SOME FEATURES OF THE ALASKAN TIN DEPOSITS.¹

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INTRODUCTORY.

The known tin deposits of Alaska that promise some future commercial importance are situated in the extreme western part of Seward Peninsula, or that portion of the American continent which approaches nearest to Asia. On the northwest this region is bounded by the Arctic Ocean, and on the southwest by Bering Sea—two bodies of water that are frozen over during seven or eight months of the year. Its position on these seas however, makes it much more readily accessible than many other parts of Alaska.

At present four localities are being prospected for tin. They are included in an area of 400 square miles, which is situated about 100 miles northwest of the city of Nome, the supply point of the region. In geographic order from north to south these four localities are Ear Mountain, Buck Creek, Cape Mountain and Lost River. Ear Mountain occupies an isolated position 40 miles north of the others, which are grouped together in the York region at the western end of the continent.

The tin occurs in both placer and lode form. Up to the close of 1908 the total production of the entire region was 160 tons of cassiterite concentrates, all of which, except a few tons from lode deposits, came from the stream tin of Buck Creek.

The region has attracted considerable attention from the mining public, and a large number of representatives of private interests have at different times examined the deposits with a view to their commercial possibilities. In the majority of cases, however, adverse reports have been returned, chiefly because of the exorbitant prices demanded for inadequately developed prospects.

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The tin deposits are nevertheless of much interest, both from a general and a scientific point of view. Tin ores and tin mining are things foreign to the American prospector's acquaintance, and in the Alaskan occurrences he has therefore confronted a new and perplexing set of conditions in which his previous experience has afforded him little help. And this perplexity is much increased by the fact that tin-bearing rock occurs throughout the region in a great variety of ways and in numerous different mineralogic associations.

Under ordinary circumstances cassiterite in the matrix is an exceedingly difficult mineral to identify with certainty, especially in a region where a large number of minerals occur that resemble it more or less closely. In consequence, the prospector has mistaken the following species for cassiterite: garnet, black tourmaline, the porphyritic augite of some quartz porphyry dikes, pyroxene in contact-metamorphosed limestone, smoky quartz, vesuvianite, magnetite, and wolframite. Furthermore, an opinion has become prevalent that stannite is a highly desirable ore of tin, and as a result, certain sulphides, principally pyrrhotite, have been mistaken for that mineral and have occasioned useless prospecting.

Another widely accepted idea is that tourmaline is an infallible indication of tin ore. The origin of this belief appears to be due in part at least to the occasional difficulty of distinguishing tourmaline from cassiterite, and in part to the reasoning that since tourmaline is so constantly associated with tin deposits the world over, it follows that abundant tourmaline must be a favorable indication of the presence of tin ore, which is, of course, an unsafe conclusion. But even this does not fully account for the tenacity with which the idea is held. An additional explanation was at last found when it was discovered that certain tourmalinic hornfels rocks from Ear Mountain contain a coal-black mineral, which, while resembling on casual examination the associated granular tourmaline, unexpectedly proves to be a hitherto unknown member of the small family of tin minerals, a magnesian iron-tin borate.

This discovery and that of another new tin mineral, that looks

not unlike the magnetite with which it is associated, explain the puzzling fact that rocks apparently similar mineralogically, would in some cases yield tin assays and in others fail to give returns. This result was commonly regarded throughout the region as due entirely to incompetence on the part of the local assayers.

The lack of American analogues from which to draw precedents has made recourse to European tin fields necessary, and some curious correlations have been established locally. The crystalline limestones of Mississippian age surrounding the granite stock of Cape Mountain have been called "killas" (the name applied to the Devonian clay slates of Cornwall), and some quartz-augite porphyry dikes, which have been prospected under the mistake that the large porphyritic augites were "tin crystals," have been regarded as "zwitter dikes," "zwitter" being the Saxon term given to altered (usually a tourmalinized), stanniferous rock other than granite. With such favorable tin-bearing formations as "killas" and "zwitter" discovered, the general optimism felt throughout the district was largely increased.

OUTLINE OF GEOLOGY.

The sedimentary rocks of the tin region comprise chiefly limestones and slates. The oldest formation consists largely of impure arenaceous slates, which are more or less calcareous or dolomitic. These rocks are overlain conformably by a great volume of thin-bedded, dense-textured Ordovician limestone, known as the Port Clarence limestone, which generally shows no evidence of metamorphism. In the vicinity of Cape Mountain (the headland at Bering Strait) there is a series of crystalline limestones with subordinate siliceous schists and quartzites, which paleontologic evidence secured by Collier¹ shows to be of lower Carboniferous age. The youngest sediments of the region are the gravels, sands, and silts of the Arctic coastal plain. Some of the stream gravels contain local concentrations of gold and placer tin, and are, therefore, of economic interest.

Four stocks of granite are intrusive into the limestones of the region, all quartzose orthoclase granites containing subordinate

¹ Bull. U. S. Geol. Survey, No. 328, p. 81.

amounts of sodic oligoclase and biotite, and all prevailingly of a coarsely granular porphyritic habit. They appear to represent contemporaneous intrusions; and as the granite at Cape Mountain is known to invade limestones of Mississippian age, it is probable that all are post-Mississippian. Together with related quartz-bearing porphyry dikes, they are the most important igneous rocks of the region, inasmuch as the tin deposits are directly associated with them.

Greenstones of diabasic character are common in the slate area near York, and where their relations can be determined are found to be present as intruded sills. A number of narrow basalt dikes are found cutting both limestones and granite, and are therefore the youngest igneous rocks of the region.

Contact Metamorphism.—The granites have invaded the various series of limestones and produced an extensive development of lime-silicate rocks, rich in the so-called pneumatolytic elements. These have been chemically fixed in the boron-bearing minerals, tourmaline, axinite, ludwigite, hulsite, paigeite, and vesuvianite; in the halogenous minerals, fluorite, scapolite, and chondrodite; and in the sulphides, galena, sphalerite, chalcopyrite, arsenopyrite, and pyrrhotite. Of similar import as proving an accession of material are the magnetite and scheelite. Such an array of minerals of this particular stamp is not characteristic of the contact-metamorphism exerted by non-stanniferous magmas.

The lime-silicate rocks produced by this metamorphism are limited as a rule to a narrow zone encircling the granite masses. Persistence of mineralogic character does not obtain throughout the length of any of these peripheral belts, but various rocks, differently constituted mineralogically, appear at different points. Only those which possess a direct bearing upon certain economic features of the tin deposits will be described here.

On Quartz Creek at Ear Mountain a prospect cut exposes a dark-colored rock, evenly flecked with a lustrous coal-black lamellar mineral, which subsequent investigation has shown to be a new boron-tin mineral, paigeite. In addition considerable tourmaline and minor amounts of chalcopyrite and magnetite are visible. Under the microscope the rock resolves itself into a con-

fused intergrowth of zonally banded tourmaline, calcite, vesuvianite, zoisite, paigeite, fluorite, and accessory phlogopite, chalcopyrite and magnetite. The paigeite is embedded in the various other constituents in trichite-like forms many of which are of capillary dimensions, and in matted aggregates of fibers. Closely associated with the paigeite hornfels is a tourmaline-pyroxene-scapolite hornfels, which reacts chemically for chlorine.

A prospect opening at the granite-limestone contact near Tuttle Creek reveals a tourmaline-axinite hornfels. The axinite is of highly vitreous appearance and of light-brown color, and is therefore readily recognizable in the hand specimen. In thin section, however, tourmaline is found to be quantitatively more important than the axinite in this hornfels. It is subhedral and displays a partially developed zonal banding, with pleochroism varying from blue to green. In addition to the tourmaline and axinite, there occur actinolite, pyroxene, quartz, fluorite, and calcite in confused intergrowth, though the last three minerals are present rather in minor amounts. Some cassiterite is found embedded in the other constituents in a few scattered grains which are large enough to allow its optical identification beyond question. This tourmaline-axinite hornfels is the only contact-metamorphic rock containing cassiterite found in the entire region, although a large number of such rocks were examined on account of the prevalent belief that they are tin bearing.

The black iron-tin borate was also found in small, nearly pure masses near the granite-limestone contact on Brooks Mountain at the head of Lost River. Impurer rock fragments showed that here it is intergrown with vesuvianite, calcite and hedenbergite, with subordinate amounts of biotite and sporadic grains of arsenopyrite.

Near this locality some assessment work has been done on an assemblage of contact-metamorphic minerals occurring in a marbled limestone ten feet from the granite contact. These minerals comprise euhedral boron vesuvianite, brown garnet showing rhombic faces, calcite, subordinate fluorite, and abundant magnetite partly intergrown with another new tin mineral (hulsite), which, although physically unlike paigeite, also proves to be a

magnesian iron-tin borate, but with different molecular ratios for magnesia and ferrous iron.¹

ECONOMIC GEOLOGY.

As previously stated, tin-ore occurs in both lode and placer form. Cassiterite, the dioxide of tin, is the only mineral that is likely to prove of economic value as a source of metallic tin. Stannite, a complex sulphide of copper, tin, zinc, and iron, is known to occur also, but at one locality only, where it is associated with galena in a remarkable argentiferous wolframite-topaz ore. Two new tin minerals (the magnesian iron-tin borates previously referred to) have been discovered in this region, but on account of their low tin content (approximately 10 per cent. Sn) are probably not worth exploitation.

The lode-tin deposits, like the majority of those throughout the world, are genetically associated with granitic intrusives, but on account of the prevalence of limestones the Seward Peninsula tin occurrences possess a number of unique and distinctive features. A variety of pneumatolytic contact rocks have been produced around the margins of the granites, and certain of these as already described in detail contain the iron-tin borates as essential constituents. The resemblance of numerous heavy contact-metamorphic minerals, such as garnet, pyroxene and others, to cassiterite, coupled with the fact that some of the contact-metamorphic rocks are actually stanniferous, has led to much prospecting along the granite-limestone contacts. As shown in the foregoing, however, only one contact rock containing cassiterite in amounts appreciable under the microscope was found during the course of the investigation of the region by the writer.²

Cassiterite occurs in Seward Peninsula in a variety of ways: (1) In a tourmaline-axinite hornfels, (2) in tourmalinized margins of granite masses and granitic dikes, (3) in quartz veins

¹ In the determinations originally given in *Am. Journ. Sci.*, 1908, p. 323, the tin had been overlooked. Work is at present being done on them by Dr. W. T. Schaller.

² "Geology of the Seward Peninsula tin deposits, Alaska," Bull. U. S. Geol. Survey, No. 358.

cutting granite and accompanied by impregnation of the wall rock, (4) in mineralized quartz porphyry dikes, (5) in quartz stringers cutting slates and limestones, (6) in beds of actinolite rock which are probably interstratified with slates.

It will be recognized that (2) and (3) are standard types of tin deposits, and, therefore, only those modes of occurrence will be described which are believed to exhibit some novel features.

In the vicinity of Lost River a number of quartz porphyry dikes pierce the limestones. In places some of these exhibit an exceedingly intense mineralization. Cassiterite, pyrite, arsenopyrite, and wolframite, associated with fluorite, zinnwaldite, and topaz, are the most characteristic minerals developed. The limestone adjoining the mineralized portions of the dikes is reticulated by a vast number of veinlets, some of which carry cassiterite, though nothing in the nature of a stanniferous stockwork has been formed. The veinlets have exerted an energetic metasomatic alteration of the limestone causing the synthesis of a large number of silicates, such as hornblende, vesuvianite, plagioclase, mica, tourmaline, and topaz. Fluorite is also a very common product. Succeeding this zone of alteration, which immediately adjoins the veinlets, is a zone in which the limestone is merely marbleized and is transfixed with sporadic prisms of tremolite. In short, the metasomatic alterations are analogous to the contact-metamorphic changes produced in the limestones by the intrusive granite magmas.

On what is known as the Dolcoath Lode a thin dike has been largely converted into danburite and tourmaline. Locally, abundant arsenopyrite and some cassiterite are found. The inclosing limestone has been coarsely recrystallized and masses of danburite, the borosilicate of calcium, richly studded with splendid crystals of cassiterite, have been formed. As shown by microscopic examination the danburite and cassiterite are in places crowded with tourmaline microlites. Euhedral crystals of cassiterite also occur embedded in the coarsely crystalline calcite, and when tested with fluorite mixture give a perceptible boron flame indicating the presence of included prisms of tourmaline. Tremolite, too, is common in the limestone, and topaz occurs locally. The impreg-

nation with cassiterite and the zone of silicates does not, however, extend farther than six inches from the altered dike.

On the west side of Lost River opposite the mouth of Tin Creek a stringer lode one foot wide containing an ore of remarkable composition has been uncovered in the normal unaltered limestone. The gangue material consists of delicately radial topaz with subordinate dark purple fluorite; embedded in these are wolframite, galena, and stannite. An assay of average ore gave a return of 22.9 ounces of silver per ton. The surface ore is in places stained black by manganese minerals and is somewhat colored by azurite.

This ore from its peculiar mineralogical composition is exactly intermediate between the *filons stannifères* and the *filons plombifères*.¹

The stannite in this deposit is the only known occurrence of the sulphostannate in the region. Chemical examination shows that it contains a notable quantity of zinc.

CONCLUSION.

The great majority of the minerals regarded as characteristic associates of cassiterite occur in the tin deposits of the Alaskan region; arsenopyrite, pyrite, wolframite, tourmaline, topaz, zinnwaldite, and fluorite. Phosphates (apatite and amblygonite) and beryl are absent. Cassiterite, however, occurs intergrown with the rare calcium borosilicate, danburite—a paragenetic association hitherto unrecorded.

There are some essential differences between the mode of occurrence of these minerals in the Alaskan region and those in the classic tin districts. In the latter topaz and zinnwaldite are common as metasomatic products resulting from the alteration of granite adjoining stanniferous veinlets. Here veinlets traversing limestone are found which consist of cassiterite, topaz, fluorite and zinnwaldite. The same minerals, moreover, occur as metasomatic replacements both of limestone and of quartz porphyry dikes. Similarly, on the Dolcoath lode danburite is

¹ Cf. Vogt, J. H. L., in "Genesis of Ore Deposits" (spec. pub. A. I. M. E.), 1902, p. 666.

developed metasomatically both in the igneous dike rock and in the adjoining limestone. In other words the metasomatic development of a considerable number of minerals was not conditioned by the character of the country rock, and in many cases the minerals thus formed are of the same species as these constituting vein fillings deposited in open spaces.

Spurr has recently described in the case of the ore deposits of Velardeña, Mexico,¹ a series of metasomatic alterations similarly independent of the nature of the country rock. It is possible that this feature may eventually be found to furnish one of the criteria for distinguishing the work of solutions of magmatic origin at high temperatures.

Two periods of stanniferous mineralization can be discriminated: one contemporaneous with the contact metamorphism, and another subsequent to the intrusion of the quartz porphyry dikes. In the earlier, iron-tin borates were the principal metalliferous minerals formed; in the later, cassiterite was mainly deposited, with stannite developed subordinately.

The restriction of the iron-tin borates to the deposits of contact-metamorphic origin appears to be broadly in harmony with certain chemical data. Boric acid is an exceedingly feeble acid, and is easily liberated from its compounds by other acids. Carbon dioxide effects the decomposition of borates at lower temperatures; only at a high temperature, viz, a red heat, is the reaction reversed.² As the contact-metamorphic process involved an abundant expulsion of carbon dioxide, it is probable that the minimum temperature at which borates are stable in the presence of carbon dioxide is a point on the geologic thermometer below which contact-metamorphic changes of the character described can not take place.

Inasmuch as the quartz porphyry dikes show chilled margins against the granites, it is probable that a considerable interval elapsed between the two periods of mineralization, and that a considerable amount of magma had cooled before vein-forming activity ensued. During this process the magmatic vapors were

¹ *ECON. GEOL.*, Vol. III., 1908, p. 705.

² *Am. Chem. Journ.*, Vol. 24, 1900, p. 130.

prevented from escaping by a peripheral shell of solid granite constantly increasing in thickness, and their preliminary concentration was thus effected by the decreasing volume of the fluid magma. The solid envelope was finally fractured by the expulsion of the quartz porphyry dikes, and egress of the magmatic vapors and solutions was facilitated. By this enforced limitation in the number of avenues of escape the mineralizing solutions were confined to certain trunk channels, and conditions favorable to an ore deposition of possible economic importance were promoted.