THE OCCURRENCE OF METALLIFEROUS DEPOSITS IN THE YUKON AND KUSKOKWIM REGIONS.

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INTRODUCTION.

Topographic and geologic surveys, together with studies of mineral resources, have been carried on by the United States Geological Survey in Alaska for 25 years, with the primary object of fostering a mining industry in the Territory. The economic geologic investigations have been planned with a twofold purpose—to gain a better understanding of the known mineral deposits and to aid in the discovery of new deposits. The first of these objectives is attained by geologic studies in various mining districts to determine the origin, character, and extent of known deposits. The second is accomplished by regional geologic investigations in unknown areas and by the application to such areas of data from developed districts. The work of the first type aids the mining operator of the present day; that of the second benefits the prospector and the mining operator of the future.

Nearly all the developed mining districts in Alaska have been examined by members of the Geological Survey, and contiguous areas have been visited and described. Such work has resulted in important conclusions, which, however, are not as available to the public as might be desired, being scattered through many reports. It is the purpose of this paper to present in a condensed form, some generalizations and deductions regarding the distribution and occurrence of mineral deposits in interior Alaska. The paper is intended primarily as a guide to the prospector.

The data here presented are based largely on investigations in the regions lying between Yukon and Tanana rivers and between the Yukon and the Kuskokwim. Relatively little is known of the region north of Yukon River, but so far as known the geologic conditions affecting the formation of ore deposits there are similar to those south of the river. Between Tanana River and the Alaska Range the same conditions exist, but the presence of glacial gravels has complicated the distribution of the placer deposits. Seward Peninsula is really a province in itself but has nevertheless many points in common with interior Alaska.

A list of publications by the United States Geological Survey containing the latest geologic and metallogenetic data on the districts of interior Alaska is given below.

Bulletin 375. The Fortymile quadrangle, Alaska, by L. M. Prindle, 1909.

Bulletin 520 (pp. 201–210). Gold placers between Woodchopper and Fourth-of-July creeks, by L. M. Prindle and J. B. Mertie, jr., 1912.

Bulletin 525. A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle, 1913.

Bulletin 532. The Koyukuk-Chandalar region, Alaska, by A. G. Maddren, 1913.

Bulletin 535. A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin, 1913.

Bulletin 538. A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle, 1913.

Bulletin 622 (pp. 292–360). Gold placers of the lower Kuskokwim, by A. G. Maddren, 1915.

Bulletin 630. The Chisana-White River district, Alaska, by S. R. Capps, 1915.

Bulletin 631. The Yukon-Koyukuk region, Alaska, by H. M. Eakin, 1916.

Bulletin 649. Antimony deposits of Alaska, by A. H. Brooks, 1916.

Bulletin 655. The Lake Clark-Central Kuskokwim region, Alaska, by P. S. Smith, 1917.

Bulletin 662. (pp. 221–277). The gold placers of the Tolovana district, by J. B. Mertie, jr., 1917.

Bulletin 667. The Cosna-Nowitna region, Alaska, by H. M. Eakin, 1918.

Bulletin 683. The Anvik-Andreafski region, Alaska, by G. L. Harrington, 1918.

Bulletin 687. The Kantishna region, Alaska, by S. R. Capps, 1919.

Bulletin 692 (p. 329). A molybdenite lode on Healy River, by Theodore Chapin, 1919.

Bulletin 692 (pp. 351–362). Lode deposits near the Nenana coal field, by R. M. Overbeck, 1919.

Bulletin 714 (pp. 207–228). Mineral resources of the Goodnews Bay region, by G. L. Harrington, 1921.

Bulletin ——. The Ruby-Kuskokwim region, Alaska, by J. B. Mertie, jr., and G. L. Harrington (in preparation).

CLASSES OF DEPOSITS.

Only the metalliferous deposits are considered in this paper. If Seward Peninsula is included, it may be said that all the common metalliferous ores are present in interior Alaska. Gold, silver, lead, copper, tin, tungsten, antimony, quicksilver, and platinum metals have been produced on a commercial scale, and zinc, molybdenum, chromium, iron, manganese, bismuth, nickel, and arsenic are found. Gold has been and probably will continue to be the main mineral product of the region. At present silver, lead, copper, and tin are also being recovered on a small scale.

The mineral deposits of interior Alaska may be divided into two general classes, lodes and placers. A complete genetic classification is not needed for the purpose of this paper, but certain subdivisions of these types, based on differences in the manner of origin, will be mentioned if such differences may influence the method of prospecting.

LODE DEPOSITS.

OUTLINE.

A lode of some kind must exist before a placer can be formed; therefore it is natural to consider first the lode deposits. Emphasis will be laid upon the ores which are now or which may be in the near future economically important. The origin and distribution of such metals as chromium, which are not likely ever to be of importance in interior Alaska, are of more scientific than economic interest and merit only the barest allusion.

Most metallic deposits have been derived directly or indirectly from igneous rocks, though in some deposits the connection is indirect and remote. In interior Alaska the connection between the metallic lodes and igneous activity is everywhere apparent, and many of the lodes are so closely associated with igneous rocks that this relation is of great assistance to the prospector in his search for minerals.

Many kinds of igneous rocks exist in interior Alaska. Silicic, basic, and intermediate types are present, both as intrusive bodies and as surface flows. Moreover, igneous rocks of the same general character have been intruded and extruded at different epochs, so that two rock bodies of the same character may be of widely different age and may have produced differing types of mineralization. At first sight this complex history of volcanism in the region may seem a stumbling block to the practical miner, who is endeavoring to utilize geology in his search for minerals. But fortunately only certain special types of igneous rocks, which are also those that are most easily recognized, have any important bearing on the metallic lodes that are likely to be of commercial value.

With the exception of the platinum metals and certain of the ores of copper, all the minerals of interior Alaska that have been or are likely to be developed on a commercial scale are connected genetically with silicic igneous rocks of the type usually designated granodioritic rocks. This group includes granite, syenite, monzonite, quartz monzonite, granodiorite, quartz diorite, and diorite, together with specialized varieties of these rocks, such as aplite, pegmatite, and certain sodic varieties. All these rocks, however, resemble one another to a greater or less degree, and the true petrographic character of many specimens can be recognized only after close examination under the microscope. The ability to determine the exact petrographic name is therefore not so important as the ability to recognize this general group of rocks in the field.

In general the granitic rocks are composed essentially of the minerals quartz and feldspar, together with mica, hornblende, or pyroxene, or mixtures of these. The quartz and feldspar are light colored; the other minerals are dark. The resulting color of the rock is usually light gray but ranges from white or creamy to dark gray, depending on the proportions of the constituent minerals. The grain is usually so coarse that the individual minerals of the rock can be easily discerned with the naked eye. Few prospectors or mining men will have any difficulty in recognizing the granitic rocks.

METALLIZATION CONNECTED WITH GRANITIC INTRUSIVE ROCKS.

GENERAL CONDITIONS.

Deposits of gold, silver, lead, tin, tungsten, antimony, quicksilver, molybdenum, and copper in interior Alaska are connected with granitic intrusive rocks. Such rocks, however, have been intruded in this region at a number of different periods during its geologic history, and it is probable that several or all of these granitic invasions have been attended by the formation of metalliferous deposits. At present definite proof of two such periods of metallization has been obtained in interior Alaska, and a third is inferred with a considerable degree of assurance. The earliest of these periods occurred during the Mesozoic era, probably in late Jurassic or early Cretaceous time. The latest occurred in late Eocene or more probably in post-Eocene time. Between these two, in early Tertiary time, a third period of metallization is believed to have occurred. It may later become necessary, as more evidence accumulates, to expand this hypothesis still further, for metallization before the Mesozoic is already suspected in some areas and may later be definitely proved.

The igneous rocks that accompanied and produced the metallization of the earliest and latest of the recognized periods differed from one another in some important respects, although they all fall under the general designation granitic rocks. These differences are of little significance in the field, but when recognized in microscopic study they aid in distinguishing the two types. A more important matter is the marked difference that exists in the character and distribution of the metalliferous lodes accompanying these two groups of rocks. This difference is easily recognized in the field and is of interest to the prospector and geologist alike.

For convenience in discussion, the three periods of metallization above postulated are designated the early, intermediate, and late periods. These designations, however, are relative, not absolute, for they are not intended to imply that this enumeration represents the totality of metallization associated with granitic rocks in this region. The age and character of the intermediate period of granitic intrusion and metallization in interior Alaska are somewhat obscure and must be inferred in part from the geology of the Alaska Range. So far as known, the metallization of this intermediate period is more nearly related in character to the early than to the late metallization; in fact, evidence of it has not yet been surely recognized except in areas affected by the early metallization. The early and intermediate periods of metallization are therefore discussed together. The late period is entirely distinct.

Metallization occurred in connection with intrusions and extrusions of basic igneous rocks at other periods also, but it was of relatively slight extent and will be discussed briefly in a separate paragraph.

EARLY AND INTERMEDIATE PERIODS OF METALLIZATION.

The most widespread metallization in interior Alaska is believed to have occurred during Mesozoic time and is therefore representative of what is here designated the early period. Metallization of this type appears to be dominant in the Fortymile, Seventymile, Circle, Fairbanks, and Rampart districts of the Yukon-Tanana region, in the Ruby-Poorman district, and in the valleys of Koyukuk and Chandalar rivers. South of the Tanana also metallization of the early type occurred, though perhaps to a less extent than farther north. The lodes of Seward Peninsula were probably formed in part during this period. The chief metallic constitutent of all these early lodes was gold.

The intermediate metallization occurred in the Fairbanks and Kantishna districts and may also be represented in the Rampart and Tolovana districts. The lodes of this period carry gold but contain in addition sulphide ores such as stibnite and galena, locally in commercial quantities.

The common intrusive rocks connected with the early period of metallization are granite, quartz diorite, diorite, pegmatite, and aplite. The intrusive rocks connected with the intermediate period of metallization are not so well known, because ore deposits of intermediate age that are entirely distinct from the early ore deposits have not been recognized with assurance. The intrusive granitic rocks in the vicinity of Broad Pass, which are believed to be in part of early Tertiary age, are described as essentially granite, quartz monzonite, and quartz diorite.[1] The granitic intrusives of the Rampart district are described as quartz monzonite and related rocks of late Mesozoic or early Tertiary age, but as no fossils have been found in

[1] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, p. 59, 1915.

the invaded sedimentary rocks near by, this determination of age can not be regarded as conclusive.[2] It is believed, however, that monzonitic rocks were important in this intermediate metallization.

Mineral associations constitute another valuable criterion in separating deposits belonging to the early and intermediate periods of metallization. Gold and silver are common to both groups of deposits. It has been shown by Brooks[3] that the stibnite ores were formed later than the Mesozoic metallization of Alaska and are probably of Tertiary age. Cassiterite, the common ore of tin, is believed by the writer[4] to have been formed only during the Mesozoic or early period of metallization, although the tin deposits near Hot Springs, in the Rampart district, may present a possible exception to this general statement. Tungsten occurs in the early group of deposits as wolframite and scheelite. Molybdenite, so far as known, occurs only with the granitic intrusives of Mesozoic age. Silver-lead ores, accompanied in places by other ore minerals, such as stibnite, chalcopyrite, bornite, sphalerite, pyrite, arsenopyrite, jamesonite, and bismuthinite, occur in associations which suggest that they originated mainly in the intermediate period. The sulphide ores of the Fairbanks and Kantishna districts are believed also to fall within the intermediate group.

The lodes of the early and intermediate periods of metallization were produced as a result of igneous intrusions, but the connection is indirect—that is, the lodes do not occur in the granitic rocks but in fissure veins and other types of deposits either near by or at some distance from the intrusive rocks. The ores commonly occur in quartz veins, but ores containing little or no quartz are found. Disseminated deposits are present at some localities, the metal-bearing solutions having followed lines of cleavage or other structural partings. Shear-zone lodes are found at some localities. Probably when more is learned of the metallization of these two periods it will be found that the intrusions gave rise also to contact-metamorphic deposits, as in southeastern Alaska, as well as deposits of other types. The type of deposit is influenced mainly by local conditions, such as the thickness and character of the superincumbent rocks.

It also appears that only the granitic bodies of smaller size were the source of economically important lodes in all three periods of mineralization. Immense bodies of granitic rocks, such as that which extends for 75 miles across the Circle quadrangle, do not appear to

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[2] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 23–24, 1913.

[3] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, pp. 14–17, 1916.

[4] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

have produced any valuable mineral deposits. The explanation lies in the probable concentration of metallization, except possibly that due to contact metamorphism, at the higher points or apexes of the invading igneous masses. By this hypothesis an immense body of granitic rock, such as the one just mentioned, may be conceived to have produced mineral deposits in the locality of its apex, when the mass was deeply buried. Such deposits and the rocks that contained them have been removed by the long-continued erosion that has bared the lower part of the intrusive body. The sedimentary rocks formed later from the products of this erosion may contain a large part of the gold content of the original deposits. The gold contained in the conglomerate that stretches from Eagle westward to Woodchopper Creek, in the Yukon-Tanana region, may have originated in this way.

The lodes of the Fairbanks district may be cited as the best-known examples of the early and intermediate periods of metallization. The group of lodes that extend from Pedro Dome northeastward show metallization of two kinds. The oldest known lodes in this group are gold-quartz veins that occupy ancient fissures in the country rock. Igneous rocks similar to those exposed at Pedro Dome doubtless lie at no great distance beneath the surface, and their intrusion doubtless caused the fractures and fissures. Solutions of ores and vein minerals, originating from these rocks at a late stage in their cooling, subsequently moved upward and were deposited in such openings, forming the gold lodes of this area. The veins appear to have been formed at moderate depth, yet under sufficient cover to insure a fair degree of regularity.

Later, probably in early Tertiary time, there was another period of metallization, here termed the intermediate, probably likewise resulting from the intrusion of granitic rocks. In the Fairbanks district the granitic intrusives of this period, if exposed at the surface, have not been separated with certainty from the Mesozoic intrusives. The deposits formed by the metallization of the intermediate period, however, are distinct. Sulphide ores, accompanied by gold, appear to form the dominant type of lodes. Stibnite is the most common sulphide, but pyrite, galena (in part silver-bearing), arsenopyrite, sphalerite, bismuthinite, jamesonite, chalcocite, and tetrahedrite are also known. Some of these lodes contain quartz and some do not, but where vein quartz of this period is present it is different in character from that in the gold-quartz veins. Some of the old gold-quartz veins were reopened in this intermediate period and enriched, so that ores of the two periods are found at some localities in juxtaposition. This same intermingling of the ores of two different periods also occurs in the lodes of the Kantishna district.

The physical conditions under which the ores of the early and intermediate periods of metallization were formed do not appear to have been materially different.

Tungsten ores, consisting essentially of scheelite, are also found in the Fairbanks district, where they occur as disseminated deposits and also in veins, almost invariably accompanied by quartz. The valuable deposits are close to a body of porphyritic granite, with which they are believed to be connected genetically. These scheelite lodes seem to be more closely related to the gold-quartz veins than to the sulphide ores, and therefore they probably belong to the early period of metallization.

LATE PERIOD OF METALLIZATION.

In late Eocene or perhaps post-Eocene time there was another period of intrusion of granitic rocks, accompanied by the formation of ore deposits.[5] These late deposits are found in the Innoko, Iditarod, and McGrath districts and thence at intervals southwestward into the lower Kuskokwim and Yukon valleys. It is possible that ore deposits formed during this period may be present almost anywhere in Alaska, for the metal-bearing solutions in their upward passage from the underlying intrusive masses must have penetrated the older as well as the younger rocks. It is a remarkable fact, however, that these later ores appear to be very scarce in the regions of dominantly older rocks. Thus, in the Yukon-Tanana region ore deposits of this late period have been recognized only at Livengood, in the Tolovana district. It appears, therefore, that the late metallic ores are restricted areally as well as geologically.

It is likely that this restricted distribution is in some way related to the orogenic history of Alaska, but the exact connection is not yet understood. If the character of the earth movements of the region has had an important influence, then the movements that accompanied the formation of these ore deposits must have been of a different type and in some degree independent of the Tertiary disturbances that resulted in the uplift of the Alaska Range, for lodes of the late type, as here defined, have not been found close to the Alaska Range on the north side, nor in the range, nor south of it.

The intrusive granitic rocks associated with these ores are quartz monzonite, monzonite, granodiorite, quartz diorite, and diorite, together with varieties of these rocks containing relatively high percentages of soda, such as soda granite and soda diorite. Although these rocks belong in the general family of granitic rocks, they show certain peculiarities that are readily recognized under the microscope.

[5] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. — (in preparation).

One is the prevalence of rocks of the monzonitic type over the true granite; a second is the common occurrence of the sodic feldspars albite and soda microcline instead of the potassic feldspars orthoclase and microcline. A third difference is seen in the character of the dark minerals of the rock. Hornblende is as plentiful as in the older granitic rocks, but pyroxene is much more plentiful, and mica is probably less plentiful and is more likely to be biotite than muscovite. The late granitic rocks, therefore, commonly have a little darker color.

The metallic content of the late lodes includes chiefly gold, cinnabar (the sulphide of mercury), and stibnite (the sulphide of antimony). Locally scheelite is found with cinnabar and stibnite in the gold placers, as on Otter Creek, in the Iditarod district, and on Lillian Creek, in the Tolovana district. These associations suggest a common origin of the gold, cinnabar, stibnite, and scheelite. It is probable, however, that these minerals may have been deposited in different stages within the one general period of metallization. Cinnabar is not known to occur in the lodes of the early and intermediate periods.

The great difference between the deposits of the late period of metallization and those of the two earlier periods is seen in their relations to the granitic intrusive rocks and in their mode of occurrence. The genetic connection between the monzonitic rocks and the lodes of the late period is direct and very intimate. At almost every locality where the late deposits have been recognized they occur either directly in or closely adjacent to bodies of quartz monzonite or related rocks. This feature is particularly apparent in the Iditarod district; on Candle Creek and the upper part of Nixon Fork of the Kuskokwim, in the McGrath district; and in the Tuluksak-Aniak district, in the lower part of the Kuskokwim Valley. The mode of occurrence of the late deposits is also different. The gold occurs usually in small veins and veinlets of bluish quartz, in places chalcedonic, which cut the quartz monzonite and the sediments near by. In some deposits quartz is absent. The gold and accompanying vein materials do not occupy strong fissures with some degree of uniformity in direction, as in the Fairbanks lodes, but form irregular stockworks and brecciated zones. The cinnabar-stibnite ores, however, which occur both with and without quartz, are more commonly at some distance from the intrusive rocks, and many of the deposits occupy somewhat stronger fissures.

In general, these lodes have originated much closer to the surface than the lodes of the early and intermediate periods, as is indicated by the character of the vein quartz and by the character and position of the fissures and other openings that contain the ores. The quartz monzonite does not reflect this difference in a finer-grained fabric, as might be expected, but recent work has shown that under favorable conditions granitic rocks may solidify with coarse grain relatively close to the surface. The differences mentioned, however, together with the restriction in areal distribution, indicate strongly that this type of metallization must be considered quite distinct from the two earlier types.

METALLIZATION CONNECTED WITH BASIC INTRUSIVE AND EXTRUSIVE ROCKS.

The metallic lodes connected genetically with basic igneous rocks in interior Alaska are of little value. The platinum metals, some of the ores of copper, and ores of chromium and nickel belong in this category, but of these only the platinum metals and copper promise to be of economic interest.

Platinum metals in small quantities are widely distributed in Alaska, but the production has been small and restricted largely to one mine. Practically nothing is known of the bedrock association of the platinum metals in interior Alaska, for these metals have been found only in placers. Platinum has been found in the placers on Boob Creek, in the Tolstoi district; in the Marshall district, on Aloric River, in southwestern Alaska; and on Dime, Bear, and Sweepstakes creeks, in Seward Peninsula. In southeastern Alaska, where a palladium-copper lode has been successfully operated, the platinum metals occur in a body of pyroxenite. More commonly, however, the platinum metals are in peridotite or in serpentine derived from peridotite. It is therefore safe to state that most deposits of the platinum metals are derived from basic rocks.

Copper ores associated in part with basic lavas and in part with diorite are found in the upper valleys of Chisana, Nabesna, and White rivers. These deposits have been described in United States Geological Survey Bulletins 417 and 630. The difficulty and expense of mining and transporting such ores is at present prohibitive in interior Alaska.

LODE PROSPECTING.

Most lode prospectors will search mainly for deposits of native gold and for high-grade sulphide ores that contain also gold and silver. From what has already been said, it is apparent that such prospecting should be done in and around the bodies of granitic rocks, more particularly near the smaller bodies. Valuable ore deposits have seldom been found in interior Alaska in association with granitic masses larger than 3 or 4 miles in diameter, and most of those known are associated with much smaller intrusive masses or with dikes and sills.

Granitic masses are relatively resistant to erosion and are therefore likely to stand out conspicuously among the other rocks of the region. Exceptions to this rule are known, however, as for instance on Candle Creek, in the McGrath district, where a body of quartz monzonite lies in the valley of Candle Creek and the surrounding ridges and spurs are composed mainly of basaltic rocks. In the Kuskokwim basin, however, the granitic intrusives are commonly surrounded or adjoined by bodies of basic igneous rocks, some intrusive and some extrusive. The presence of basic rocks in this part of Alaska is therefore an indication that granitic rocks may also be present.

Dikes and sills are also important to locate, for they have been the source of some valuable ores. The Innoko district is one example of the importance of dikes and small intrusive bodies as metallizing agents, and the Parks quicksilver lode, on Kuskokwim River, is another. Such smaller intrusive bodies are difficult to find, because of their inconspicuousness and lack of topographic expression. They may occur close to larger bodies of granitic rocks, and their presence may sometimes be inferred from this fact. Some dikes, however, are offshoots from underlying larger bodies of igneous rock that do not crop out. Only diligent prospecting will reveal the location of such dikes.

On geologic maps made by the Geological Survey the positions of the larger masses of granitic rocks are shown. Sometimes, however, especially in reconnaissance geologic mapping, smaller granitic masses are overlooked, and it is probable that a large proportion of the existing dikes and sills are not seen on a linear traverse. As it is these smaller intrusive masses and dikes that are likely to have originated ore deposits, reconnaissance geologic maps should be taken as general guides rather than infallible indicators of metallization or the lack of it.

After a small intrusive body of granitic rock is found it still remains to be determined whether the intrusion has given rise to any metalliferous deposits. Not all intrusive bodies nor even all small intrusive bodies of granitic rocks have effected metallization, but, on the other hand, no valuable ore deposits have been found in interior Alaska that were not connected in some way with such rocks. They are therefore the most favorable places for prospecting, but they are by no means certain to yield commercial ores. Two general methods of prospecting can be recommended. In the Kuskokwim region, where ore deposits are closely associated with the granitic rocks, the prospector should confine his work to these rocks and their immediate margins. If no signs of metallization are found in a narrow zone close to the main granitic mass, further search might be made for dikes and other inconspicuous intrusive bodies in the near vicinity before turning to a new area. In the upper Yukon, Tanana, Koyukuk, and Chandalar valleys, however, where ores of the early and intermediate periods are more abundant, the prospector should search for a considerable distance from a granitic body, looking particularly for quartz veins, before he decides that this particular granitic intrusive has not produced any ore deposits. The search in these regions is really a search for quartz veins as such, the position of granitic masses serving only as a general indicator of areas that may be favorable prospecting ground.

The above paragraphs have been written for the lode prospector who is going into a new country. It happens more often in Alaska that lode prospecting follows the development of some gold-placer district. Commercial placers have not usually been transported any great distance from their bedrock source; and if the lodes that have produced the placers are also of commercial value they are usually located sooner or later by considering the position and direction of the pay streaks and by laborious prospecting. Knowledge of the character of the metallization in a region, however, will often be of great value in deducing and locating the bedrock source of the placer deposit. Short cuts that result from an understanding of conditions are certainly worth while.

PLACER DEPOSITS.

Most of the metals and metallic ores known in the lodes are found likewise in the placers, but only a few of them occur in placers of commercial value. Gold, of course, is the chief commercial placer metal of Alaska. Tin-placer mining is carried on in a small way on Seward Peninsula, and cassiterite has been recovered on a small scale at other places in connection with gold-placer mining, notably near Hot Springs, in the Rampart district. Tungsten has also been recovered from the placers. A residual scheelite placer on Seward Peninsula was worked during the war, and some wolframite was saved from the placers in the Circle district. The platinum so far recovered in interior Alaska has come entirely from placers that were mined primarily for their content of gold.

TYPES OF PLACERS.[6]

Placer deposits may be divided into several classes, as follows:

I. Residual placers.

II. Eluvial placers.

[6] Alfred H. Brooks has discussed the classification of Alaska gold placers in U. S. Geol. Survey Bull. 328, pp. 111–139, 1908, and Bull. 592, pp. 27–32, 1914.

III. Fluviatile placers:
- A. Simple stream placers:
  - 1. Present stream placers.
  - 2. Ancient stream placers:
    - a. Bench placers.
    - b. Deeply buried placers.
- B. Coalescing stream placers:
  - 1. Present coalescing stream placers.
  - 2. Ancient stream placers:
    - a. Coalescing bench placers.
    - b. Coalescing deeply buried placers.

IV. Glacio-fluviatile placers.

V. Beach placers:
- A. Present beach placers.
- B. Ancient beach placers:
  - 1. Elevated beach placers.
  - 2. Buried beach placers.

All these types are found in Alaska, but not all are economically important in interior Alaska.

Residual placers are formed by rock weathering and decay in place, transportation by water playing no part in the process. Such deposits may be considered the disintegrated surficial parts of metalliferous lodes. Deposits of this type are rare in Alaska. The scheelite deposit on Sophie Gulch, in the Nome district, is a typical example.

Eluvial placers are residual placers that have been transported to some extent by means of soil creep, frost heaving, and the action of tiny rivulets within the decayed rock débris. Such deposits are common in interior Alaska and are more likely to be of economic value than true residual placers, because the movement of the soil and rubble results in concentration of the gold near bedrock. Hillside placers and the uppermost placers of gulches belong to this type. The "upgrade" placers at the head of Flat Creek, in the Iditarod district, have been described as residual placers, but in a strict sense they belong to the eluvial type.

Fluviatile or stream placers of present streams are too common and too well understood by mining men in Alaska to require any description. Corresponding placers that have formed in ancient streams, however, are not so well understood. All bench placers, when first laid down, were stream placers similar to those of the present stream valleys. In the course of time the stream gravels, if not reworked by later erosion, may be left as terraces or benches on the sides of the valley, if the local base-level is lowered and the stream continues to cut down its channel. Such deposits constitute the so-called bench gravels. On the other hand, if the regional or local base-level is raised, the original placer may be deeply buried and a second or later placer deposit may be laid down above it. This has occurred on Olive Creek, a tributary of Tolovana River, in the Tolovana district, where a shallow and a deep channel have been formed at different times. The deep channel is probably synchronous with the elevated or bench channel on Livengood Creek, in the same district. If the local base-level remains practically stationary for a very long period, a condition seldom realized, ancient and recent placers may form a perfectly continuous deposit in a long valley, for the deposition of a gold placer is known to occur at that point in a valley where the stream action changes from erosion to alluviation, and such deposits are therefore formed progressively upstream.

Where several parallel and contiguous streams that are forming placers emerge from their valleys upon an open plain, perhaps into some wide valley floor, a continuous or coalescing placer may be formed along the front of the hills. If the streams empty into some lake or estuary, a delta placer, genetically the same but perhaps different in some minor respects, may be formed. Manifestly such compound placers may be formed by either present or ancient streams and may be elevated or buried in the same way as simple stream placers. Some of the gravel-plain placers of Seward Peninsula are coalescing placers of this general character, and there is evidence that some of the placers near Hot Springs, in the Rampart district, may also be in part compound.

Glacio-fluviatile placers are small and very irregular pay streaks in outwash glacial gravels, some of which are valuable enough to render profitable the mining of great banks of glacio-fluviatile gravel and glacial débris. Such placers are found only in regions that have been extensively glaciated, such as the slopes of the Alaska Range. Placers of this type are worked in the Yentna district, south of the range, but are unimportant in interior Alaska.

Beach placers are formed through the sorting and distribution of the heavy constituents of gravel by shore currents and waves. They are not known in interior Alaska, but those in the present and ancient beaches of the Nome district are of high value.

PROSPECTING FOR PLACERS.

The prospector of interior Alaska will continue to search for stream and bench placers of gold, for these are the only types of placer deposits, both as to metal content and as to origin, that warrant exploitation at present.

All that has been said of lode prospecting applies equally well to placer prospecting, for the lode antedates the placer. It is a great waste of time and effort to prospect blindly from year to year, as many prospectors do, without having any good reason for believing beforehand that a gold placer may exist where they undertake to prospect. Some rich placers have been found in this way, but it is equally true that an understanding of geologic conditions has often resulted in discoveries that otherwise might not have been made for a long time. The discovery of the high-bench ancient beach placers at Nome is a case in point, for it was predicted by Federal geologists,[7] and other examples might also be cited in interior Alaska, where men who have been guided by geologic knowledge, either their own or that gained from others, have been able to precede the uninitiated in making important discoveries.

In searching for placers the prospector should hunt first for areas of granitic rocks that give evidence of having been metallized, just as in lode prospecting, and then after the occurrence of metallization has been established he should prospect the streams leading from such areas. One difference, however, must be cited. It is not necessary to find a high degree of metallization nor to discover a rich lode before beginning placer prospecting, for a lode deposit of very low grade may by long-continued erosion and stream concentration develop into a high-grade placer. The placers of the Klondike region are an example of this condition. In fact, if the prospector finds a small area of granitic rocks or an area cut by many quartz veins or granitic dikes, he would do well to prospect the streams draining such an area, even if evidence of metallization had not been discovered in the bedrock. If a commercial gold placer is present in the vicinity, some inkling of the fact is rather likely to be obtained by panning on the bars and riffles of some of the streams near by.

Another point that deserves stress is the desirability of searching in particular for bench deposits. The conditions that make for the development of continuous commercial pay streaks are long-continued and deep residual weathering, moderate stream gradients, and a nice adjustment between the factors that regulate the erosion and transportation of rock débris. It is believed that favorable conditions of this sort prevailed more generally in interior Alaska during the physiographic cycle just preceding the present one than they do now. For this reason where bench and stream placers both occur the former are likely to be the richer. The placers of the Fairbanks and Tolovana districts prove the correctness of this hypothesis. Bench placers, of course, are harder and more costly to prospect, because the gold in them is usually buried beneath a great thickness of muck and gravel. The discovery of a pay streak in the present

[7] Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region (U. S. Geol. Survey special publication), pp. 22–23, 1900. Brooks, A. H., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900 (U. S. Geol. Survey special publication), pp. 80–91, 1901.

creek channel may perhaps be a logical preliminary step, but when this is accomplished, a thorough search for bench gravels should be made. The original discoverers of placer gold on Livengood Creek did not profit in fullest measure by their discovery, because they overlooked the possibility of a higher channel, and the rich bench placers fell into the hands of later arrivals in the camp.

Last of all some consideration should be given to the physiographic type of country in which workable placers are most likely to be developed. One of the conditions that is regarded as favorable for the accumulation of commercial placers is a moderate stream gradient; and such gradients are prevalent in the lower parts of the country. To be sure, moderate gradients may be found in the lower courses of larger streams, even in a district of high relief, but the chances for the formation of a workable placer are less in a wide valley drained by a large stream than in the smaller tributary valleys. It does not necessarily follow from these considerations that workable placers will not be found in the higher country, for a sufficiently rich lode may give rise to rich placers under conditions that in general are considered very adverse. The chances of discovering workable placers, however, are much better in the regions of low relief if the conditions for bedrock metallization appear to be equally favorable. With few exceptions the rich placer camps of interior Alaska have been found at an elevation of less than 1,000 feet. The Koyukuk camp is an important exception to this rule, but even in this rugged country the principle has its application, for the richest placers occur on the lower parts of the tributaries close to the middle, south, and north forks of Koyukuk River and to Bettles, Wild, and John rivers—all large streams. The gradients of the parts of the streams that contain the placers are therefore the lowest that the country affords.

Although the gold and the valuable sulphide ores in interior Alaska are all derived originally from the granitic rocks, yet some gold placers have a proximate source of different character. Although the gold contained in the belt of conglomerate that stretches westward from Eagle to Woodchopper Creek, in the Yukon-Tanana region, came originally from granitic rocks, yet for the prospector of to-day this conglomerate may be considered a bedrock source of the gold. Not all the placer gold in this belt, however, comes from this conglomerate, for without doubt some is derived directly from the older rocks, but the importance of the conglomerate as a contributing source of gold should not be overlooked. This example is given to illustrate a principle rather than to indicate that this particular area is of any great importance as a placer field.

Another example of a proximate source of placer gold other than the original bedrock source is afforded by the glacial gravels and débris. Mention has already been made of the possibility at some localities of working such deposits. More commonly, however, the original glacial deposits have been reworked by the present streams, which have concentrated the gold and developed workable stream placers. Practically nothing can be said that will aid the prospector either in finding the original pay streaks in the glacial gravels or in finding the stream placers derived from them. Fortunately placers of this type are rare in interior Alaska, being confined largely to the slopes of the Alaska Range.

INDEX.

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

All these publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained free of charge (except certain maps) on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost. The publications marked with an asterisk (*) in this list are out of stock at the Survey but can be purchased from the Superintendent of Documents at the prices stated.

4. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL.

REPORTS.

*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp. No copies available. May be consulted at many public libraries.

*Placer mining in Alaska in 1904, by A. H. Brooks. In Bulletin 259, 1905, pp. 18–31. 15 cents.

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*The mining industry in 1906, by A. H. Brooks. In Bulletin 314, 1907, pp. 19–39. 30 cents.

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*Economic developments in southeastern Alaska, by F. E. and C. W. Wright. In Bulletin 259, 1905, pp. 47–68. 15 cents.

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Juneau special (No. 581A); scale, 1:62,500; by W. J. Peters. 10 cents retail or 6 cents wholesale.

Berners Bay special (No. 571B); scale, 1:62,500; by R. B. Oliver. 10 cents retail or 6 cents wholesale. Also contained in Bulletin 446.

Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1:62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

Copper Mountain and vicinity, Prince of Wales Island (No. 540B); scale, 1:62,500; by R. H. Sargent. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87.

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*Mineral deposits of the Ellamar district, by S. R. Capps and B. L. Johnson. In Bulletin 542, 1913, pp. 86–124. 25 cents.

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Controller Bay region (No. 601A); scale, 1:62,500; by E. G. Hamilton and W. R. Hill. 35 cents retail or 21 cents wholesale. Also published in *Bulletin 335. 70 cents.

Chitina quadrangle (No. 601), reconnaissance map; scale, 1:250,000; by T. G. Gerdine, D. C. Witherspoon, and others. 50 cents retail or 30 cents wholesale. Also published in Bulletin 576.

Nizina district (No. 601B); scale, 1:62,500; by D. C. Witherspoon and R. M. La Follette. In Bulletin 448. Not issued separately.

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The Bering River coal fields; scale, 1:62,500; by G. C. Martin. 25 cents retail or 15 cents wholesale.

The Ellamar district (No. 602D); scale, 1:62,500; by R. H. Sargent and C. E. Giffin. Published in Bulletin 605. Not issued separately.

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