols indicating prospects or mineralization. Johnson [57] evidently did not regard the occurrence as of economic significance, for he states that so far as known molybdenite does not occur in commercial quantities. From general evidence it seems probable that the bedrock is dominantly formed of members of the slate-graywacke series and that these metamorphic sediments have been cut by acidic dikes comparable with those noted in the area near the Oracle mine. It is highly improbable that any extensive mass of granitic intrusives occurs in the neighborhood of Chickaloon River.

GIRDWOOD DISTRICT

CROW CREEK AREA

Immediately north of Turnagain Arm is the small settlement of Girdwood, and in the hills to the north of it both lode and placer gold mining have long been in progress. These mineral deposits were studied in considerable detail in 1931 by C. F. Parks [58] of the Geological Survey. As a result of that work he reported, "Molybdenite is a common constituent in several veins. * * * Molybdenite occurs in partly filled vugs in quartz." In his description of the individual mining companies, Parks [59] notes that on the Bruno Agostino property, near the head of Crow Creek, "Several veins contain molybdenite, especially one vein in the bottom of Crow Creek and one of the so-called crosscutting veins. A random sample on this crosscutting vein gave 0.26 percent molybdenum." The ownership of this Agostino property has changed hands a number of times in the past and at one time was known as the Barnes property. It was under the name Barnes property that Johnson [60] had earlier recorded the occurrence of molybdenite in a narrow stringer that carried, in addition to that mineral, chalcopyrite and pyrrhotite. And further on in his report [61] he stated that in a crosscut tunnel on the Stella claim of the Barnes property the molybdenite and sulfides occurred in a small vein, the gangue of which was a vitreous-looking

[56] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., pl. 3.
[57] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 137.
[58] Parks, C. F., The Girdwood district, Alaska: U. S. Geol. Survey Bull. 849-G, p. 409, 1933.
[59] Parks, C. F., op. cit., p. 417.
[60] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 137.
[61] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 176.

quartz. The sedimentary beds forming the bedrock in the vicinity of this property are considered to be the continuation of the slates and graywackes of the Kenai Peninsula, but in the Crow Creek area they have been intruded by several masses of light-colored fine-grained granites and fine-grained to aphanitic acidic dikes, which are offshoots from more remote and larger granitic masses. The source of the mineralization is attributed to solutions incident to the emplacement and injection of these igneous rocks. All of the known veins are small and irregular, both along the strike and the dip, so that they will be difficult and expensive to mine.

WILLOW CREEK DISTRICT

The Willow Creek District is one of the principal lode-gold districts of the Territory. Its principal mines are situated about 45 miles north of Anchorage. In the main the bedrock of the district consists of a large central mass of granitic intrusives, mainly of Mesozoic Age, but possibly including some of Tertiary Age. These rocks are flanked on the south, outside the productive area, by metamorphic schists of pre-Cambrian Age, which they intrude, and Tertiary sandstones and shales, which lap over onto the granitic rocks. Ray [62] recognized molybdenite as associated with chalcopyrite and quartz in a few of the veins studied by him. He states that the molybdenite occurs in platy aggregates, some of which are as much as several centimeters in diameter and that "It is believed that the veins containing it (molybdenite) are older than the other veins of the district here classed as intermediate temperature veins." One of the plates accompanying Ray's report [63] shows a chalcopyrite-molybdenite stringer in normal quartz diorite at the head of Craigie Creek. No specific references are given by Ray as to the localities at which he recognized molybdenite. Capps,[64] who earlier had studied the district, in his report, also makes no specific mention of places where molybdenite was seen though he states "Specimens of molybdenite associated with quartz have been obtained in the district, but no molybdenite was seen in the gold-bearing quartz veins, and the specimens may have come from the pegmatite veins." [65] In one of his later reports, however, Capps [66] mentions two specific localities where molybdenite had been observed. One of these was on the Fern property, in the upper basin of Fairangel Creek, and one between

[62] Ray, J. C., The Willow Creek gold lode district, Alaska: U. S. Geol. Survey Bull. 849–C, p. 192, 1933.

[63] Ray, J. C., op. cit., pl. 12, *A*.

[64] Capps, S. R., The Willow Creek district, Alaska: U. S. Geol. Survey Bull. 607, 86 pp., 1915.

[65] Capps, S. R., op. cit., p. 59.

[66] Capps, S. R., Gold lode mining in the Willow Creek district, Alaska: U. S. Geol. Survey Bull. 692, p. 186, 1919.

Archangel and Purches Creeks. The locality on Fairangel Creek is doubtless on claims at one time forming part of the old Talkeetna property, where molybdenite was later seen by the present writer.

Martin,[67] in 1917, noted the occurrence of a molybdenite deposit at a locality he referred to as "on Reid Creek, a tributary of Little Susitna River, in the Willow Creek district." This description is believed to be incorrect, as there is no Reid Creek in the district, though there is a Reed Creek, a tributary of Archangel Creek, which is in turn a tributary of Little Susitna River. This alteration in the description seems entirely justified, as it would place the location of the reported occurrence of molybdenite within a radius of not more than 3 miles from the well-authenticated site on Fairangel Creek and in an area that is closely comparable geologically with it.

CURRY DISTRICT

Curry is one of the division points on The Alaska Railroad, about midway between its two terminals. Geologically the district has features characteristic of the Alaska Range in its western part and of the Talkeetna Mountains in its eastern part. Considerable tracts in the district have not been examined, even on exploratory standards. In spite of this lack of adequate surveys, molybdenite mineralization has been reported at two rather widely separated localities, namely, at mile 247, near Curry, and on Portage Creek, some 30 or more miles to the northeast of that settlement.

MILE 247 AREA

The locality here called mile 247 is close to The Alaska Railroad and less than 2 miles south of Curry. The bedrock in its vicinity is in general formed of slates and graywackes of Mesozoic age, which are correlated broadly with certain of the rocks already described in the Kenai and Girdwood districts. At mile 247 these sedimentary rocks are cut by a granitic dike 300 to 500 feet wide, which trends about N. 10° W. Tuck [68] describes the dike rock as light-gray, even-textured, and composed of plagioclase feldspar, biotite, and minor amounts of muscovite and apatite. Toward the margins, the rock is slightly gneissic. Occasionally a few flakes of molybdenite are found, which are usually associated with small veins of quartz and narrow aplite dikes that traverse the main mass of the dike rock. The molybdenite occasionally lines small joints and fractures in the main dike. From these facts Tuck concludes that most of the molybdenite was introduced during the last phases of the intrusive, after the dike had partly solidified. The main dike is regarded by Tuck

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[67] Martin, G. C., The Alaskan mining industry in 1917: U. S. Geol. Survey Bull. 692, p. 23, 1919.

[68] Tuck, Ralph, unpublished report, 1935.

as genetically related to the large mass of granite that forms the backbone of the ridge between Susitna and Chulitna Rivers, as well as to that occurring in the northern part of the Talkeetna Mountains. The amount of molybdenum mineralization at this place is obviously too small to attract development, and its main significance is to show the association of that element with the intrusive phenomena that are widespread throughout this section of Alaska.

PORTAGE CREEK AREA

The occurrence of molybdenum mineralization on Portage Creek has been reported to members of the Survey by A. M. Johnson, who has long prospected in that area. Unfortunately, details as to the exact site of the showings or as to the geology of the area are not available. Portage Creek is a tributary of Susitna River, joining that stream about 8 miles due east of the station called Canyon on The Alaska Railroad. A good trail leads from Chulitna station to a point on Canyon Creek, some 2 or 3 miles above its mouth. Apparently the molybdenum showings are several miles upstream from that point. The general geology of this part of Canyon Creek, as shown by the map accompanying Capps' report,[69] is rather complex, the bedrock in places consisting of bodies of granitic rocks that intrude sediments, some of which are of Paleozoic age and others of Mesozoic age. Presumably such molybdenum mineralization as does occur is in or close to the contact zones of some of these intrusives. No information was obtained as to the amount of molybdenite found at the better showings, but it was understood that the owner claimed that abundant molybdenite was present. In the absence of a more disinterested source of information it is necessary to suspend judgment as to the significance of these finds, though the writer feels confident that some molybdenum mineralization does occur in the area.

LAKE CLARK DISTRICT

KIJIK AREA

Lake Clark is a long, narrow lake lying within the southern part of the Alaska Range and discharging westward, ultimately into Bristol Bay. In the main it lies west of the large body of intrusive granitic rocks that form the backbone of the Alaska Range in this part of Alaska, but sporadic small masses of granite, which are believed to be offshoots from this main body, occur irregularly distributed throughout the extent of its drainage basin. The most recent map and report covering the general geology of the area were prepared by Capps.[70] The only place in the Lake Clark district at

[69] Capps, S. R., Geology of The Alaska Railroad region: U. S. Geol. Survey Bull. 907, pl. 2, 1940.

[70] Capps, S. R., The southern Alaska Range: U. S. Geol. Survey Bull. 862, 101 pp., 1935.

which molybdenite has been reported is described by the writer[71] as on Kijik River, about 10 miles northwest of the extreme northern end of Lake Clark, at a point where some prospecting for gold lodes was in progress. The molybdenite is described as occurring in scattered grains in a pegmatite associated with granitic intrusives. The occurrence was not seen by the writer, and later, in 1929, when Capps traversed much of the Kijik River Valley, he made no mention of any signs of prospecting, either old or current, being seen or of any showing of molybdenum minerals. Capps mapped no granitic rocks in the vicinity of Kijik River near the point where the molybdenite was reported to occur, so that doubtless such a body, if it does occur, is small. The results of these later investigations, therefore, confirmed the writer's earlier-expressed opinion that the molybdenite was not abundant enough to have commercial value and that because of its remoteness there was little inducement to search for workable deposits of molybdenum in the district. It should, however, be noted that the molybdenum-bearing ore was reported to carry gold, and it was mainly on account of the content of precious metal that the prospecting was being carried on. It is readily apparent that if the ore carried sufficiently high values in gold it might be possible to recover some molybdenite as a byproduct and that the presence of molybdenite is often regarded as a favorable indication of the presence of gold concentrations in the nearby rocks.

ILIAMNA DISTRICT

MEADOW LAKE AREA

The bedrock throughout much of the eastern part of the area adjacent to Iliamna Lake is formed of the great batholithic mass of granitic intrusives that make up the heart of the Alaska Range in the region. There is, however, a tract 4 to 6 miles in diameter lying south of the headward part of Iliamna Lake and adjacent to Meadow Lake in which Paleozoic schists and greenstone and Triassic limestone form the country rock and where, in places, strong mineralization occurs. Meadow Lake and the contiguous area drains westward through a series of lakes and connecting water courses to Iliamna Lake, north of Kakhonak Bay, but access to the area is usually by way of a good trail about 14 miles long from Cottonwood Bay, on the western shore of Cook Inlet. Lodes were discovered north of Meadow Lake in 1901 by S. J. Goodro and were later developed by the Dutton Mining and Developing Co. When the Iliamna district was surveyed by Martin and Katz in 1909 active development work on this property had practically ceased. In the

[71] Smith, P. S., The Lake Clark-Central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 132, 153, 1917.

report[72] of this expedition the occurrence of molybdenite was specifically noted on the Dutton prospects. At that place there is a band of Triassic limestone, which is succeeded on the north by an altered igneous rock, which Martin and Katz referred to as a greenstone. This greenstone is described as a fine-grained rock, which was probably originally a diabase or diorite. The mineralization took place mainly in the contact zone between these two rocks. In the limestone, in addition to a number of common metallic sulfides and contact metamorphic minerals, Martin and Katz noted the presence "much less commonly" of molybdenite. These metallic minerals are not uniformly developed but are in irregular masses more or less parallel to the contact. On the claim at the extreme northeastern end of the group the molybdenite is described as occurring in minute scattered particles in the quartz veins with copper and iron sulfides and also as thin scales on some of the fractures in the so-called "ore rock." That the amount of molybdenite in these showings was very small is indicated by the following comment by Martin and Katz:[73] "In passing let it be noted there is here far too little molybdenite to constitute an ore, and that which is present is in too small scales to be concentrated."

YUKON REGION

The Yukon region, embracing as it does almost the whole central part of the Territory west of the international boundary, displays a wide range of geologic phenomena in its various parts. Much of its less accessible parts are surveyed inadequately, if at all, so that it is not yet possible to state fully or even to forecast what mineral deposits may occur in some of those areas. In spite of the inadequacy of the available information it has been determined that in at least six districts the presence of molybdenite has been well demonstrated and that in two others it is probably present, though the information regarding the occurrences in them is much less definite. These eight districts, named in succession from the international boundary westward, are Nabesna, Chisana, Goodpaster, Delta, Fairbanks, Chandalar, Kaiyuh Hills, and Marshall. Such information as is available regarding the molybdenite occurrences in each will be set down in that order in the following pages.

NABESNA DISTRICT

The Nabesna district includes part of the southeasternmost section of the Yukon region in central Alaska. It takes its name from the Nabesna River, a large tributary of Tanana River from the south that rises in one of the large glaciers of the Alaska Range. Near

[72] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 120–121, 1912.
[73] Martin, G. C., and Katz, F. J., op. cit., p. 121.

the northern terminus of Nabesna Glacier is a low prominence locally known as Orange Hill because of its striking coloration, caused by the weathering of metallic minerals that occur in the rocks of which it is composed. This hill is described [74] as consisting mainly of a mass of quartz diorite, which projects through the surrounding mantle of unconsolidated gravels. The diorite is cut by innumerable small quartz stringers, many of which carry pyrite and a few of which carry molybdenite. Evidently the amount of molybdenite present is negligible, for Moffit and Knopf made no further reference to the occurrence, and Schrader,[75] who had visited the district in 1898 and had had a number of specimens of veins from Orange Hill assayed for their gold content, made no mention at all of having recognized molybdenite in the specimens he collected.

CHISANA DISTRICT

Chisana River and its tributaries form the main drainage system throughout that part of Alaska that embraces the northern slopes of the Alaska Range adjacent to the international boundary west of longitude 141° and north of latitude 62°. In the tract, which is usually called the Chisana district by the Geological Survey, some placer mining has long been in progress. In the course of that mining, in addition to gold, which is the principal mineral of value sought, other metallic minerals have been noted. Moffit [76] has recorded the presence of molybdenite in the concentrates from some of the sluicing operations on Bonanza Creek. This stream is a small tributary of Cathenda, or Johnson Creek, which joins Chisana River from the east about 6 miles north of the present terminus of Chisana glacier. The bedrock source of the molybdenite has not been found. The presence of granitic intrusive rocks in the hills that form the western part of the Bonaza Creek Basin suggests that the molybdenite probably came from the contact zone between these igneous rocks and the shales, limestones, and lava flows, tuffs, and agglomerates that form the bedrock in the eastern part of the valley of Bonanza Creek. The quantity of molybdenite in the concentrates is so small that the occurrence can, at present, be regarded as of little more than mineralogic interest.

GOODPASTER DISTRICT

MOUNT HARPER AREA

The Goodpaster district, as that term is used here, includes a large tract of country lying north of Tanana River, northeast of

[74] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 58, 1910.

[75] Mendenhall, W. C., and Schrader, F. C., Mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, p. 44, 1903.

[76] Moffit, F. H., Geology of the Nutzotin Mountains (in preparation).

the point where the Richardson Highway crosses Tanana River. In part its eastern crestline forms the western boundary of the Fortymile district. The highest point on this divide is Mount Harper, whose top stands 6,575 feet above sea level. It is the highest mountain in the entire tract between the Yukon and Tanana Rivers in Alaska. The occurrence of molybdenite was first described by Chapin, who, however, did not personally visit the deposit. Chapin's information was obtained from a report made to the owners by Albert Johnson, of Fairbanks. According to this report [77] the deposit occurs on the southern slope of the mountain, then called Rainey Mountain but later renamed Mount Harper, at an estimated elevation of 6,000 feet or more above sea level. The ore occurs as a quartz fissure vein with granite walls trending east and dipping north. Its extent had been traced by shallow pits and float throughout the length of three claims, and it appeared to be continuous for that distance. The ore material is said to be hard white quartz, which carries bunches of molybdenite scattered sparingly, but rather evenly, throughout the vein. The topographic situation of the deposit is such as would present certain difficulties for its development. Owing to its lofty elevation the open season at the prospect is short, and it lies so high above the timber line that the nearest trees are more than 3 miles distant. The remoteness of the region evidently soon discouraged prospecting, for when the writer was in the general neighborhood in 1920 no work was in progress, and so far as can be learned none has subsequently been undertaken. The activity that has lately taken place in prospecting for gold lodes in the western parts of the valley of Goodpaster River now makes the more distant eastern parts of that drainage system near Mount Harper much less difficult to reach and may revive interest in these claims. The country, for a radius of more than 5 miles in every direction from Mount Harper, has for its bedrock granitic intrusive rocks. One would expect the area near the borders of this granitic mass, where it is in contact with the metamorphic schists of the Birch Creek series of pre-Cambrian age, to be the most favorable place for the occurrence of such molybdenite mineralization as may have taken place.

DELTA RIVER DISTRICT

PTARMIGAN CREEK AREA

The Delta River district embraces parts of the drainage basins of Delta, Dry Delta, and Little Delta Rivers, streams which rise on the northern flanks of the Alaska Range, 60 to 80 miles southeast of

[77] Chapin, Theodore, A molybdenite lode on Healy River: U. S. Geol. Survey Bull. 692, p. 329, 1919.

Fairbanks, and are tributary to Tanana River from the south. The best available geologic map of the district is that by Capps,[78] but his surveys were made before the discovery of molybdenite in the district. The following notes, therefore, are based on information obtained mainly by the writer from Frank Gillespie in 1920 and by L. M. Graves from conversation with A. W. Conradt in 1940.

The discovery of molybdenite in the district appears to have been made in 1914 by Gillespie, on claims adjacent to Ptarmigan Creek. This creek is a tributary to Dry Delta from the west, the junction being about 35 miles due south of the old roadhouse at Richardson. Most of the highland to the south of Ptarmigan Creek is granite, whose contact with older black slates cuts across the creek transversely. Near this contact but entirely within the area occupied by the granite is a feature described by Gillespie as a "blow out," and it is at the southern and eastern ends of this feature that the greatest amount of molybdenite occurs. The molybdenite is described as occurring in fractures in the granite associated with quartz. In the period from 1914 to 1918 considerable prospecting and development work was done, in the course of which several drifts, some as much as 30 feet long, were driven. The inability of the operators to dispose of the product resulted in discontinuance of the work and abandonment of considerable ore that had been stacked up on the dump. A long period of quiescence then ensued, which ended late in 1937, when Conradt and associates began new prospecting in the area. In 1940 a tunnel 90 feet long was driven to prospect the more promising showings. Samples, which were probably picked specimens, were said by the owner to have been sent to the Climax Molybdenum Co. of Colorado and to have been found by that company to contain 2.71 percent of molybdenite. Other samples from the Gull claims, near the lower end of the holdings and about a mile distant from the first-mentioned claims, are said to have shown a content of 1.71 percent of molybdenite. The specimens seen by the writer consisted almost exclusively of quartz in which leaves and patches of molybdenite were irregularly scattered in and adjacent to small fractures. Martin[79] stated that the quartz veins at this place vary greatly in width, ranging from only a few inches to as much as 2 feet. He also stated that some of the quartz veins carried supplementary values in gold. At that time a few tons of ore had been mined but none shipped, a statement that is believed to hold good for the entire period up to the close of 1940.

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[78] Capps, S. R., The Bonnifield region: U. S. Geol. Survey Bull. 501, pl. 2, 1912.

[79] Martin, G. C., The Alaskan mining industry in 1918: U. S. Geol. Survey Bull. 712, p. 24, 1920.

FAIRBANKS DISTRICT

STEELE CREEK AREA

The Fairbanks district in central Alaska has long been the most productive of the mining areas of the interior. In general the bedrock of the district consists of members of the Birch Creek schist, which is of pre-Cambrian age. At a number of isolated places through the district these sedimentary rocks have been intruded by granitic rocks that are assigned to the Mesozoic. The only place in the district at which molybdenite has been reported is on the property of the Columbia Mining Co., which was being developed mainly for the tungsten content of some of the veins occurring there. The general conditions at this place were studied by Theodore Chapin [80] in 1917 and described in the report he prepared, from which the following statements have been abstracted. The principal showing of molybdenite found by the company seems to have been on the Spruce Hen claim, on the divide between First Chance Creek, a northward-flowing tributary to Goldstream Creek, and Steele Creek, a southward-flowing tributary to Chena River. The claim is about 10 miles northeast of Fairbanks. The mineralization occurs in proximity to a large intrusive mass of porphyritic granite, which cuts calcareous and siliceous schists. The best showings of mineralization were found in a lode trending N. 50° E. and dipping 45° NW. The lode material appears to be composed mainly of silicates, which have replaced nearby limestone beds, and is cut by a number of quartz stringers. The principal mineral of value in the lode is scheelite, a tungsten oxide, but associated with it is a little molybdenite. From Chapin's description it seems evident that the molybdenite formed but a minor part of the lode filling and of itself would not deserve attention as a commercial source of molybdenite ore.

No molybdenum mineralization is recorded as having been noted in connection with the extensive gold lode mineralization that has attracted attention and commercial development in the area bordering the granitic mass of Pedro Dome, north of Fairbanks, and in the area adjacent to Ester Dome, west of Fairbanks. The absence of this mineral at these places cannot be attributed to oversight through the haste with which the examinations were made, because both areas have received more than ordinarily thorough examinations by a number of the Survey geologists, the latest detailed examination being that by Hill.[81]

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[80] Chapin, Theodore, Mining in the Fairbanks district: U. S. Geol. Survey Bull. 692, pp. 326–327, 1919.

[81] Hill, J. M., Lode deposits of the Fairbanks district: U. S. Geol. Survey Bull. 849–B, pp. 29–164, 1933.

CHANDALAR DISTRICT

HODZANA AREA

An indefinitely described locality in the Hodzana district was the source of specimens of molybdenite received by the Geological Survey in 1923. These specimens were sent in by T. Sturrock, of Beaver, Alaska, a miner who had spent much time prospecting in the headwaters of Hodzana River. The Hodzana River is one of the tributaries of the Yukon from the northwest and joins that stream about midway between Fort Yukon and Stevens Village. The specimens were inspected by J. B. Mertie, Jr., and in a letter to Mr. Sturrock dated December 15, 1924, he wrote "The second type of material consists of quartz, pyrite, sphalerite, and molybdenite. This is an interesting specimen particularly with regard to the assemblage of these three sulphides in one small specimen. I think it is also a good indication for gold mineralization on Trout Creek." It is not now possible to identify closely the stream referred to as Trout Creek. From general familiarity with the region Mertie feels sure that it is one of the small streams forming the extreme headwater part of the Hodzana Valley, possibly flowing into the Pitka Fork of that river. None of the maps of the Geological Survey show the bedrock geology of this part of the Hodzana Valley, but from surveys in adjacent areas it seems probable that a large part of the area has for its bedrock granites that were intruded into schists that are probably of pre-Cambrian age. The contact between these two types of rocks is believed to run more or less eastward across the headward part of the Hodzana Valley, so that the granite lies mainly to the north in the divide between the Hodzana Valley and the West Fork of Chandalar River and the schist to the south in the larger part of the Hodzana Valley. Doubtless satellitic masses of granite lie south of this main contact, and it is equally probable that isolated patches of the schist may occasionally be found to the north of that line. It would therefore appear likely that the molybdenite specimen here recorded came from the contact zone near one such intrusive.[82]

KAIYUH HILLS DISTRICT

East of the Yukon, in that part of its course that lies between Anvik and Kaltag, are a group of low hills, which form the southwestern prolongation of the higher Kaiyuh Hills to the north and east. This area has not been examined by members of the Geological Survey, but Mertie, who surveyed the more northern part of

[82] Mertie, J. B., Jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, pl. VI, 1925. Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pl. V, 1913.

this highland, in the course of that work received some specimens from A. Muller that contained molybdenite. These specimens were reported to have been taken from a point in the low hills about 70 miles south of Kaltag. They consisted of some small pieces of vein quartz and the normal country rock. According to Mertie,[83]

> The vein material was found to consist of vein quartz containing numerous anhedral grains and clumps of molybdenite. The country rock proved to be a fine-grained rhyolite porphyry * * *. The rock also contained considerable pyrite * * *. The proportion of potash feldspar indicates strongly that this rock is the fine-grained equivalent of a granite. The age of this granitic rock and of the associated mineralization is indeterminate.

Evidently the molybdenite mineralization that occurs in this part of the Kaiyuh Hills is closely associated with granitic intrusives and doubtless was deposited in or close to the contact of those rocks with the older rocks that they penetrated. So far as known, no developments have been undertaken at this place to open up the molybdenite showings to test their extent and value. In view of the remoteness of the area and the difficulty that would be experienced in marketing such product as might be obtained, there is little reason or justification to expect that such exploration will be undertaken in the near future.

MARSHALL DISTRICT

WILLOW CREEK AREA

Near the western limit of the Yukon Valley is the small settlement of Marshall. Its name has also been adopted for the large district that embraces most of the southwestern part of the Yukon region. In that district are a number of widely scattered sites at which mining, principally placer-gold mining, has been carried on successfully. About 7 miles in an air line southeast of the settlement of Marshall is Willow Creek, and near the head of that stream some lode-gold mining and prospecting has been carried on for a number of years. The principal lode developments have been on claims known locally as the Arnold lode. The geology of these claims, as well as of other parts of the Marshall district, was examined in 1916 by Harrington,[84] on the basis of whose report the following statements are made. The Arnold claims lie to the east of Willow Creek, not far from the head of the stream. Two or more veins occur on the property and at the time of Harrington's visit had been slightly opened up by surface cuts and trenches. In the best showings the vein was 4 to 8 inches wide. The minerals occurring in this vein included calcite, pyrite, galena, and free gold. According to Harrington, "Some of the dirt

[83] Mertie, J. B., Jr., The Kaiyuh Hills, Alaska: U. S. Geol. Survey Bull. 868-D, p. 174, 1937.

[84] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683, pp. 63-64, 1918.

from the open cut was panned. In addition to the vein minerals mentioned above, the concentrates from panning included small amounts of wulfenite, the yellow to orange-colored molybdate of lead, and anglesite, the white sulphate of lead." The bedrock in the vicinity of Willow Creek consists in general of greenstones and associated sediments, which have been assigned to the late Carboniferous. These rocks are cut by a number of granitic intrusives, both stocks and dikes. In chemical composition these igneous rocks are closely allied with soda granite, though dioritic and dacitic phases have been identified. From the close areal relationship between the known mineral deposits and these intrusive rocks Harrington concluded that—

Both the large granite masses and dacite dikes appear to have been concerned in the mineralization. The quartz veining that followed is also related to the intrusions, and much of the gold occurs in the vein quartz, but wall-rock impregnation has also taken place. Besides the gold the sulfides of iron, lead, molybdenum, and copper occur as pyrite, galena, molybdenite, and chalcopyrite in the veins and mineralized wall rock. These minerals have not been found in the soda granite or dacites but doubtless were formed as a consequence of their intrusion.

An examination of certain of the specimens containing wulfenite made by M. N. Short, of the Geographical Survey, showed that, in general, wulfenite occurred in cleavage cracks in the vein quartz and was usually associated with limonite. Wulfenite had also been recognized by Mertie in other specimens sent the Geological Survey, together with an unidentified mineral of which he said "dark mineral with metallic luster is some lead sulfide or sulfosalt probably containing molybdenum." These minerals were obviously of secondary origin and probably had been formed through weathering of the original molybdenite in the nearby rocks.

KUSKOKWIM REGION

In the vast region included within the drainage basin of the Kuskokwim River, Survey parties and others have made but few examinations, and most of these have been hasty exploratory trips into the more accessible parts. As a consequence, tens of thousands of square miles are still untraversed except by the random prospector or hunter, most of whom have not made their knowledge of the region available to others. As a consequence, there is a woeful lack of information regarding the geology and mineral resources of most of the more remote parts of the region and only inadequate information as to the better-known parts. From what is now known of the geology of the region it is regarded as highly probable that in many places conditions exist comparable to those that in other regions have given rise to molybdenum mineralization. Unfortunately, as yet the validity of this belief has not been demonstrated by definite reports of the actual recognition of molybdenum minerals in place, though specimens containing molybdenite that are said to have come from a single locality in the Kuskokwim region have been furnished the Geological Survey. The locality from which the specimens referred to were obtained can be identified only approximately, but it appears to be situated in the Akiak district, in the western part of the Kuskokwim Valley.

AKIAK DISTRICT

The recorded occurrence of molybdenite in the Akiak district rests on certain specimens sent to the Geological Survey by D. E. Stubbs, of Akiak, in 1918 and 1919. Unfortunately no record is now available as to the precise locality from which the specimens came. However, the Geological Survey has records that show that the principal sites of Mr. Stubbs' prospecting at that time extended from the Russian Mountains, a few miles north of Kolmakof, a settlement on the Kuskokwim River, to Canyon and other creeks tributary to Kwethluk River and nearby creeks that have their sources in Marvel Dome and the range of hills 40 or more miles east of Akiak. The limits of his activities in this area are obviously very indefinite, as the area extends nearly a hundred miles from north to south. Furthermore, it is not possible to state with certainty that the specimens in question actually were obtained from this area, though it is confidently believed that they did come from it. According to Mr. Stubbs,[85] "The outcrop occurs on the side of a mountain, the side being lined with float. From the large amount of float one might judge there would be found a large body of ore in place. I have a few pieces of mineral I found an inch or so across." The Survey geologist who examined the specimens accompanying Mr. Stubbs' letter noted that "the molybdenite foils in the quartz are associated with a light-colored oxidation product, probably powellite, which is a lime-tungsten-molybdenum compound."

The locality was evidently difficult of access at the time of Mr. Stubbs' visit, as he refers to having had to backpack the specimens and his gear, and he did no development work on the showings then, though he intended to return later. So far as the Geological Survey is informed, the deposit has not been revisited either by Mr. Stubbs or others, and there is no further information regarding it. The general geology of the district is such as to suggest a number of places at which molybdenum mineralization might well be expected. Such areas are in proximity to some of the granitic intrusives of late Mesozoic or Tertiary age that intrude deformed Paleozoic or Mesozoic sedimentary beds. These intrusive masses have been

[85] Letter, Aug. 23, 1919.

recognized by Survey geologists in the Russian Mountains and in the mountains south of the Kuskokwim River and east of Akiak. It is in the contact zones of such masses that molybdenum and other types of mineralization may be sought with greatest likelihood of success.

SEWARD PENINSULA REGION

Seward Peninsula is among the most extensively mineralized regions of Alaska. In spite of this condition the occurrence of molybdenum mineralization appears to be exceedingly rare. In fact, in Cathcart's rather exhaustive description [86] of the known mineral deposits of the southern part of the peninsula there is no mention at all of the occurrence of minerals containing this element, and in a search of all the available sources the writer has been able to find record of molybdenum minerals in only three areas in Seward Peninsula. Probably more detailed field examinations would add somewhat to this list of localities, but it is believed that such studies would not augment it greatly, because on the whole the reconnaissance surveys already made have covered all parts of the peninsula with a rather exceptional degree of thoroughness and detailed surveys have already been made in some of the most typical areas. These known occurrences will be discussed under the areal designations of Council, Nome, and York districts.

COUNCIL DISTRICT

The Council district embraces a considerable tract in the central part of the peninsula adjacent to the town of Council. The bedrock of the area consists of a complex assemblage of old schists and limestones, which, in the mountains 20 or more miles to the north and northwest of town, have been intruded by granites, presumably of Mesozoic age. In the immediate vicinity of Council considerable placer-gold mining has been in progress since the earliest stampedes into the peninsula, and the district probably has produced more placer gold than any other of the Seward Peninsular districts, with the single exception of the Nome district. The single recorded occurrence of molybdenite in the Council district is that of a specimen that was picked up in the course of placer mining. This specimen was shown to Mr. Cathcart by Mr. T. F. O'Shaughnessy, the operator of the claim, and was thus definitely identified. As the mineral was found in a pebble in the unconsolidated deposits, its original bedrock source was not evident. Much of the gravel that was being mined at that time near Council had characteristics that indicated that it might have been carried for considerable distances, as both fluviatile

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86 Cathcart, S. H., Metalliferous lodes in southern Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 722–F, pp. 163–261, 1922.

and glacial agencies in part were responsible for the transportation. Many of the individual cobbles were composed of rocks that had no counterparts in the neighborhood of Council. It appears to the writer probable that the specimen containing the molybdenite came from a contact zone adjacent to the granites, the nearest one of which that is known is about 20 miles north of Council.

NOME DISTRICT

The bedrock geology in the vicinity of Nome in many features resembles that of the Council district, already described. In general the stratigraphic sequence, according to Moffit,[87] consists of highly metamorphic quartzose schists and some recrystallized limestones, both of which are considered members of the Nome group, which is assigned to the Paleozoic, though the possibility is admitted that it may be in part pre-Paleozoic. In places, especially in the Kigluaik Mountains, north of Nome, this group, as well as certain older schists, is intruded by granitic rocks that are of Paleozoic or Mesozoic age. Although these granitic rocks do not crop out at many places in the southern part of the Nome district, it is the general consensus of opinion that they may underlie a large part of that area at only a moderate depth below the present surface.

One of the recorded occurrences of molybdenite in the Nome district is on claims at the extreme head of Goldbottom Creek, in the saddle leading to Mountain Creek, a tributary of Stewart River. This property at different times has been known by a number of different names. In the description by Mertie [88] it was designated the California quartz lode. The lode material consists of shattered quartz is a complex assemblage of chlorite, sericite, and graphitic schist, with some thin bands of limestone. No granite is known to occur in place in the vicinity of the prospect, but granite boulders, probably brought in by now-vanished glaciers, are abundant in all the nearby surficial deposits. In addition to pyrite and arsenopyrite, which are the principal metallic minerals present in the ore, Mertie states that "Molybdenum and tungsten are also reported from assays." It seems evident therefore that molybdenum minerals were so sparse that they were not readily noticeable in the ore.

The only other locality in the Nome district at which molybdenite has been definitely identified is that mentioned by Moffit [89] as occurring near King Mountain, 7 to 8 miles north of Nome. Concerning this locality, Moffit wrote "Nearby quartz veins in the schist carry a

[87] Moffit, F. H., Geology of the Nome and Grand Central quadrangles, Alaska: U. S. Geol. Survey Bull. 533, 140 pp., 1913.

[88] Mertie, J. B., Jr., Lode mining and prospecting on Seward Peninsula: U. S. Geol. Survey Bull. 662, pp. 426–427, 1918.

[89] Moffit, F. H., op. cit., pp. 130–131.

small amount of gold and a little molybdenite. Two or three veins of this kind are exposed near the wagon road leading over the hill to Glacier Creek. One of these varies in thickness from 1 to 2½ feet and is included between schist and a thin overlying bed of limestone. It can be traced for a distance of about 100 feet along the surface." The quantity of molybdenite in these veins does not appear to be large enough to justify giving serious consideration to their commercial development as a source of molybdenum under existing conditions, even though some of the veins may contain enough gold to warrant further prospecting.

YORK DISTRICT

The western part of Seward Peninsula is here described as the York district. It has attracted considerable attention in the past, because from it and adjacent areas has come most of the tin that has made Alaska almost the only possession of the United States from which any significant amount of tin has been derived. The geology of the area has been studied by several expeditions from the Geological Survey, but owing to its complexity many features still present unsolved problems. Several limestones that differ from each other in age make up the sedimentary sequences in the area. They formerly were believed to range in age from Ordovician to Carboniferous and to include black slates of uncertain relations, but at present they are regarded as of early Paleozoic or pre-Paleozoic age. Certain of these rocks are cut by greenstones, which, in part at least, represent old lava flows. Later than any of the foregoing rocks are granitic intrusives of post-Paleozoic age, which seem to have been the main agents through which most of the valuable mineralization of the area was introduced.

According to Steidtmann and Cathcart,[90] molybdenite "Occurs in small amounts associated with the cassiterite ores at Cassiterite Creek. * * * Commonly occurs in flakes, scales, or plates * * *. Molybdenite usually occurs distributed through débris of granite, crystalline limestones, porphyry, and pegmatite. No occurrence of economic importance is known in the York region." At the specific locality mentioned, Cassiterite Creek, which is a tributary of Lost River, there are several quartz porphyry dikes, which, after partial consolidation, were fractured, and the openings thus formed became the locus of fissure veins in which quartz and the various minerals characteristic of the tin ores were deposited.[91]

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[90] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. 733, p. 40, 1922.

[91] Idem, pp. 58–60.

SUMMARY OF PRACTICAL DEDUCTIONS

The foregoing descriptions of all the known Alaska occurrences of molybdenum minerals have set forth such information as is available as to the kinds, distribution, and character of each deposit. In so doing perhaps it has been inevitable that certain of the general features and broader applications of the observations have been obscured. It therefore seems desirable to present and to emphasize in the following pages some of those more comprehensive aspects that may have escaped due recognition.

None of the Alaska molybdenum deposits have yet been developed to the stage of affording a continuous supply of ore, and so far as the Geological Survey is informed no shipments other than for experimental tests have ever been made from any of the Alaska properties. In fact, at only half a dozen of these properties have there really been serious attempts to examine the molybdenum showings with the degree of thoroughness essential to undertaking a wisely planned scheme of development. That molybdenum mineralization is already known at widely dispersed areas throughout the Territory has been amply demonstrated. That there are other occurrences as yet undiscovered, both in the entirely unexplored areas and in the areas that to a degree have been surveyed, seems beyond question. Under existing conditions search for such undiscovered deposits in the expectation that they will be capable of early development seems entirely unwarranted. This conclusion rests principally on factors other than the probability of finding some molybdenum minerals. For instance, the remoteness of much of the unexplored regions, the absence of transportation facilities, labor, and supplies in such areas, and the already well-supplied condition of the market for molybdenum ores would inevitably prove heavy handicaps to such development. Indeed, many of these same factors would operate as they have operated in the past to discourage development of even the best of the known deposits.

These present drawbacks, however, will doubtless become less important factors as the settlement and development of Alaska as a whole inevitably takes place. It is, therefore, with an eye on the future that one must consider the molybdenum resources of the Territory. When that is done it becomes clear that already a few of the known deposits deserve watchful consideration. According to late statistics the tenor of molybdenum ore now being mined so successfully from the deposits at Climax, Colo., averaged 0.567 percent of MoS_2 for the year 1939, whereas considerably higher tenors have been reported[92] for the ore from Shakan and Baker Island, though the quantities of ore that the engineers estimated were available at these

[92] Bureau of Mines, Minerals yearbook 1940, Review of 1939, pp. 617–623, 1940.

places were insignificant in comparison with the output from the Colorado deposit.

In general all of the known Alaska occurrences of molybdenum ores have been very close to intrusive masses of granitic rocks. These are, therefore, the places on which such exploration as may be attempted should be focused. Many such localities are present, of which some are already delimited approximately, but many others have not been examined. The great arc of the Alaska and Coast Ranges, which sweeps through southeastern, south central, and southwestern Alaska, presents innumerable localities where such intrusives occur. But the granitic intrusives are by no means limited to this part of the Territory, for comparable rocks crop out in practically all of the major geographic regions, from the far-off Brooks Range, of northern Alaska, to remote parts of the Yukon and Kuskokwim regions. The mere recognition of granitic rocks, however, should not be stressed too strongly, because such rocks have been found that differ greatly in age, composition, and relationships, and it has not yet been demonstrated conclusively whether the molybdenum mineralization is associated with only one or with several types. Mertie, as a result of his general studies of the granitic intrusives throughout a large part of Alaska, has distinguished at least two main periods of intrusions, one in the later part of the Mesozoic and one in the Tertiary. According to him[93] "Molybdenite so far as known occurs only with the granitic intrusives of Mesozoic age." It is not possible to date closely the intrusion of some of the bodies of granitic rocks, but a possible exception to Mertie's generalization appears to be afforded by the occurrences of molybdenum minerals in the Willow Creek area of the Marshall district. There the principal granitic rocks are of the soda-rich type, which usually are considered characteristic of the later granitic intrusives of Tertiary age.

In general it is true that most of the granitic rocks of the Coast Range and its extensions, of most of east-central Alaska, and of Seward Peninsula are now considered as having been intruded during the Mesozoic era, whereas most of the granitic rocks of the Livengood and Iditarod districts of the Yukon region and of the western districts of the Kuskokwim region were probably intruded during the Tertiary period.

In the description of the individual occurrences it was shown that most of the molybdenum mineralization seen bore either of two main relations to the granitic intrusives. It either occurred in the contact zone between these igneous rocks and the rocks they invaded or in fractures within the granitic rocks that were formed during their

[93] Mertie, J. B., Jr., The occurrence of metalliferous deposits in the Yukon and Kuskokwim regions, Alaska: U. S. Geol. Survey Bull. 739, p. 154, 1923.

cooling. In the contact zone the emanations from the granitic masses impregnated and altered the invaded rocks, and as the temperatures and pressures permitted deposited the materials they carried. In this way an aureole that varied in extent and differed from both the intruded and intruding rock was produced, which is distinctive and readily recognized. Such zones are usually more resistant to weathering and related destructive processes than the contiguous rocks, so that often they can be traced readily in surface exposures. In these contact deposits the molybdenum minerals are likely to be rather widely dispersed throughout the contact rock and not segregated. Therefore, unless the quantity of molybdenum minerals thus disseminated is so large that a considerable part of the zone of contact rock will pay for treatment, mining of the deposit will be a problem, for there will be no guide to planning development so as to restrict activities to the areas of better ore.

In the deposits formed within the borders of the intrusive rock the mineralization is more or less limited to the fractures that have been formed subsequent to the general emplacement of the mass. This indicates that considerable cooling of the granitic rocks had taken place and that the introduction of the valuable minerals was among the later events attendant on the intrusion. The fractures thus formed would necessarily have a radial or concentric arrangement with respect to the cooling igneous rock and obviously are more likely to be found near the borders of those masses than near the centers, which presumably cooled more slowly. As to the continuity of these fractures and the minerals filling them, it is evident that probably many of them do not extend to considerable depths, because far below the surface the temperatures were higher, so that there the rocks were less likely to fracture or retain such fractures as might be formed, and the mineral-bearing emanations were not apt to deposit their molybdenum ores if they were still highly heated. However, molybdenite is one of the minerals that characteristically is formed in deposits that originated at moderately high temperatures, so that the vertical range in which it may be expected is rather large. In other words, the molybdenite deposits occurring in fissures within the granitic rocks are not likely to be restricted to a shallow surface zone but are apt to extend downward as deep as the fissures themselves persist.

In the search for deposits of molybdenum or other minerals, the geographic factors that pertain to the occurrences deserve equal or perhaps even greater consideration than some of the purely geologic phases. It is readily apparent that for a commodity like molybdenite, which, even in the richest deposits forms but a small part of the material that must be handled in the course of its recovery, geographic environment of the deposits is of paramount importance. The position of the deposit with respect to transportation routes, markets, supplies of labor and material, climate, and sources of power may make for the failure of an enterprise that otherwise might seem attractive. True, the natural handicaps that some of these factors may present can be somewhat lessened by the construction of man-made facilities by which their adverse effects may in a measure be offset. This, however, almost always entails large expenditure of funds or roundabout methods, the adoption of either of these substitutes narrowing the already slim margin that nowadays separates commercial deposits from those that cannot be mined profitably. Because of these geographic factors prospectors for molybdenum minerals would be wise to avoid searching in the more remote parts of the Territory and to center their efforts on places of suitable geologic environment that present advantageous geographic situations with respect to accessibility, safe and economical facilities for transportation, and that are in proximity to areas that contain potential water power or fuel resources.

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