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NOTES ON A KENNECOTT TYPE OF COPPER DEPOSIT, GLACIER CREEK, ALASKA

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Introduction.

A recent discovery of interesting copper ore at Glacier Creek, Alaska, disclosed another deposit of the Kennecott type of metalization. Since it lies some 35 miles from Kennecott, and consists of generally similar ore, it indicates a widespread distribution of this type of metallization. The ore itself is unusual consequently a few notes about the deposit may be of interest.

The deposit lies at an elevation of 3,100 feet on the west side of the valley of Glacier Creek, a swift tributary of the Chitistone River, which, in turn, forms a part of the Copper River drainage. It is readily accessible by horse or on foot, except for the difficulty of fording swift, treacherous, glacial streams. The region is mountainous and rugged, with flat-bottomed, steep-sided glacial valleys whose walls rise precipitously to elevations of 6,000 to 8,000 feet. Most of the tributary streams are headed by glaciers.

The property was worked for a year by the Kennecott Copper Corporation but was abandoned in 1930. It was studied by the writer, in company with BeVan Presley [1] and W. A. Richelsen, [2] in the summer of 1930.

GENERAL GEOLOGY.

The general geology of the region in the vicinity of Glacier Creek has been described recently by Moffit, [3] whose map includes a part of the Glacier Creek section. The mapping was completed, however, before the discovery of the copper deposit. The regional geology is, in general, similar to that at Kennecott.

<u>Rock Formations.</u>—The formations in the vicinity of the property include only the Triassic Chitistone limestone, the underlying Nikolai greenstone of Permian or Triassic age, and recent deposits, chiefly fluvio-glacial.

The greenstone here consists of about 5,000 feet of basaltic lava flows, altered for the most part, and stained widely with copper minerals. It forms the middle and lower slopes of the valley walls.

The Chitistone limestone in this vicinity is about 2,000 feet thick and is separated from the underlying greenstone by a three-foot shale band. It forms the tops of the mountains and its blocky weathering yields imposing castellated peaks. The Chitistone limestone here, as at Kennecott and elsewhere in this region, has undergone partial dolomitization. All the commercial ore is confined to the to the Chitistone formation.

The bottom of the limestone on the west side of Glacier Creek lies at elevations of from 4,000 to 6,000 feet; the greenstone extends down to the creek level at an elevation of 2,500 feet. However, where Glacier Creek joins Chitistone River, a large wedge-shaped slice of the limestone, some 7,000 feet long, 2,000 feet wide, and about 1,300 feet high has been relatively down-faulted several thousand feet so that the limestone touches the river gravel at the north end of the block and, due to its dip, lies 700 feet above the river at its south end. The ore deposit lies within this faulted limestone block.

The sequence of lower beds of the Chitistone formation is the same as at Kennecott, namely, greenstone, shale, pyritic limestone, black limestone, gray limestone, and gray dolomite.

Strudure.--A broad, shallow syncline trends northwesterly throughout ~~this region~~. Kennecott lies on its southwesterly side and Glacier Creek on its northeastern limb, some 35 miles southeast of Kennecott. The formations therefore strike northwesterly and dip gently (15° - 20°) to the southwest.

A great thrust fault with a southwesterly dip has been followed across the region in a northwesterly direction for some 15 miles.[4] Its southward extension is up Glacier Creek. Opposite the mouth of Glacier Creek is an imposing spectacle, shown on a grand scale on the steep valley side, of the underlying Nikolai greenstone over-riding the overlying Chitistone limestone. A few hundred feet of the lower Chitistone beds are doubled sharply under themselves on the hanging wall surface of the fault. It must have a displacement of several thousands of feet. This great thrust crosses the corner of the mountain at the mouth of Glacier Creek. The limestone block that was previously mentioned as containing the ore deposit lies beneath it, and lower greenstone lies above it. The normal greenstone-limestone contact above the fault lies some 2,500 feet vertically above and west of the similar contact in the detached block. Consequently, the throw of the fault must be several thousand feet and the displacement along the fault surface much greater.

Within the block, the limestone beds are much distrubed by minor faults (normal and reverse) whose strikes are at high angles to the trend of the great thrust. It is along these minor faults that the copper metallization occurs. The minor faults are probably contemporaneous in age with the great thrust fault and resulted from the jostling sustained by the underlying block at the time of the major movement.

There has also been considerable post-mineral minor faulting that dislocated the ore.

ORE DEPOSITS.

Character of Ore.-- The ore exposed is practically identical with that at Kennecott. It is high-grade copper ore with appreciable silver content, consisting chiefly of chalcocite and covelite but with more enargite, bornite, and chalcopyrite than the Kennecott ore. Masses of pure sulphide ore are common, but for the most part the copper minerals occur as blebs or bunches inclosed in carbonate rock. A few small shipments have been made of hand-sorted "high grade" that yielded about 60 per cent copper.

Nature of Deposits.--The ore disclosed occurs in steeply inclined narrow fissures and along bedding planes in the limestone and dolomite beds of the Chitistone formation. The types of deposits are almost identical with those at Kennecott except that they are smaller and more discontinuous.

The fissure vein ore is in thin bands of copper sulphides that enlarge here and there into irregularly shaped bunches up to a few feet in diameter. It is "spotty ore." The fissures have little continuity; they lack virility and weaken and fade abruptly, or terminate against bedding planes, or are cut off by small post-mineral faults.

The bedding plane ore consists of thin bands or bunches of sulphide that extend out along favorable bedding planes from either side of cross-cutting fissures. Unfortunately, the ore fades out along the bedding within short distances from the intersecting fissures. Its distribution up and down the bedding planes likewise lacks continuity.

Insufficient ore was developed to justify the initiation of expensive operations in this remote locality.

THE ORES.

The ore consists almost exclusively of sulphides of copper; pyrite is rare, and introduced gangue minerals are absent. Chalcocite makes up about 75 per cent. of the ore minerals; covellite is next in abundance; enargite is common, and there are appreciable amounts of bornite and a little chalcopyrite. Some luzonite has also been identified. The chalcocite, like that of Kennecott, is of especial interest.

Chalcocite.--Three varieties of pure chalcocite may be recognized in hand specimens, namely, (1) "steely," (2) fine crystalline, and (3) coarse "platy" chalcocite. The last is rather unusual. It resembles granular magnetite. It is distinctly granular and is made up of individual grains, each with a cleavage surface from 1 to 5 mm. across, arranged in haphazard pattern. The specimen scintillates in the light like a piece of diorite. All three varieties may be intimately admixed with covellite.

Under the polarizing reflecting microscope the two kinds of chalcocite may be readily distinguished, namely, the anisotropic or common orthorhombic chalcocite, and the isotropic or uncommon isometric chalcocite. The Glacier Creek deposits, therefore, constitute another occurrence of natural isometric chalcocite.

The isometric chalcocite is found only in those specimens in which covellite is present. It may make up the whole of the specimen or only part of it. It remains isotropic under crossed nicols. This means that it has been formed at a temperature above 91° C. and its inversion to the normal chalcocite has been prevented by the presence of 8 per cent. or more of covellite in solid solution. Numerous microscopic laths of covellite are scattered through the chalcocite and are of the type that has been formed by ex-solution.[5]

The orthorhombic chalcocite is prominently anisotropic under crossed nicols. All the "platy" chalcocite referred to above is of the orthorhombic class, as is also much of the steely variety. Orthorhombic and isometric chalcocite may occur in the same specimen. Orthorhombic chalcocite may indicate that it has been formed (1) at a temperature above 91° C. and inverted to the orthorhombic form upon cooling; (2) that it was formed originally as orthorhombic chalcocite by hot solutions at a temperature below 91°C; (3) that it formed from cold surface waters as supergene chalcocite. This orthorhombic chalcocite is intimately associated with the isometric, which suggests strongly that they were both formed from hot solutions and that the orthorhombic variety is hypogene, not supergene. This conclusion is further substantiated by etch reactions. When solutions of HNO_3 or KCN are applied to the polished surface of the orthorhombic variety a triangular or isometric etch pattern may develop. This shows that such chalcocite has an inherited isometric structure which may have been inherited from ancestral high-temperature chalcocite or from some other isometric mineral that it may have replaced. Since there is no evidence to indicate, and much to oppose, that this chalcocite has been formed by replacement of another isometric mineral, the inference is highly probable that the isometric etch pattern is inherited from ancestral isometric or high-temperature chalcocite. In addition, some of this orthorhombic chalcocite is lamellar, which is considered by Schneiderhohn [6] proof of an inversion from the isometric to orthorhombic system. Consequently it is considered that this orthorhombic chalcocite is also hypogene and was originally formed at temperatures above 91° C.

Some of the chalcocite yields upon etching a rectangular (orthorhombic) etch pattern. Also, some of the orthorhombic and isometric varieties yield an irregular etch pattern resembling "crackled porcelain," considered by Lindgren to indicate original colloidal deposition--a mode of formation considered probably for the Kennecott chalcocite.[7]

<u>Covellite</u>.--The covellite occurs massive or as specks disseminated in chalcocite. Under the polarizing reflecting microscope, the massive variety is seen to be made up of a felted mass of interlocking covellite laths, set in a sparse matrix of bluish isometric chalcocite. Such laths for the most part are slender and small with average widths of 0.02 mm. and have high interference colors.

The disseminated covellite ranges from sparse slender threads imbedded in orthorhombic chalcocite and visible only under high magnifications, to stout broad laths and plates up to 0.35 mm. in width, forming "diabasic" covellite. The plates are irregular in shape and have low interference colors, in contrast to the high colors of the laths.

Where the covellite laths are plentiful, the inclosing chalcocite is isometric, otherwise it is orthorhombic.

The "diabasic" covellite is the counterpart of that which has been found[8] to be formed by ex-solution from an earlier-formed solid solution of covellite in chalcocite. Since this covellite also occurs in isometric chalcocite, which in turn must contain eight per cent. or more covellite in solid solution, it is interpreted as hypogene covellite that has been formed above a temperature of 91° C. and has unmixed upon slow cooling to form the covellite laths. The presence of this unmixed covellite is also a further indication of the hypogene origin of the including chalcocite.

Enargite.--Enargite occurs as bunches of pure mineral of hand specimen size or as small grains admixed with the other minerals. Under the polarizing microscope the massive variety is seen to be made up of large grains surrounded, for the most part, by minute grains of varied optical orientation, resembling arkose in texture. The enargite has clearly replaced limestone, numerous embayed residuals of which are included in the enargite grains.

Luzonite.--The pinkish variety of enargite, luzonite, occurs in small grains and veinlets inclosed in chalcocite. The veinlets appear to be later in age than the chalcocite, although the possibility is recognized that veinlets of a mineral may be left as residuals in chalcocite that has replaced it.

Bornite.--Bornite occurs in minor amounts as isolated areas inclosed in chalcocite. Some of it incloses small areas of chalcocite. Part of the bornite, at least, is earlier than chalcocite that embays it. Some appears to be contemporaneous with the chalcocite.

Two kinds of bornite are present; one, the usual isotropic variety, and the other, an unusual anisotropic variety. Both exhibit the same color, behave similarly to etch reagents, and resemble each other in all respects, save that the one is isotropic and the other anisotropic.

Other Minerals.--A few small specks of pyrite and chalco-pyrite and one grain of galena, were observed. Their relationships to the other minerals could not be determined. No silver minerals were observed. The silver content of the ore must, therefore, be present in solid solution with the copper minerals.

OXIDATION AND ENRICHMENT.

There is no evidence of any supergent enrichment of the ore. Hypogene sulphides outcrop on the surface. Oxidation is almost lacking; only a thin veneer of copper carbonates exists. Even stains of "limonite" are scarce. The deposit is not favorably situated for the preserval of zones of oxidation or enrichment. It lies near the bottom of a great valley that has been widened and deepened by vigorous glacial erosion. The glacier itself has only recently receded from the site of the deposit, and from the outcrop one may see the retreating ice mass less than four miles upstream, where it fills the upper part of the valley to a depth of hundreds of feet. Any oxidized or enriched zone that may have existed has been eroded away and the time that has elapsed since the exposure of the outcrop to the air has been too short, and the climate too cool, for new zones to have been formed.

SIMILARITY WITH KENNECOTT DEPOSITS.

The character of the ore, its mineraolgy, and its localization in the lowermost beds of the Chitistone limestone are all similar to the ore occurrence at Kennecott. As at Kennecott, the ore is quite unique; it consists chiefly of massive hypogene chalcocite and the chalcocite itself is unusual in that much of it is coarsely granular and the high-temperature isometric variety is present; ex-solution forms of covellite in chalcocite are present; copper-iron sulphides are scarce; pyrite is almost lacking; and quartz is absent. At both places, metallization consisted of copper, silver, and sulphur with minor amounts of arsenic, a little iron, and a noteworthy absence of silica.

The similarities of these two unique deposits are so striking that the conclusion is inescapable that they must have been formed at the same time, from the same source, and by similar processes, and thus have a common ancestry. Still other offsprings of the same metallization occur as unimportant deposits scattered over this region. These deposits indicate that this peculiar metallization was quite widespread, remarkably uniform in composition, and almost entirely restricted to the lower beds of the Chitistone limestone.

ORIGIN OF DEPOSIT.

The Glacier Creek deposit is shown, by the presence of isometric chalcocite, unmixed covellite, enargite, and bornite, to have been formed from hypogene solutions at a temperature above 91° C. The mode of emplacement was chiefly by replacement of the dolomitic limestone, and some of the covellite and chalcocite may have been deposited as colloids. The solutions apparently were sufficiently attenuated to penetrate minute cracks.

As to the source of the solutions and of the introduced metals, the deposit and its surroundings offer no conclusive evidence. It is customary, in keeping with the modern conceptions of the origin of ore deposits, to associate the solutions and metals genetically with some nearby intrusive or magmatic reservoir. In the case of the Glacier Creek deposits there is no immediately adjacent intrusive. The nearest one, a light colored quartz-diorite porphyry, lies about ten miles to the west. It may be a possible source of the copper and the solutions. The gold quartz deposits of the Nizina district are believed to be genetically connected with it, and the Kennecott deposits may possibly be connected with another part of the same intrusion. However, at Kennecott, a light-colored dike, an apophyse of this intrusive, cuts diagonally across one of the copper veins and is later than the ore. Consequently, if the Glacier Creek and Kennecott deposits are of the same age, as seems reasonable, the Glacier Creek ore must also be earlier than the dikes that extend out from the main intrusive mass. This fact, combined with the lack of iron and silica in the deposit, and the distance of the deposit from the intrusive, offers difficulties in the acceptance of a genetic connection between the ore and the quartz-diorite intrusive.

The only definite evidence, therefore, is that the solutions were hot and hypogene, that they were of uniform composition over a wide area, and that the deposition of the metals was confined largely to the lowermost beds of the Chitistone formation.

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[3]Moffit, F. H.: Notes on the Geology of the Upper Nizina District, Alaska. U. S. Geol. Surv. Bull. 813-D, pp. 143-163, 1930.

[4]See also Moffit, op. cit., plate 3.

[5]Bateman, Alan M. and Lasky, S. G.: Chalcocite-Covellite Solid Solution and Ex-solution. ECON. GEOL., vol. 27, pp. 52-86, 1932.

[6]Schneiderhohn, H., and Ramdohr, Paul: Lehrbuch der Erzmikroskopie, vol. II, pp. 285-288. Berlin, 1931.

[7]Lasky, S.G.: A Colloidal Origin of some of the Kennecott Ore Minerals, Econ. Geol., vol. 25, pp. 737-757, 1930.

[8]Bateman, Alan, and Lasky, S. G.: op. cit.