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GEOLOGY

OF THE

SEWARD PENINSULA TIN DEPOSITS

ALASKA

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By Alfred H. Brooks.

Since the discovery of stream tin in the York region by the Geological Survey in 1900 the tin deposits of this district have been discussed in several Survey publications. In all cases, however, the statements were based on investigations that were incidental to other work, and as this district had attracted much notice as a possible source of tin and considerable money had been spent in mining and prospecting, it appeared time, in the spring of 1907, to undertake a more thorough investigation.

To this task Mr. Knopf was assigned, with instructions to make a careful study of the mineral deposits and, so far as time permitted, to determine the laws of their occurrence and origin. It was thought best to emphasize the more purely scientific phase of the investigation, for the commercial phase can best be solved by the mining expert and engineer. Therefore, those who expect to find in this volume a statement of the commercial value of individual ore bodies will be disappointed. In the opinion of the writer, however, the presentation of the chief facts regarding the mineralogy and geology of the tin deposits, together with a careful analysis of these data, will have more value to the district as a whole than any attempt to publish a statement of commercial features of individual ore bodies. Moreover, it has become an established policy in the Alaskan work not to attempt to sample ore bodies, as such work is believed to fall outside of the province of the Federal geologist, and obviously without careful sampling the valuation of any given deposit is impossible.

The reader should not infer from the foregoing remarks that this paper is regarded as a final statement on the occurrence and genesis of the tin deposits. Difficulty of access, limited exposures, and lack of time prevented Mr. Knopf from making exhaustive studies. It is believed, however, that this report marks a great advance in the knowledge of the subject.

GEOLOGY OF THE SEWARD PENINSULA TIN DEPOSITS, ALASKA.[a]

By ADOLPH KNOPF.

INTRODUCTION.

Stream tin was discovered in the York region of Seward Peninsula during the fall of 1900 as a heavy and objectionable constituent which accumulated in the sluice boxes of the placer-gold prospectors. Some of this material was brought to Washington by A. H. Brooks, of the United States Geological Survey, who was engaged in a hasty reconnaissance of the mineral resources of the region, and was identified as cassiterite.[b] The discovery was soon heralded by the public press.

The true nature and value of the mineral once known, search was directed toward finding a wider distribution of the stanniferous gravels and toward locating the bed-rock source of the cassiterite. Two factors combined to stimulate this search—the failure of the gold placers of the region and the high market price of metallic tin in recent years. Ever since their discovery the Alaskan tin deposits, as they are popularly styled, have continued to attract considerable attention from the mining public—an interest due in large part to the fact that there are no producing tin mines in the United States proper.

Several reports of a preliminary character have been issued by the Geological Survey describing the geology and mineral resources of the York region, in which the chief deposits of tin occur. The presence of placer tin in Anikovik River and in its tributary, Buhner Creek, was first recorded by Brooks.[c] On the basis of a reconnaissance of the northwestern part of Seward Peninsula in 1901, Collier[d] was able to offer certain advice as to where search for lode tin might profitably be made. In 1903 he assisted a number of prospectors in making the original discovery of lode tin in Seward Peninsula and

[a] A summary of the results given in this paper was published several months ago by Brooks, A. H., and others, in Mineral resources of Alaska; report on progress of investigations in 1907: Bull. U. S. Geol. Survey No. 345, 1908, pp. 251–267.

[b] Brooks, A. H., A new occurrence of cassiterite in Alaska: Science, new ser., vol. 13, No. 328, 1901, p. 593.

[c] Brooks, A. H., An occurrence of stream tin in the York region, Alaska: Mineral resources U. S. for 1900, U. S. Geol. Survey, 1901, p. 270. Also, A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900 (a special publication of the U. S. Geol. Survey), 1901, pp. 132–139.

[d] Collier, A. J., Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 49.

was able to publish the first authentic information on the occurrence of cassiterite in place.[a] On returning from his examination of the Cape Lisburne coal fields in 1904, he spent a few days in the York region and noted the progress of development in opening up the tin deposits.[b] Later developments, in the fall of 1905, were fully described by Hess.[c]

No member of the Survey visited the region in 1906, but numerous popular reports indicated that extensive development work was in progress. Owing to the fact that the earlier investigations, which were incidental to field work in other parts of Seward Peninsula, were hampered by lack of time and by the inadequate development of the region, it was deemed advisable to give an entire field season to an examination of the tin deposits, including those of Ear Mountain, which had not been previously visited. With this purpose in view, the writer was instructed to examine all known occurrences of tin ore in Seward Peninsula, giving especial attention to the origin of the ores and the commercial importance of the field. Field work was commenced at Tin City on June 23, and ended at Teller on September 6, 1907.

Acknowledgments are due for the many courtesies extended to the writer while in the region, and it is an especial pleasure to thank Mr. John Vatney, of Ear Mountain, Mr. M. R. Luther, of Tin City, and Messrs. William C. Randt and S. Read, of Lost River, for their generous hospitality and substantial aid in furthering the field work. Thanks are also due Dr. W. T. Schaller, Dr. E. C. Sullivan, and Prof. E. F. Smith for assistance in chemical and mineralogical work.

PRODUCTION AND PROSPECTING.

The total production of tin ore in the entire region to the close of 1907 was about 160 tons of concentrates, all of which, except a few tons from lode deposits, came from the stream tin of Buck Creek.

The approximate annual value of the tin production of the York district since mining began is as follows:

Value of tin produced in York region, Alaska, 1902–1907.

1902	$8,000
1903	14,000
1904	8,000
1905	4,000
1906	38,640
1907	20,000
	92,640

[a] Collier, A. J., Tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 225, 1904. See also Bull. 229.

[b] Collier, A. J., Recent development of Alaska tin deposits: Bull. U. S. Geol. Survey No. 259, 1905, pp. 120–127.

[c] Hess, F. L., The York tin region: Bull. U. S. Geol. Survey No. 284, 1906, pp. 145–157.

At present four localities are being prospected for tin. They are included in an area of 400 square miles, 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 west end of the continent.

GEOGRAPHY OF THE REGION.

The region here to be considered comprises the extreme western projection of Seward Peninsula, or that portion of the American Continent which approaches nearest to Asia. On the northwest it is bounded by the Arctic Ocean, and on the southwest by Bering Sea—two bodies of water that are frozen over during seven months of the year. In 1907 navigation opened to Tin City, which is situated at the tip of the continent, on June 22, and a few days later the last of the ice had drifted northward through Bering Strait. During the open season gasoline schooners maintain a weekly service between Nome and points on Bering Sea, and a small passenger steamer, carrying the mail, calls every ten days while en route to Kotzebue Sound. A nominal ten-day mail service is thus afforded during the summer months, but a regular weekly service is obtained in the winter with sled and dog team.

The topographic character of the region is well brought out on the map (Pl. I). Toward the north the Arctic coastal plain forms a wide expanse of gently rolling topography with a relief of less than 50 feet, and so heavily grown over with moss as to be practically impassable to wagons. Numerous lakes dot the landscape, and the streams wind across the plain in tortuous courses, emptying into broad lagoons impounded behind barrier beaches. In the vicinity of Shishmaref Inlet the lower stretches of the streams are affected by the tidal ebb and flow.

Toward the south the York Mountains rise abruptly from the coastal plain. They are an exceedingly steep and rugged group, with an average altitude of 2,500 feet. Broad stream valleys, however, penetrate the mountains from both the Bering and Arctic sides and render them easily accessible, so that wagons have been taken across them at a number of points without difficulty. Where the mountains abut upon the Bering coast they are broken off by bold sea cliffs, and a magnificent terrace 1 to 4 miles wide with gentle seaward slope has been carved upon their flanks at an elevation of 600 to 800 feet.[a] Westward this feature merges into the York Plateau—a level upland surface ranging in altitude from 200 to 600 feet. The larger streams

[a] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 37.

have cut wide, shallow valleys in this plateau, and these furnish good wagon roadways of easy grade.

The western extremity of the continent is marked by an isolated mountain mass, known as Cape Mountain, which rises sheer from the water's edge to a height of 2,250 feet. This impressive promontory, usually swathed in chill fogs, forms the American portal of Bering Strait.

There are no harbors in the region and consequently landing is often impossible on account of fog, surf, or storm. The nearest harbor is that of Port Clarence, 20 miles distant.

GENERAL GEOLOGY.

OUTLINE.

The sedimentary rocks of the tin region comprise chiefly limestones and slates, all probably of Paleozoic age. The oldest rocks are a series of impure arenaceous slates of undetermined age. These are overlain conformably by a thick formation of thin-bedded Ordovician limestones (Port Clarence limestone), which generally show no evidence of metamorphism. Near Cape Prince of Wales there is developed a series of crystalline limestones with subordinate siliceous schists and quartzites. These rocks are of "Lower Carboniferous" age, and are faulted off against the slates to the east. Greenstones are common in the slates and a number of granite stocks have invaded the limestones.

The youngest sediments of the region are the gravels, sands, and silts of the Arctic coastal plain. The distribution of the rocks is indicated on the sketch map (fig. 1), in which use has been made of the earlier published results. In the succeeding pages the salient features of the various formations of the York region are briefly described, but no attempt is made to discuss the metamorphic rocks of Ear Mountain under the heading of general geology, inasmuch as their stratigraphic relations are unknown.

SLATES NEAR YORK.

In the vicinity of York a belt of slates 8 or 10 miles wide trends northwestward across the west end of Seward Peninsula. The slates are prevailingly of an impure arenaceous character and exhibit a variable degree of metamorphism throughout the area, though the great bulk of the series consists of but slightly metamorphosed rocks. Typical black clay slates are locally interstratified as thin beds with the more siliceous types. The arenaceous slates are as a rule more or less calcareous or dolomitic. Massive members of the series consist of fine-grained dolomitic sandstone. A graphitic siliceous schist (the graphite, however, is poorly individualized) represents the highest phase of metamorphism in the York region, but this type has no great areal distribution. Petrographically the slates consist chiefly of comminuted quartz and feldspar, and as an accessory mineral a constant though minute amount of clastic brown tourmaline was noted from all parts of the area. In the dolomitic member the quartz grains are generally well rounded, and the carbonate, whose mag-

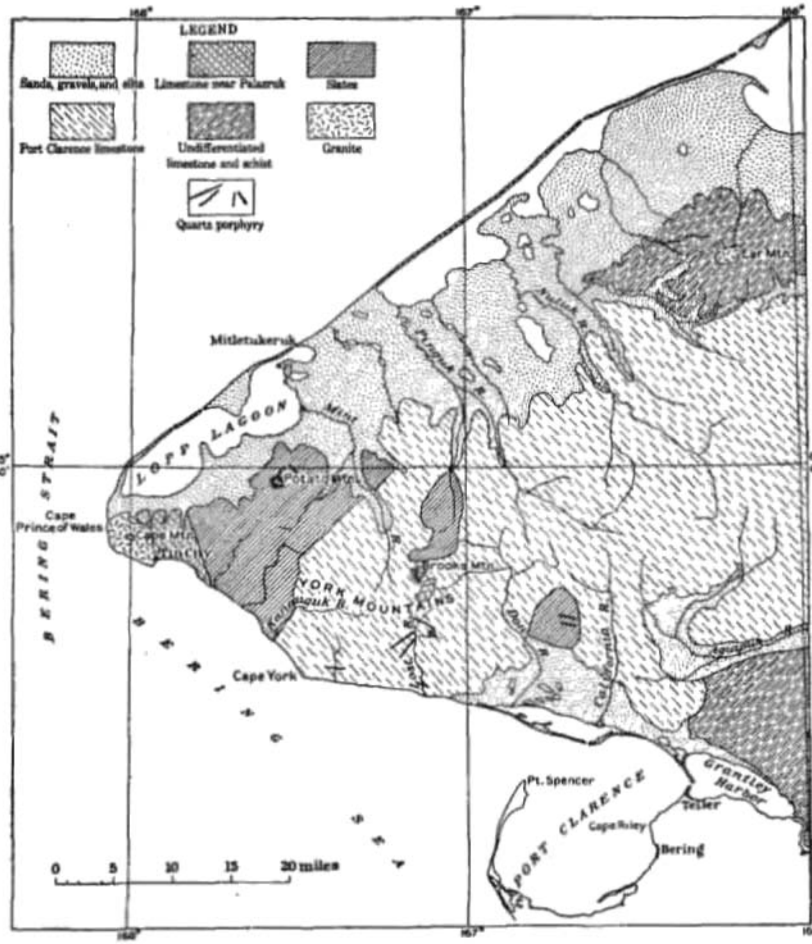


FIG. 1.—Geologic sketch map of the Seward Peninsula tin region.

nesian character was determined chemically, is commonly in the form of small rhombohedra scattered throughout the binding material.

The degree of cleavage of the slates is variable. The rocks range from nearly massive—rocks little more than shales—to thinly fissile slates. Cleavage and stratification may coincide locally, but within a short distance may stand at right angles. Measurements of strike and dip of the cleavage have little value on account of this abrupt variation, as the sedimentary banding can rarely be observed. These relations are best displayed in the beach section between York and Kanauguk Point. The slates are affected by faults, and one was noted to have offset a dike 400 feet. They are fractured and veined with quartz stringers, some of which carry cassiterite, blue tourmaline, arsenopyrite, and pyrite.

The slates are faulted against a series of crystalline limestones on the west, and underlie the Port Clarence limestone conformably on the east.

PORT CLARENCE LIMESTONE.

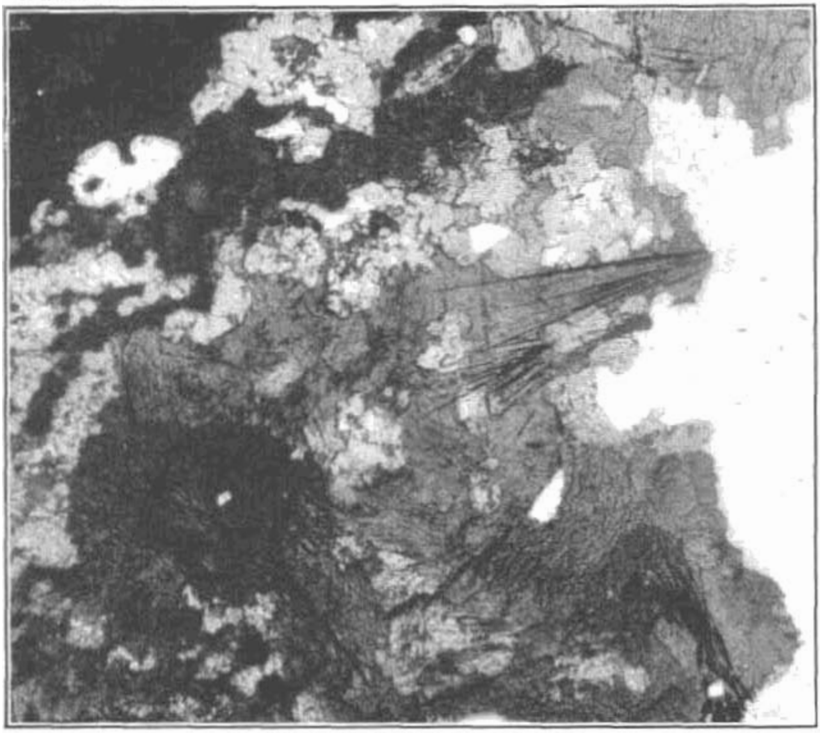
The Port Clarence limestone was so named by Collier [a] on account of its typical exposure north of Port Clarence, where it occupies an area of 1,400 square miles. Here it comprises a thick volume of thin-bedded limestones of dense texture, generally unaffected by metamorphism. Four types of rock can be discriminated—an ash-gray variety, a dark lead-gray variety, magnesian and tremolitic phases, and an argillaceous banded variety. The first two are the commonest types, and occur together in interstratified beds. The dark lead-gray limestone forms massive beds up to 6 feet thick, but the ash-gray variety, which is fine grained, like lithographic stone, is thin bedded and commonly breaks into large, thin slabs whose surfaces are covered with fucoid fragments. These limestones were found to be nonmagnesian in the specimens examined, the ash-gray variety containing considerable aluminous material, and the dark lead-gray limestone being pure carbonate rock. Some beds of fine-grained dolomite occur in the Port Clarence formation, but on account of their close resemblance to the prevailing dense-textured limestones their quantitative abundance is not known. Occasionally there occur interbedded with the normal Port Clarence limestones strata which show numerous small prisms of tremolite in random orientation. This is the highest degree of metamorphism displayed by the formation, except for purely local manifestations surrounding granitic intrusives.

The basal portion and lower horizons of the Port Clarence formation consist of an impure banded limestone, the banding being produced by laminæ of argillaceous material. This phase is commonly in a highly contorted condition (Pl. II, *B*). Locally, as at Cassiterite Creek, tremolite has been noted as an abundant constituent, though the possibility is not excluded that the amphibole may have been produced by the action of vein-forming agencies.

In the Lost River region the Port Clarence has a thickness of 2,000 feet. Collier [b] has indicated that the thickness may be as great

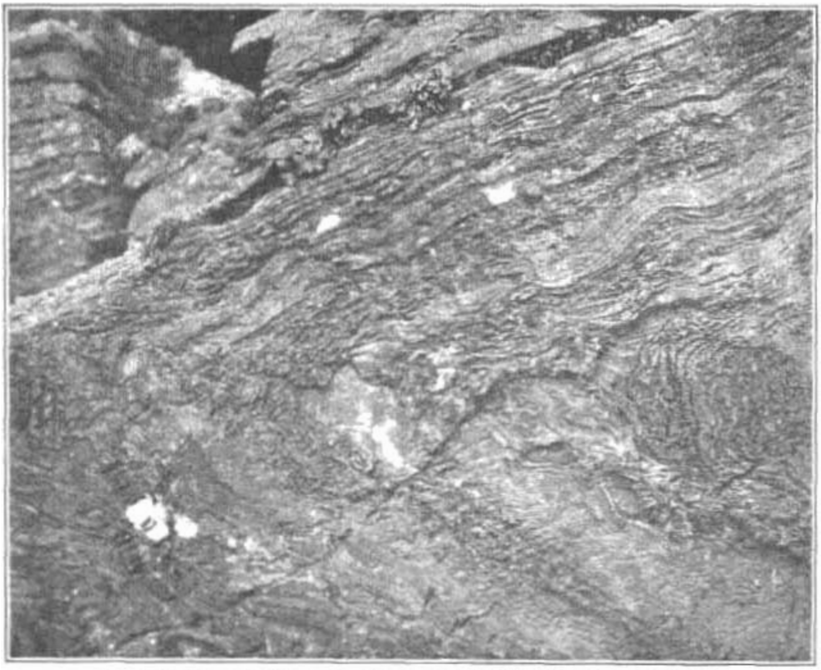
[a] Collier, A. J., Reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 18.

[b] Collier, A. J., Tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, 1904, p. 19.



A. THIN SECTION OF PAIGEITE HORNFELS.

Magnification 60 diameters. Black, opaque fibers of paigeite in tourmaline. Colorless mineral is fluorite.



B. PORT CLARENCE LIMESTONE NEAR HEAD OF CASSITERITE CREEK.

Showing crumpled character of the argillaceous banded variety.

as 5,000 feet, but on account of the prevalence of faults and shatter zones in this region it is probable that the smaller figure is more nearly correct. The dip of the limestone is usually low—about 20° N.—although it may reach as high as 60° along the upper course of Kanauguk River.

The Port Clarence limestone overlies the slates of the York region conformably. As exposed along the western flank of the York Mountains the basal argillaceous schistose limestones of the Port Clarence formation merge imperceptibly into members of the slates, the transitional zone being several hundred feet thick. The same relations are evident on the northwest flank of Brooks Mountain, where the transition is more abrupt, but is marked by an intimate interlamination of slate and limestone. The transition zone has been a zone of weakness, and exhibits more or less severe dynamic deformation. As already indicated, the lower horizons of the Port Clarence are acutely crumpled, locally passing into a brecciated condition. Viewed in the large, however, this phase maintains the appearance of undisturbed and simple structure, characteristic of the Port Clarence as a whole.

Farther east, in the vicinity of Bay Creek, the Port Clarence limestone gives place to the graphitic, chloritic, and calcareous schists characteristic of the Nome region. The exact relations are, however, obscure. In the hills behind Teller Mission the limestone is highly argillaceous and in many places acutely contorted, indicating that the basal portion of the Port Clarence is exposed. According to this interpretation the Port Clarence is regarded as folded into a synclinorium, with one limb exposed on the western flank of the York Mountains and the other at Bay Creek. Subordinate folds have brought the underlying slates into the zone of erosion in isolated areas, as at Brooks Mountain and California River.

The age of the Port Clarence limestone, according to Collier,[a] is either Ordovician or Silurian. The writer found at the head of Cassiterite Creek a few poorly preserved fossils, which, as identified by Kindle, appear to belong to the genera *Raphistoma* and *Liospira*, indicating an Ordovician age.

LIMESTONE NEAR PALAZRUK.

Between the granite headland of Cape Prince of Wales and the mouth of Baituk Creek is a belt of crystalline limestone, which is finely exposed in the cliffs that front Bering Sea. Sericitic siliceous schists, phyllites, and thin-bedded white quartzite are present, but are of very subordinate importance. The siliceous schists find their main

[a] Collier, A. J., The gold placers of a part of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, p. 79.

development on Cape Mountain, where they are apparently 300 feet thick, and overlie the limestone capping the summit of the granite stock.

A striking feature of the limestone is the variable degree of metamorphism which it exhibits in different parts of the area. It varies from a dense-textured dark-blue limestone on the north side of Cape Mountain to a faintly schistose snow-white marble in the section displayed along Bering Sea.

The thermal metamorphism produced by the granite invasion is strictly local in character. Marmorization extends 200 feet from the intrusive at a maximum, producing a coarsely granular aggregate of calcite crystals several millimeters in diameter. The calcareous quartzites, however, remain unaffected at this distance. In the limestone patch overlying the granite the siliceous laminæ have been converted into wollastonite bands which exhibit a remarkable degree of minute crinkling. Some phases of the limestone show a development of metamorphic minerals unconnected with the presence of visible intrusives. In the old sea cliff 1 mile east of Tin City a series of interstratified ash-gray and dark-blue beds, each individually a few feet or less in thickness, show numerous foils of phlogopite, long prisms and radial groups of tremolite, and cubes of pyrite. Phlogopite is areally the most persistent mineral, and the phlogopite-bearing limestone can be traced as far west as the head of Cape Creek. A certain original content of magnesia is indicated by the formation of phlogopite and tremolite and can be detected chemically in the carbonate of the dark-blue limestone. Whether the formation of these minerals is due to thermal metamorphism is an open question, but the field evidence suggests that it has been caused by the same agency which produced the crystalline marbles—namely, a mild regional metamorphism.

The structure within the limestone area is prevailingly simple. The beds lie nearly horizontal, with a slight easterly dip. Here and there rolls with dips up to 20° occur. Locally individual strata are acutely crumpled and doubled back upon themselves. On the basis of relative degree of metamorphism this limestone would be regarded as the oldest formation in the York region, but paleontologic evidence procured by Collier[a] has shown it to be of Mississippian ("Lower Carboniferous") age—younger than the less highly metamorphosed Port Clarence limestone 8 miles east of it. The limestone appears to be faulted against the slates on the east. Both formations are lying flat near the contact, though locally the limestone may show almost vertical dips. The line of contact, however, does not follow the contours as it should if one horizontal formation were resting

[a] Collier, A. J., The gold placers of a part of Seward Peninsula: Bull. U. S. Geol. Survey No. 328, p. 81.

upon the other, but cuts across them indifferently. Furthermore, various friction breccias are found in the vicinity of the contact, and an abundant quartz veination occurs in the slates. These features—the shattering, crushing, and local dragging of the strata, and the fact that the contact is independent of the topography—indicate that the limestone is cut off to the east by a fault.

SURFICIAL DEPOSITS.

Surficial deposits have a relatively small distribution in the York region. They comprise the shallow gravels of the present streams and the beach deposits of the narrow coastal shelf bordering Bering Sea. Toward the north, however, all bed rock is mantled by the silts and gravels beneath the low-rolling arctic tundra that stretches between Cape Prince of Wales and Cape Espenberg.[a]

Some of the stream gravels contain local concentrations of gold and placer tin, and are therefore of economic interest.

IGNEOUS ROCKS.

Four stocks of granite are intrusive into the limestones of the region, all quartzose orthoclase granites containing subordinate 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 Prince of Wales is known to invade limestones of "Lower Carboniferous" (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, and their description is therefore given in greater detail under the separate localities at which each occurs.

Greenstones of diabasic character are common in the slate area near York. Where their relations can be determined they are found to be present as intrusive sills. The texture of the greenstones ranges from aphanitic to coarsely granular, and petrographic examination shows that they are composed essentially of chloritized augite and altered plagioclase in ophitic arrangement, with abundant accessory ilmenite and leucoxene. In many places the alteration is exceedingly thorough, but the rocks are unaffected by shearing.

Narrow basalt dikes of rare occurrence are found cutting both limestones and granite, and are therefore the youngest igneous rocks of the region.

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[a] Collier, A. J., Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 25.

MINERALOGY OF THE REGION.

The world's supply of tin is obtained from cassiterite, the dioxide of tin (78.6 per cent Sn). At a very few places stannite, a complex sulphide of copper, tin, iron, and zinc, has been found in sufficient quantities to be raised as an ore, but apparently never for its tin. The stannite formerly found so abundantly in the Carn Brea mines in Cornwall was sold simply for the copper it contained.[a] In recent years only one occurrence is known, namely, at the Oonah mine in Tasmania,[b] where an argentiferous stannite has been mined as a copper-silver ore. The tin was rejected as waste product, but arrangements were finally made with the smelter that for ore containing at least 8 per cent of tin $5 per ton should be paid in addition to the ordinary returns for copper and silver. The latest reports from Tasmania indicate, however, that difficulty has been experienced in treating the stannite ore.[c] At Borah Creek, New South Wales,[d] stannite is also found, and occurs associated with chalcopyrite, arsenopyrite, and galena in a silver-quartz ore. With these two exceptions stannite is of rare occurrence and is not regarded as an ore of tin.

Cassiterite is the only mineral likely to be of economic importance as a source of tin in the Seward Peninsula region. Stannite in association with galena and wolframite is known from one locality only, and there the prospective value of the deposit is probably in silver and tungsten, and not in tin.

Placer gold is found with the stream tin of the York region, but its paragenesis with relation to the cassiterite is unknown.

The Seward Peninsula tin deposits are associated with granitic intrusives which have invaded various series of limestones. The magmas were rich in mineralizers and produced an intense pneumatolytic contact metamorphism along their margins. Conspicuous among the products of this activity are the prevalent boron minerals, tourmaline, axinite, a boron vesuvianite, ludwigite, and two magnesian iron-tin borates new to science, which have been named hulsite and paigeite. Fluorite, scapolite, and chondrodite prove the presence of the halogens in the magmatic exhalations, and sulphur is indicated by the various metallic sulphides that have formed in the contact-metamorphic rocks.

A total of 52 minerals are listed from the region, 16 of which have not previously been recorded and two of which are new species.

Gold.—Some of the streams of the York region carry placer gold. In fact, the prevalence of an undesirable heavy brown mineral in the

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[a] Trans. Royal Geol. Soc. Cornwall, vol. 7, p. 85.

[b] Waller, G. A., Zeehan silver-lead mining field, Govt. Geol. Office, Tasmania, 1904.

[c] Progress of the mineral industry for the quarter ending 30th September, 1907, Govt. Geol. Office, Tasmania, p. 10.

[d] Min. Res. New South Wales, Geol. Survey, New South Wales, p. 120.

sluice boxes of the placer-gold miners led to the discovery of cassiterite and to the search for its bed-rock source. Placer gold is associated with the cassiterite of Buck Creek, the only locality from which there has been an actual production of stream tin, but no authentic figures are available as to the amount of gold obtained per ton of concentrates. Nuggets up to $20 have been obtained.[a]

Stibnite (Sb_2S_3; 71.4 per cent antimony).—Some float stibnite, associated with purple fluorite, was found in the saddle at the head of Tin Creek by H. E. Angstadt, of the Survey party.

Molybdenite.—Molybdenite occurs in sparing amount, associated with cassiterite, in the Lost River region.

Galena.—On Brooks Mountain, galena, associated with an iron-rich zinc blende, occurs intergrown with minerals of contact-metamorphic origin. The Ear Mountain occurrences are of similar nature. In the Lost River region it occurs in fracture zones in the Port Clarence limestone. One occurrence in this region is absolutely unique, namely, galena associated with stannite and wolframite in a vein filling of topaz and fluorite.

Sphalerite.—Sphalerite (zinc blende) of contact-metamorphic origin is common on Brooks Mountain. It possesses a brilliant black luster identical with that of wolframite, with which mineral it has been confused. Analysis by W. T. Schaller shows that specimens contain 19 per cent of ferrous iron. It is distinguished from wolframite by its inferior gravity (sphalerite having a specific gravity of 4 and wolframite of 7.3), greater softness, and more complex cleavage. Wolframite shows but a single cleavage direction; sphalerite may show as many as six. Some thin quartz-tourmaline veinlets carrying pyrite and lustrous black sphalerite were found cutting the granite of Ear Mountain. In this material blowpipe tests were necessary to distinguish the sphalerite from wolframite. A small amount of sphalerite of somewhat resinous appearance is found associated with the tin ore on Cassiterite Creek.

Pyrrhotite.—Magnetic iron pyrites, or pyrrhotite, is found, together with galena and sphalerite of contact-metamorphic origin, on Brooks Mountain. Considerable amounts of it occur in a copper prospect at the mouth of Tin Creek. Small amounts are disseminated in the pyroxene hornfels at Cape Mountain. Pyrrhotite is commonly regarded as stannite throughout the tin region, but can infallibly be distinguished from that mineral by its magnetic character.

Chalcopyrite.—Yellow copper pyrites, associated with pyrrhotite, is found in a fluorite gangue near the mouth of Tin Creek. The lime-silicate hornfels surrounding the granite of Ear Mountain is locally flecked with chalcopyrite.

[a] Oral communication by F. L. Hess.

Pyrite.—Irregular disseminations of pyrite occur in the granite of Cape Mountain. It is a common constituent in the tin ores of the region, and occurs in the form of rolled nuggets with the stream tin of Buck Creek.

Arsenopyrite.—The silver-white sulphide of iron and arsenic occurs in considerable abundance in the tin ore of Cassiterite Creek, and is found in the contact-metamorphic deposits of Brooks Mountain, associated with tourmaline, fluorite, sphalerite, etc. It occurs with actinolite and cassiterite in the Buck Creek region.

Stannite (tin pyrites; 29.5 per cent copper, 27.5 per cent tin).—The rare mineral stannite, a sulphide of copper, tin, iron, and usually zinc, is known from Lost River only, where it occurs associated with galena and wolframite in a gangue of topaz and fluorite. The Alaskan stannite gives a strong qualitative reaction for zinc. It has a brown-black color and a metallic luster, and possesses an imperfect cleavage. Stannite is a mineral whose identification in any particular case must be confirmed by chemical examination.

Fluorite.—Fluorite occurs in a variety of ways throughout the region—as a contact-metamorphic mineral, as a gangue mineral of tin and of copper deposits, and as a metasomatic replacement of limestone adjoining stanniferous veinlets. It shows a variety of colors—purple, green, yellow, rose—and is also colorless, but the purple is the most common. Specimens from the Cassiterite lode show numerous cubes and, rarely, aggregates of columnar crystals. Fluorite is distinguished from quartz by its relative softness and fine octahedral cleavage. A characteristic feature is its power of phosphorescence, which becomes highly conspicuous during the drying of ore samples.

Quartz.—The granites of the region contain abundant quartz, which is prevailingly of a smoky character. The quartz porphyry dikes contain numerous sharply defined crystals of quartz, and these, too, are commonly smoky, and consequently have been mistaken for cassiterite to some extent. Greasy milk-white quartz ("vein quartz") carrying cassiterite forms stringers cutting the slates of the York area.

Hematite.—Nuggets of red oxide of iron occur with the stream tin of Buck Creek. Hematite is used as a pigment by the Eskimos of Shishmaref Inlet.

Ilmenite.—Ilmenite occurs as an abundant microscopic constituent of the greenstones, and is largely converted to leucoxene.

Spinel.—Perfect little octahedra of black spinel are found associated with chondrodite in contact-metamorphosed limestone near Read's galena prospect on Brooks Mountain.

Magnetite.—Nuggets of magnetite (magnetic iron ore) are fairly common in the stream tin of Buck Creek. The ore is found in place in visible crystals and clumps associated with calcite, hulsite, and vesuvianite on Brooks Mountain, and occurs also in narrow bands in contact-metamorphic limestone at Tin Creek.

Cassiterite (SnO_2; 78.6 per cent tin).—Cassiterite is a mineral which can not be positively identified by the eye alone. The only convincing test is the actual production, from specimens in question, of beads of metallic tin. On account of the difficulty of recognizing cassiterite the prospectors of the region have mistaken for it a great variety of minerals, including garnet, black tourmaline, augite in quartz porphyry dikes, pyroxene in contact-metamorphosed limestone, smoky quartz, vesuvianite, and wolframite. In color the Alaskan cassiterite varies from black to light yellowish or almost colorless. Some from Cape Mountain and Lost River was noted to show a fair degree of cleavage, which increases its resemblance to pyroxene. The specific gravity of cassiterite is about 7—considerably higher than that of the other minerals mistaken for it, except wolframite. Crushing and panning may therefore serve as a rough test, a gray or colorless residue in the pan indicating cassiterite. But inasmuch as considerable useless prospecting has been done on minerals mistaken for cassiterite, it seems advisable to test the suspected minerals for the only conclusive property of cassiterite—its ability to yield metallic tin. Pebbles and rolled grains of cassiterite occurring in stream gravels are known as stream tin. That of Buck Creek is prevailingly of a brown color, and much of it contains small cavities lined with clear, glassy, yellow crystals. Quartz adheres to many of the larger nuggets.

Rutile.—Rutile occurs as a microscopic constituent in the granites of Cape Mountain.

Pyrolusite.—Perfect dendrites, which are referred to pyrolusite, occur on the joint planes of the limestone near the Cassiterite lode.

Limonite.—Limonite occurs very abundantly in the gossan of galena bodies in the Lost River region.

Calcite.—The limestones in immediate proximity to the granite bosses of the region have been converted into aggregates of coarse white calc spar in many places. On the Dolcoath lode, near Cassiterite Creek, finely crystallized cassiterite occurs embedded in coarsely crystalline calcite associated with danburite, tremolite, and topaz.

Dolomite.—Certain strata of the Port Clarence limestone are composed of dolomite. It occurs also in the form of minute rhombohedra in some of the slates of the York area.

Cerusite.—The gossan of a galena prospect on Tin Creek was noted to contain white crystals of cerusite (lead carbonate).

Azurite.—Rock from the wolframite-topaz lode on Lost River is slightly incrusted with the blue copper carbonate, azurite, doubtless derived from the oxidation of stannite in the ore.

Feldspar.—Large porphyritic crystals of orthoclase and microcline occur in the granites of the region. Albite was detected as a constituent of the wolframite-quartz veins on Cassiterite Creek. Plagioclase is common in the igneous rocks of the region, and in the limestones as a metasomatic mineral.

Pyroxene.—Large crystals of augite, up to 2 inches in size, occur as a constituent of a quartz porphyry dike on Ear Mountain. They are of brown color and rarely show cleavage visible to the eye. They have been mistaken for cassiterite and have occasioned considerable useless prospecting. Augite is approximately half as heavy as cassiterite, and is readily fusible before the blowpipe. By this simple test with the blowpipe, were it available to the prospector, all the minerals usually mistaken for cassiterite, except smoky quartz, might be rejected from consideration. Pyroxene, probably near hedenbergite in composition, is common in the contact-metamorphosed limestone adjoining the granites of the region, particularly that of Cape Mountain. It resembles some of the cassiterite very closely, and the contact rocks have been prospected for tin. This fallacy is encouraged by the fact that the contact rocks are relatively heavy, having a weight corresponding to a 10 per cent quartz-tin ore.

Wollastonite.—Wollastonite occurs on Cape Mountain in proximity to the granite, locally forming white masses up to 3 feet in thickness.

Amphibole.—Tremolite, the colorless variety of amphibole, is prevalent in the form of glistening white fibers in the limestone adjoining the cassiterite occurrences on Cassiterite Creek. It also occurs as fine radial groups in the limestone east of Tin City. The light-green variety, actinolite, constitutes the gangue material of some newly discovered tin-bearing rocks on Buck Creek. Hornblende is common in the limestone adjoining cassiterite veinlets, and gives it a dark-green color.

Garnet.—As a product of contact metamorphism garnet is of widespread occurrence, the finest specimens coming from Tin Creek, on Lost River. It is commonly crystallized in rhombic dodecahedral forms, yielding diamond-shaped faces. Where only the apex of the dodecahedron is visible garnet bears a deceptive resemblance to the four-sided pyramid characteristic of cassiterite. Vesuvianite is usually associated with the garnet.

Olivine.—Olivine forms part of the basalt dikes of Cape Mountain, and is noted only microscopically.

Scapolite.—Chlorine-bearing scapolites are found in specimens of lime-silicate hornfels from Ear Mountain and Cape Mountain. Its identification is possible only by microscopical and chemical methods. In a number of specimens it was found that the birefringence, as indicated by the negative uniaxial interference figures, ranged from low to comparatively high values in the same thin section.

Vesuvianite.—Vesuvianite is one of the commonest contact-metamorphic minerals of the region. It is especially prevalent on Brooks Mountain and along the headwaters portion of Yankee Creek, where fine crystals showing ideal development occur in great abundance embedded in a matrix of coarsely crystalline calcite. The color of the vesuvianite is some tone of green, ranging from gray-green to brown-green. The crystals are usually in the form of square prisms.[a] As radial aggregates and branching forms, vesuvianite associated with garnet is abundant near the granite of Tin Creek on Lost River. It also forms metasomatically near stanniferous veinlets in limestones.

Zircon.—Zircon is noted as a microscopic constituent of the granites of the region.

Danburite.—The rare borosilicate of lime, danburite, was identified as the gangue material of cassiterite in the Dolcoath lode on Cassiterite Creek, where it occurs as replacement both of the dike rock and of the contiguous limestones. (For partial analysis see p. 52.) The optical properties of the danburite in thin section are indecisive; it is colorless and biaxial and shows the interference tints of feldspar and a relief near that of the associated tourmaline.

Topaz.—As a constituent of the tin ore in the Lost River region topaz (fluosilicate of aluminum) is exceedingly abundant. It occurs in altered quartz porphyry dikes, as vein mineral in veinlets in limestones, and as a metasomatic product in the limestone adjoining such veinlets. It is commonly associated with fluorite and zinnwaldite. The most remarkable occurrence, however, is that on the Oregon claim, where delicately radial topaz with subordinate fluorite forms the gangue of an argentiferous ore containing wolframite, galena, and stannite. (For analysis see p. 58.)

Zoisite.—Zoisite occurs in small amount in lime-silicate hornfels on Ear Mountain.

Epidote.—Radial groups of epidote are found on Brooks Mountain near the granite contact.

Axinite.—Small crystalline aggregates of axinite occur in a tourmaline hornfels from Ear Mountain. It is highly glassy in appearance and of a peculiar brown color. Many of the crystal faces are striated and acute edged. Axinite also occurs microscopically in a contact-metamorphic deposit on Brooks Mountain, associated with tourmaline, fluorite, arsenopyrite, and sphalerite.

Chondrodite.—Small honey-yellow crystals of chondrodite occur, together with numerous minute black octahedra of spinel, in a contact-metamorphosed limestone on Brooks Mountain.

Tourmaline.—Tourmaline is exceedingly common throughout the entire region and is regarded by many of the local prospectors as an

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[a] Forms measured crystallographically are given in Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 323.

infallible indication of tin ore. Although it is true that tourmaline is pretty generally associated with cassiterite, it is far from true that cassiterite is always associated with tourmaline. Great deposits of tourmaline that carry no tin whatever are known in various parts of the world.

In the Seward Peninsula tin region tourmaline occurs in a great variety of ways. It is found in granite apophyses on Ear Mountain as an original constituent (of the pneumatolytic stage of consolidation). It forms an essential mineral of the lime-silicate rocks surrounding the granite and occurs along seams and stringers in the granite itself, and in the quartz porphyry dikes with fluorite, arsenopyrite, and possibly cassiterite. On Cape Mountain it is abundant in the granite, and also occurs embedded in coarsely granular calcite. In the Buck Creek area the quartz stringers contain small rosettes of blue tourmaline. It is common in the Lost River and Brooks Mountain regions. Black, dark blue, and more rarely brown green are the prevailing colors. It is commonly crystallized in three- and six-sided prisms and columns, generally arranged in radial groups. As a rule the columns are aggregated together, and it is therefore usually difficult or impossible to distinguish the geometric form of individual crystals. Tourmaline has a specific gravity of 3, or less than half that of cassiterite. This property and its form, where discernible, are its most characteristic differences from cassiterite, with which it has frequently been confounded.

Muscovite.—White mica occurs at Ear Mountain in granite tongues extending from the central mass out into the surrounding sedimentary rocks.

Zinnwaldite.—The lithium-iron mica, zinnwaldite, occurs abundantly in the cassiterite veinlets on Cassiterite Creek, and is habitually associated with topaz and fluorite. It resembles muscovite, both to the eye and under the microscope, but differs from it by possessing a smaller axial angle. It fuses readily to a black magnetic globule. (For analysis see p. 54.)

Biotite.—The granites of the region contain black mica as a subordinate constituent in the form of small lustrous plates. It occurs also in a pegmatite on Brooks Mountain, in plates up to one-half inch in size.

Phlogopite.—Phlogopite, the magnesia mica, is found as small flakes associated with vesuvianite in contact-metamorphosed limestone on Brooks Mountain, and with tremolite is abundant in the limestone east of Tin City.

Chlorite.—Chlorite is common in the greenstone of the slate area near York.

Kaolin.—Kaolin occurs abundantly as an alteration product in the Cassiterite lode.

Apatite.—Apatite occurs as a microscopic constituent of the granites.

Ludwigite ($3MgO.B_2O_3+FeO.Fe_2O_3$).—A finely fibrous dark-green mineral, soluble in hydrochloric acid, forms small radial aggregates in a contact-metamorphosed limestone from Brooks Mountain. It gives a decided flame reaction for boron, and is therefore tentatively identified as ludwigite.

Paigeite.—The new boron-tin mineral, paigeite,[a] was found at two localities, near Read's cabin on Brooks Mountain in loose blocks and at Ear Mountain in situ. The Brooks Mountain material is intergrown with vesuvianite, calcite, and hedenbergite, with subordinate biotite and arsenopyrite in sporadic grains. At Ear Mountain it occurs evenly disseminated through a tourmaline-lime-silicate hornfels consisting essentially of calcite, tourmaline, vesuvianite, fluorite, and zoisite, with accessory phlogopite, chalcopyrite, and magnetite. It is a lustrous coal-black foliated mineral, and has a hardness of about 3, with a density of 4.71. Analysis of material from Brooks Mountain gave the following result, which is recalculated on the basis of 100 per cent; it contains probably 15 per cent SnO_2:

Analysis of paigeite from Brooks Mountain.

FeO	51.99
MgO	1.68
Fe_2O_3	19.54
H_2O	2.37
SnO_2 B_2O_3	24.42
	100.00

Hulsite.[b]—On the northwestern flank of Brooks Mountain a prospect cut has been opened on a showing of contact-metamorphic minerals occurring in a marmorized limestone 10 feet from the granite contact. Examination of this deposit indicated that an unknown mineral, which subsequent investigation proved to be a new boron-tin mineral, was present in considerable abundance. Hulsite, as the mineral was named, is closely associated with magnetite and a boron vesuvianite in a matrix of coarse calc spar, in which garnet and fluorite occur in subordinate amounts. The characteristic features of the new mineral are its strong submetallic luster, black color, good cleavage after the prism of 57° 38′, and tendency toward a tabular development. Its hardness is about 3; density, 4.28. It contains probably 20 per cent SnO_2.[c]

[a] Knopf, A., and Schaller, W. T., Two new boron minerals of contact-metamorphic origin: Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 323.

[b] Op. cit., p. 323.

[c] Chemical work is at present in progress by W. T. Schaller, with a view to determining the formulæ of hulsite and paigeite. It appears that the original determinations of B_2O_3 were defective, so that the formulæ proposed are untenable.

Wolframite ($Fe,MnWO_4$; 76.4 per cent tungsten trioxide).—The valuable mineral wolframite occurs associated with cassiterite on Cassiterite Creek and with galena and stannite in a topaz-fluorite gangue on the Oregon claim on Lost River. Its distinguishing features are its great weight (specific gravity, 7.3), black color, and brilliant submetallic luster on fine cleavage surfaces. Its hardness is 5.5, which means that it can be rather readily scratched with a knife. The resemblance of wolframite to the iron-rich zinc blend of Brooks Mountain has already been pointed out.

Scheelite ($CaWO_4$; 80.6 per cent tungsten trioxide).—The mineral scheelite has been detected as a microscopic constituent of certain lime—silicate contact rocks of Cape Mountain. It was also found as minute grains in a number of small cassiterite veinlets on Cassiterite Creek and in the altered limestone adjoining the veinlets. As an alteration product it forms microscopic coatings around wolframite crystals. None of these occurrences are of possible commercial importance. Scheelite is a heavy white mineral of vitreous luster, having a specific gravity of 6 and a hardness ranging from 4.5 to 5.

ECONOMIC GEOLOGY.

OUTLINE.

Tin ore occurs in both lode and placer form, but up to the present time practically the only production has been from the placers of a single stream—Buck Creek. Placer tin is known to be widely distributed in the streams of Seward Peninsula,[a] and has been found in some of the gold placers near Nome, but in amounts that are commercially unprofitable.

Cassiterite is the only mineral that is likely to prove of economic value as a source of tin. Stannite is also known to occur, but at one locality only, where it is associated with galena in a remarkable argentiferous wolframite-topaz ore. Two new tin minerals (magnesian iron-tin borates) have been discovered, but on account of their low tin content (approximately 15 per cent SnO_2) are probably not worth exploitation.

The lode-tin deposits are genetically associated with the granitic intrusives, and on account of the abundance of limestone in the region 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 contain the iron-tin borates (hulsite and paigeite) as essential constituents. The resemblance of numerous heavy contact-meta-

[a] Collier, A. J., Recent developments of Alaskan tin deposits: Bull. U. S. Geol. Survey No. 259, 1905, p. 127.

morphic minerals, such as garnet, 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. Only one contact rock containing cassiterite in amounts appreciable under the microscope was found, however, during the course of the present investigation.

Tin-bearing rock occurs also in tourmalinized granite, in fractured quartz porphyry dikes cutting limestone, and in the adjoining limestone itself, intergrown with danburite, tourmaline, tremolite, and topaz. Cassiterite is found in quartz stringers in granite, in slate, and in limestone, accompanied by an intense metasomatism. Veinlets in limestone may consist wholly of cassiterite, topaz, zinnwaldite, and fluorite. In the slate area cassiterite also occurs embedded in tabular masses of radial actinolite which appear to be interstratified with horizontal slates.

Most of the prospects have been but imperfectly opened. Some are of promising character, but from the point of view of the conservative mining man their value is yet to be demonstrated.

Each of the four localities at which lode tin is being prospected—Ear Mountain, Buck Creek, Cape Mountain, and Lost River—shows certain distinctive features, so it has been found advisable to describe them separately in geographic order, as enumerated. To these has been added Brooks Mountain, on which some stanniferous contact-metamorphosed limestone has been found, though no cassiterite-bearing rock has yet been discovered there.

LODES.

EAR MOUNTAIN.

INTRODUCTION.

Ear Mountain is located in the northwestern part of Seward Peninsula, in latitude 66° north and longitude 166° west. It is 50 miles north of Teller and 15 miles south of Shishmaref Inlet, a large, shallow embayment from the Arctic Ocean. The region is not readily accessible, and with the present means of communication it is practically impossible to bring in supplies during the summer months. Steamers of light draft do not venture to approach nearer than within 1½ miles of Sarichef Island, at the mouth of Shishmaref Inlet, though gasoline schooners make landings directly on the island. The inlet itself is not navigable other than by oomiaks and flat-bottomed dories. The first steamer of the season of 1907 bound for arctic points passed northward through Bering Strait on July 2. At this time the last ice floes from the spring break-up were drifting out of Shishmaref Inlet.

Ear Mountain has long, smooth slopes on the north and east sides, but on the south and west sides rises abruptly above the tundra-covered plateau from an elevation of 1,000 feet to a maximum of 2,308 feet above sea level. The mountain possesses two flat-topped summits, of which the southern is slightly the higher. Two great granite monoliths rest upon the broad northern summit, and are visible, but as very diminished objects, from ships on the Arctic Ocean, 20 miles distant. They were noted by the early navigators, and from them the mountain received its rather fanciful name.

Cassiterite in the form of stream tin was accidently discovered on Eldorado Creek, on the northeast side of the mountain, in 1901. Nuggets several inches in diameter can be picked off the bed-rock riffles of this stream, but on account of the small body of gravel the creek offers no placer possibilities. The bed-rock source of this cassiterite has not yet been discovered. None of the rocks that are being prospected show visible cassiterite, and only a few show small amounts microscopically. Attention has lately been directed to some occurrences of chalcopyrite and galena found in contact-metamorphic rock.

GENERAL GEOLOGY.

The rocks flanking Ear Mountain are prevailingly of a calcareous character, and comprise contorted limestone and lime-mica schists. On the south side of the mountain some black siliceous schists appear. Intrusive into these sedimentary rocks and forming the core of Ear Mountain is a large mass of coarsely crystalline granite from which numerous apophyses of fine-grained white granite extend into the surrounding sedimentary rocks. (See figs. 2 and 3.) The limestones were highly susceptible to contact metamorphism and succeeded to an unusual extent in fixing the magmatic emanations in such minerals as tourmaline, axinite, paigeite (a magnesian iron-tin borate), fluorite, scapolite, galena, and chalcopyrite.

The youngest rocks of the region occur as quartz-augite porphyry dikes cutting both limestone and granite. The two most prominent of these dikes are 15 feet thick and can be traced for several thousand feet, striking N. 30° E. and north and south (magnetically).

Granite.—The granite of Ear Mountain consists of feldspar (orthoclase with subordinate amounts of oligoclase-albite and microperthite), quartz, and biotite. Both quartz and feldspar tend to assume idiomorphic forms, even in the coarsest grained phases. The quartz is smoky, and has not infrequently been mistaken by the prospector for cassiterite, especially where the color was more intense. Near the contacts the granite is finer grained, and is, in many places, a typical granite porphyry. In the central portion of the main granite body a small area of this type of rock was found, but whether it represents a mere variation in texture or a separate intrusion could not be determined. Black tourmaline is common in the granite of Ear Mountain, but is always associated with seams consisting of quartz and

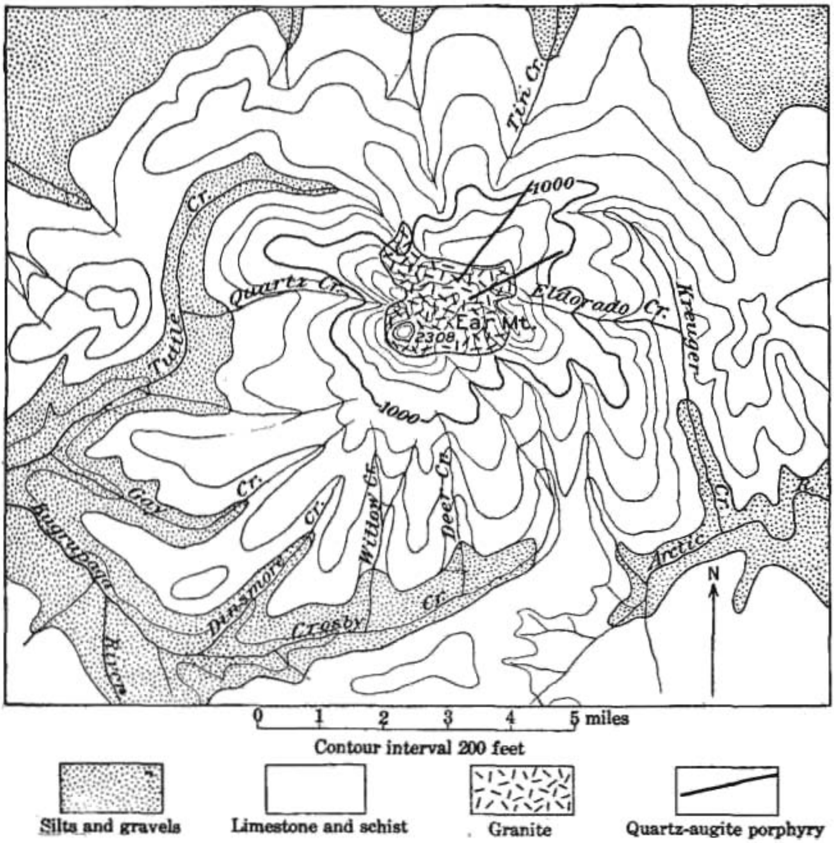


FIG. 2.—Geologic sketch map of Ear Mountain.

tourmaline, and adjoined by bands of tourmalinized granite 2 or 3 inches broad. The quartz-tourmaline seams, on account of their resistance to atmospheric attack, weather out in relief. Several such

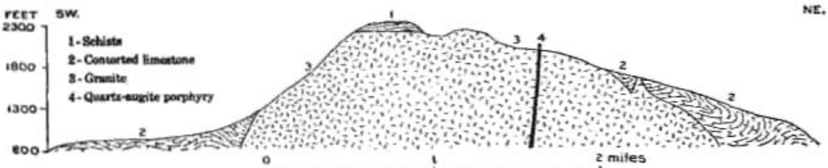


FIG. 3.—Geologic section through Ear Mountain.

seams can be seen running up and down the "Ears"—the granite monoliths from which the mountain was named.

The offshoots from the main granite body are finer grained and lighter colored. They contain, besides quartz and feldspar, white mica, and in many places numerous small prisms of tourmaline, evenly distributed throughout the body of the rock and unconnected with the presence of seams. In addition to the constituents visible to the unaided eye, the microscope shows a small amount of topaz. Some fluorite is associated with the muscovite, which, like the topaz, occurs in skeletal growths. Minute cassiterite prisms surrounded by pleochroic halos occur embedded in the muscovite. The tourmaline, which is brown, usually occurs in discrete prisms, but may also form skeletal growths. The three minerals—muscovite, topaz, and tourmaline—were formed after the feldspar and quartz, and apparently by similar processes. They are absent from the granite of the main mass, and indicate an enrichment of fluorine and boron in the apophyses.

Contact metamorphism.—An extensive development of lime-silicate hornfels, rich in the so-called pneumatolytic minerals, has been produced around the periphery of the granite mass. The limestones that were metamorphosed were originally impure limestones irregularly laminated with thin bands (one-eighth to one-fourth inch thick) of argillaceous material. The contact metamorphism has consisted in part in a recrystallization of the sedimentary material and in part in an accession of new material by magmatic emanations.

The simplest case of contact metamorphism is that of the tourmalinized limestone formed on the south side of Eldorado Creek. Here the argillaceous laminæ have been converted into black tourmaline and the calcareous bands have been marmorized, producing a rock resembling a gneiss. The tourmaline is pleochroic in tones of blue and green. Tremolite has also been developed, with diopside and vesuvianite in minor amounts. At other points along the contact the original banded character of the limestone is preserved, and even emphasized, by the production of trains of vesuvianite crystals. On Quartz Creek the limestones have been converted into pyroxene-scapolite hornfels. A prospect cut at this locality 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, and which has been named paigeite.[a]

In addition to the paigeite, considerable tourmaline and minor amounts of chalcopyrite and magnetite are visible. Under the microscope the rock resolves itself into a confused 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,

[a] Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 323.

many of which are of capillary dimensions, and in matted aggregates of fibers (Pl. II, *A*). Closely associated with this 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. It reacts for boron and manganese. In thin section it is colorless with faint blue pleochroisms, but shows no recognizable cleavage, although agreeing otherwise in its optical properties with those cited by Rosenbusch. Tourmaline is quantitatively more important than the axinite in this hornfels. It is subhedral and in numerous places zonally banded, with pleochroism varying from blue to green. In addition to the tourmaline and axinite, actinolite, pyroxene, quartz, fluorite, and calcite are confusedly intergrown, though the last three minerals occur rather in minor amounts. Some cassiterite is found embedded in the other constituents in grains 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 Alaskan tin region, although a large number of such rocks were examined on account of the prevalent belief that they are tin bearing.

Quartz-augite porphyry dikes.—The quartz-augite porphyry dikes consist of a dense-textured rock of dark-blue or green color containing numerous phenocrysts of feldspar and smoky quartz, with lesser amounts of augite and biotite. The augites attain unusually large dimensions—as much as 2 inches or more—and are commonly regarded as "tin crystals" by the local prospectors. The presence of these augite phenocrysts thus mistaken for cassiterite has led to considerable prospecting of the quartz porphyry dikes. In thin section the quartz phenocrysts are seen to be corroded and embayed; the plagioclase, which corresponds to bytownite ($Ab_{25}An_{75}$), is also corroded. Augite and biotite are rare. The groundmass consists of plagioclase laths approximating $Ab_{40}An_{60}$ in composition, and they are disposed in fluxional arrangement. Apatite is unusually abundant. According to this characterization the dikes are augite dacites. Calcite and tourmaline are common as secondary minerals. Where tourmalinization has been more intense fluorite, arsenopyrite, and cassiterite appear.

Two periods of tourmalinization can therefore be distinguished—one contemporaneous with the contact metamorphism and one following the intrusion of the augite dacite dikes. That a considerable lapse of time separated these periods is indicated by the fact that the granite now exposed to view had become thoroughly cooled during this interval and was able to chill the later intrusives.

MINERAL OCCURRENCES.

In addition to vesuvianite, tourmaline, axinite, and other contact-metamorphic minerals, the contact rocks at certain localities are flecked with galena, chalcopyrite, and a lustrous coal-black iron-tin borate, which has been named paigeite. It is this type of rock which has raised hopes that copper and lead deposits of economic value exist at Ear Mountain. Cassiterite-bearing rock also is believed by the prospector to occur along the contact at many points.

The practical importance of understanding how the deposits were formed arises from the following considerations:

(1) That the size and persistence of the deposits are dependent on the mode of origin.

(2) That their probable value, besides being affected by the size and persistence of the deposit, is also dependent on the mode of origin.

Under the first heading attention may be drawn to certain structural features of the granite boss of Ear Mountain—features which also occur at Cape Mountain and at Brooks Mountain. It can be

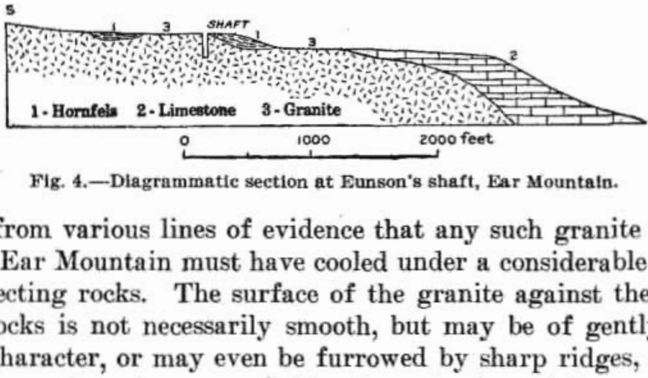


Fig. 4.—Diagrammatic section at Eunson's shaft, Ear Mountain.

shown from various lines of evidence that any such granite mass as that of Ear Mountain must have cooled under a considerable blanket of protecting rocks. The surface of the granite against these overlying rocks is not necessarily smooth, but may be of gently undulating character, or may even be furrowed by sharp ridges, such as, for instance, have been revealed by the extensive mining operations in Cornwall. The troughs or depressions between these granite ridges will be occupied by the overlying rocks, which will therefore appear immersed beneath the general surface of the granite. At Ear Mountain erosion has proceeded far enough to strip off much of the protective capping of sedimentary rocks which formerly arched over the granite, though on the highest peak—the south peak—the granite is still covered by a thickness of 100 feet of schists and sheared greenstone. This erosion has revealed the fact that the former surface of the granite boss was slightly uneven. The limestones and schists resting in the inequalities now occur as isolated patches surrounded on all sides by granite. A section across Ear Mountain (fig. 4) illustrates this feature. These rocks may show locally indications of ore, but the rock, being of contact-metamorphic origin, will have a small areal extent, will have no great depth, and will give out when the underlying surface of the granite is reached. The prospector, therefore, should use considerable caution before attempting any exploitation of ore bodies occurring in such patches of rock lying upon the surface of the granite.

Along the periphery of the granite the ore deposits of contact-metamorphic origin are more likely to have permanence in depth. What is known of contact-metamorphic deposits in other parts of the world, however, is not of a character to encourage extravagant hopes for the similar occurrences found at Ear Mountain. They are usually of low grade and irregular in form. Such deposits are mined in southeastern Alaska for their copper content, but conditions must be exceptionally favorable to make them of commercial value.

On the northeastern side of the mountain, near Vatney's cabin, where the contact metamorphism has been more pronounced than usual, some metamorphosed limestone in proximity to a granite dike was being prospected for tin ore. It contains small bunches of a reddish-brown mineral showing crystal faces, which, when carefully examined, are seen to be diamond shaped. This is typical of garnet. When only the apex of the garnet crystal is visible it bears an exceedingly deceptive resemblance to the four-sided pyramid characteristic of cassiterite.

Near Tuttle Creek a prospect trench has been opened to uncover some contact-metamorphosed limestone at the granite contact. The stanniferous tourmaline-axinite hornfels whose microscopic features have already been described occurs at this locality, but no cassiterite is visible in the rock to the unaided eye. The microscope, however, shows the presence of a small fraction of 1 per cent—an amount too small, in view of the nature of the deposit and the remoteness of the region, to give rise to any extensive hopes that commercial bodies of cassiterite exist along the contact.

The quartz-tourmaline seams that cut the granite have already been described. At various places on Ear Mountain interlacing networks of such seams occur, and an extensive tourmalinization of the adjoining granite has taken place. Masses of quartz-tourmaline rock have been produced, little resembling the original granite. Such occurrences have been opened by shallow prospect pits at a number of points. It is quite possible that some deposits of this character may carry low-grade values in tin, but those opened thus far lend small encouragement to this idea.

On the northeast side of Ear Mountain an augite-quartz porphyry dike has been opened by a shaft and explored by a drift 112 feet long.

Nothing but hard, barren rock was encountered. Work was suspended, and at the time of visit the shaft was flooded with water. Farther southwest on the extension of the same dike a number of open cuts have been made on account of the prevalence of numerous large augite crystals embedded in the dike rock. Chemical analyses of "ore" samples, made in the laboratory of the Survey, show the presence of only traces of tin, amounting to a few hundredths of 1 per cent.

A shaft known as Eunson's shaft (fig. 4) was sunk near the point where a quartz porphyry dike striking north and south crosses the granite-limestone contact. The shaft was reported to be 30 feet deep, but at the time of visit was flooded with water and partly caved in. On the dump a variety of rock is represented. Contact-metamorphosed limestone, granite, granite porphyry, quartz porphyry, and various altered modifications of the quartz porphyry appear. The quartz porphyry is partly tourmalinized and contains small patches of purple fluorite, abundant arsenopyrite, and microscopic grains of cassiterite. The tin ore reported from this locality probably came from highly altered portions of the quartz porphyry dike.

BUCK CREEK.

GEOLOGIC FEATURES.

The Buck Creek area is a part of the slate belt previously described. The bed rock consists of fine-textured arenaceous slates, usually lying flat. Along Buck Creek the rocks do not display a highly metamorphosed aspect, but are in large part shalelike, associated with beds of banded yellowish fine-grained sandstone and bluish kaolinic sandstone. The slaty cleavage, however, is developed in an irregular and variable degree in different parts of the area. At the head of Sutter Creek the arenaceous banded rock is thinly fissile, with the cleavage at right angles to the sedimentary banding. Greenstones of diabasic character occur with the slates, but can rarely be found in place. A prominent exposure, however, forms a low ridge immediately to the north of Buck Creek.

Two quartz porphyry dikes cut the slates at the head of Buck Creek. The characteristic feature of these dikes, especially of the one extending northward from Potato Mountain, is the abundance of large quartz phenocrysts, many of them smoky, embedded in a dense light-gray matrix. The feldspars are less conspicuous. The margins of the dikes have been strongly chilled, and show a bluish-black rock containing small phenocrysts of quartz and feldspar. On the summit of Potato Mountain the dike is but 1 foot thick and consists entirely of this kind of rock. Farther north the thickness increases to 10 feet. The other quartz porphyry dike, which trends N. 34° W. (magnetic), has a maximum thickness of 50 feet and a length of several thousand feet. These are the only acidic igneous intrusives known in the region.

ECONOMIC GEOLOGY.

Cassiterite occurs in three ways in the bed rock of the Buck Creek area—(1) as an impregnation in quartz porphyry dikes, (2) in quartz stringers cutting the slates, and (3) intergrown with arsenopyrite in a gangue of radial actinolite. Development, however, has not yet proceeded far enough to demonstrate the commercial importance of any of these occurrences.

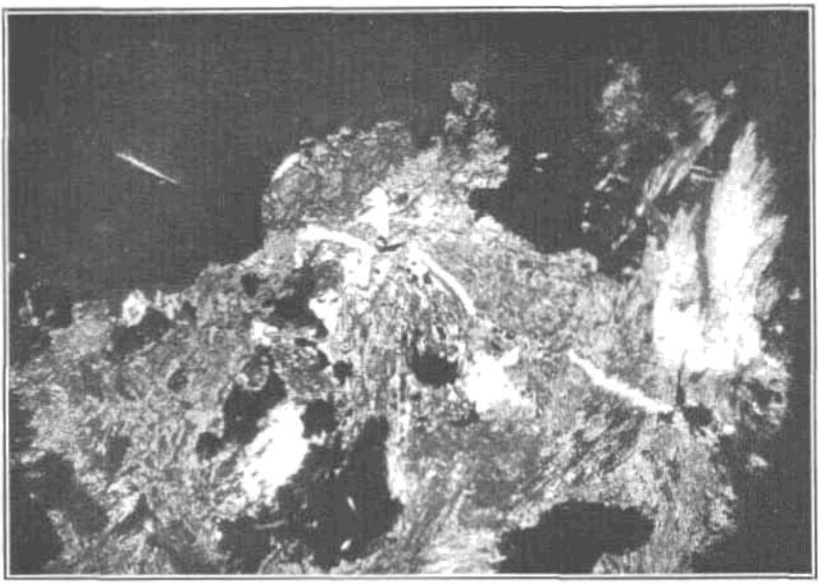
At numerous points on the ridge of hills at the head of Buck Creek open cuts have made made, exposing networks of quartz stringers in the slates. The veinlets are usually a few inches thick, and here and there contain cassiterite. Some merely show rosettes of blue tourmaline or are barren. Gold is probably present in some of them, as placer gold is found in the stream tin of Buck Creek. On the divide, at an altitude of 1,140 feet, a prospect pit discloses a fine showing of tin quartz. The hole is 10 feet deep and exposes a face of 7 feet of quartz carrying a considerable percentage of cassiterite. The developments are inadequate to give either dip or strike of the ore body with any degree of certainty, nor is its linear persistence known. The depth attained is not great enough to expose solid bed rock, and the walls are consequently still in a highly shattered condition due to the heave of the frost. The ore is a milk-white quartz of greasy luster, and contains cassiterite disseminated through it in crystalline aggregates, intimately intergrown with arsenopyrite and small needles of blue tourmaline. In thin section the tourmaline is found to be light blue in color, the pleochroism varying from clear blue to colorless (alkali tourmaline). The slate wall rock has a greenish cast, and under the microscope is found to consist almost entirely of minute tourmaline prisms in parallel orientation, with a small amount of interstitial feldspar. The bright boron flame which the slate yields when treated with fluorite mixture abundantly confirms the microscopic diagnosis. About 60 feet from the prospect pit the outcrops consist of normal arenaceous slate lying nearly horizontal.

At the head of Peluk Creek (a small tributary of Buck Creek) a shaft, reported to be 20 feet deep, was sunk on quartz stringers in the slate. The material on the dump shows abundant pyrite and a little cassiterite. In the same general vicinity float tin ore has been discovered in which the cassiterite occurs in totally different paragenetic association. It is found embedded in a green rock composed of radiating groups of actinolite. Relatively large amounts of arsenopyrite are usually intergrown with the cassiterite. A number of open cuts have been made in the effort to locate the bed-rock source of this tin-bearing rock. At time of visit the owner of the property had just succeeded in uncovering the edge of the deposit in place, so that few facts are available as to its geologic relations and probable value. Where exposed it was highly oxidized, and apparently represented a tabular mass intercalated between horizontal slates. In thin section the ore rock consists of sheaf-like bundles of actinolite, with which some finely granular calcite is associated. A small amount of quartz occurs in the immediate vicinity of the cassiterite, and both these minerals are transfixed by needles of actinolite (Pl. III, *A*). Tourmaline in the form of a few small prisms occurs as an accessory mineral. The slate in contact with the stanniferous rock is of a dense, poorly fissile variety. Under the microscope it shows no decided evidence of metasomatic alteration. It contains abundant magnetite disseminated through it in minute grains, which may possibly be of epigenetic origin.

At a number of points the quartz porphyry dikes are somewhat impregnated with pyrite, especially in the vicinity of seams. A small amount of tourmaline in radial groups appears, and white mica replaces the feldspar phenocrysts. Specimens containing a small amount of cassiterite have been obtained, but appear to be of extremely rare occurrence. The largest quartz porphyry dike has been faulted approximately 400 feet in a north and south direction. The line of this fault is marked by a great quartz vein 15 feet or more in thickness, which can be traced for considerably over a mile. The vein contains a vast number of slate fragments, each of which has acted as a nucleus around which quartz crystals commenced to grow. Failure of the crystals to coalesce in their outer extremities has produced a vuggy vein lined with innumerable hexagonal pyramids of quartz. No mineral except some botryoidal limonite incrusting the quartz crystals has been observed in the vein, so that it is without economic importance. Whether the formation of this vein was contemporaneous with that of the stanniferous quartz veinlets is of considerable practical interest. If of the same period of origin there is a strong possibility that persistent tin-quartz veins may yet be found in the slate area.

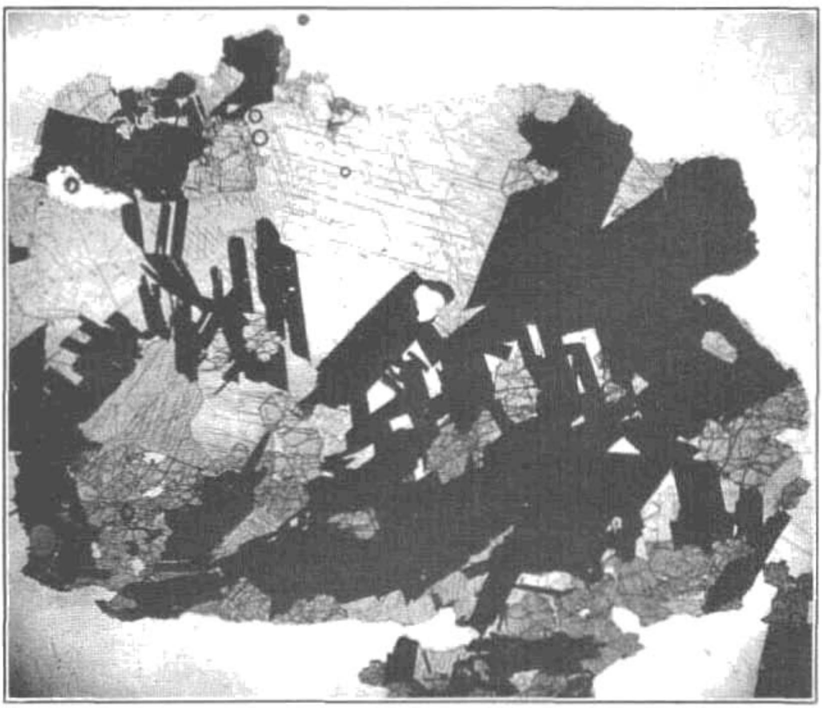
ORIGIN OF THE ORES.

The developments and exposures are entirely too inadequate to allow a very extended discussion of the origin of the ores. From analogy with the Lost River area, however, it is believed that a granite mass underlies the Buck Creek region and that the quartz porphyry dikes represent the final expulsive effort of this magma. After the advent of the porphyry emanations carrying metallic salts in solution



A. THIN SECTION OF ACTINOLITE-CASSITERITE ROCK; CROSSED NICOLS.

Magnification 32 diameters. Shows cassiterite transfixed by actinolite needles.



B. THIN SECTION OF STANNIFEROUS METAMORPHOSED LIMESTONE FROM BROOKS MOUNTAIN.

Magnification 12 diameters. Hulsite (black opaque mineral) intergrown with vesuvianite in a matrix of calcite.

ascended from unknown depths. These solutions moved in part along preexisting lines of weakness marked by the quartz porphyry dikes and in part along fractures in the slates. They contained the elements silicon, oxygen, sulphur, arsenic, boron, iron, aluminum, and tin, and probably gold. The metasomatic alterations indicate that the solutions were at high temperatures. The actinolite rock was probably produced by stanniferous solutions which, as leakages from the main channels of circulation, moved laterally through impure dolomite beds, such as the petrographic study of the slates has shown to occur through the region. The association of cassiterite and arsenopyrite in a gangue of actinolite is unique. Actinolite, together with axinite and other borosilicates, however, occurs as a gangue material in certain Tasmanian copper deposits.[a] The explanation advocated for these is essentially similar to that given above.

CAPE MOUNTAIN.

Cape Mountain forms the promontory fronting Bering Strait at the westernmost extremity of the American Continent. On the eastern flank of the mountain are a few widely scattered houses, which form the settlement known as "Tin City." Tin City is 110 miles by steamer route from Nome, with which it is connected by telephone.

GENERAL GEOLOGY.

Granite.—Cape Mountain consists of a granite mass, which has invaded a series of crystalline limestones of Carboniferous age. (See fig. 5.) The limestones are lying nearly flat, but with a slight easterly dip, and extend eastward nearly to the mouth of Baituk Creek, where they are faulted against the slates of the York area. At the cape the limestones dip in toward the granite. Locally along the contact, as on Village Creek, the limestone is crumpled and turned up at high angles—phenomena ascribable to the dynamic activity of the intrusive. Some fine-grained olivine basalt dikes, vesicular and in part filled with calcite amygdules, cut both granite and limestone. They are without doubt by far the youngest rocks of the area.

The granite of Cape Mountain is of a coarse-grained gray type, containing numerous large porphyritic feldspars, either microcline or orthoclase, commonly an inch or so in length. Quartz, acid plagioclase, and biotite comprise the remaining essential constituents. The quartz is prevailingly smoky. Along the contact with the limestone the feldspars are locally aligned with their longer axes parallel. More commonly, however, the granite is fine grained along its margin, and fluorite, tourmaline, and white mica appear. Pegmatite blebs

[a] Weed, W. H., Copper mines of the world, New York, 1907, p. 171.

white marble, extending at a maximum 200 or 300 feet from the contact. Proximity to the granite contact is in many places indicated by a peculiar rough appearance of the limestone, due to the development of small patches of lime-silicate minerals, ordinarily invisible to the eye. These weather out in relief and give it a characteristic "shaggy" appearance near the granite. At other points delicate radial groups of tremolite appear on the weathered surfaces of siliceous phases of the limestone. A faint banding is also evident, due to the fact that the pure carbonate laminæ have been converted to calc spar. The siliceous bands in the limestone overlying the granite near the summit of Cape Mountain have been converted into wollastonite. At the contact on Bering Strait beds of almost solid wollastonite 2 or 3 feet thick inclose an alaskite sill 1 foot thick and extend 30 feet from the main granite mass.

Contact metamorphism involving an addition of material is of relatively rare occurrence and is confined mainly to the limestone adjoining the dikes and sills. On the Canoe claim an open cut exposes a

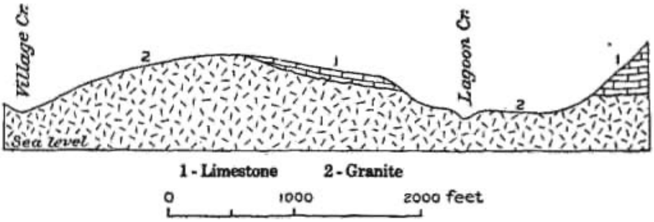


FIG. 6.—Geologic section across Lagoon Creek, Cape Mountain.

sill 8 feet thick, consisting of the normal porphyritic granite of Cape Mountain. The upper 1½ feet, however, consist of coarse alaskite-pegmatite composed of orthoclase and quartz individuals 4 to 5 inches in length. Between the pegmatite and the porphyritic granite a zone of relatively fine-grained granite up to 6 inches thick intervenes, but no great regularity can be observed for this feature, as all three phases may be confusedly intermingled. The question whether the pegmatite did not represent a separate intrusion along the contact was considered, but as large quartz individuals with pyramidal terminations were found projecting from the pegmatite into the fine-grained granite, and as transitions are everywhere observable between the three phases, the conclusion was unavoidable that it was practically contemporaneous with the granite. Some tourmaline is of later origin and is developed along seams. This occurrence resembles the "stockscheider"—a peripheral zone of giant granite enveloping the stanniferous granite bosses of the Saxon Erzgebirge—and suggests Élie de Beaumont's observation[a] "that the peculiar

[a] Cotta, B., Gangstudien I, Freiberg, 1850, p. 398.

cause of the coarsely crystalline character of the granite had acted mainly upon the marginal portion of the eruptive mass." The limestone overlying the pegmatite selvage is marmorized, and where in immediate contact has been converted into a heavy green finely granular rock. Under the microscope this proves to be a pyroxene-fluorite hornfels composed essentially of hedenbergite and fluorite, with accessory calcite and quartz. Scheelite and pyrrhotite occur in a few scattered grains. The association of a pyroxene hornfels with similar pegmatitic selvages is repeated at various other points on Cape Mountain. Near the Percy shaft the hornfels consists of hedenbergite, calcite, and scapolite, with accessory scheelite. The scheelite occurs in round, droplike grains embedded in calcite or intercrystallized with the pyroxene. It resembles titanite and cassiterite, but may be distinguished from the former by its positive uniaxial character and from the latter by its moderate birefringence (0.016). Inasmuch as scheelite is not commonly recorded as a contact-metamorphic mineral, the hornfels was submitted to E. C. Sullivan, of the United States Geological Survey, who verified chemically the presence of tungsten. The pannings from approximately 10 grams of rock were fused with Na_2CO_3, the fused mass was leached with water, the tungsten was precipitated with $HgCl_2$ as Hg_2WO_4, the mercury was expelled from the tungstate by heat, and the residue was examined by the reduction tests with Zn and Sn. The rock was also tested for chlorine by Doctor Sullivan and gave a strong reaction for this element, thus confirming the optical determination of the scapolite.

ORE DEPOSITS.

Cassiterite probably occurs in three ways at Cape Mountain—(1) in tourmalinized peripheral portions of the main granite mass and in tourmalinized granite dikes; (2) in contact-metamorphic rock, and (3) in veins in granite and as an impregnation of the adjoining wall rocks. From experience in developed tin regions it appears that the first type of occurrence is apt to be of low grade, and that the second is an unlikely source of tin ore. The occurrences on Cape Mountain indicate that the Alaskan deposits will prove to be no exceptions to this rule. The third is the normal type the world over, and has yielded the deepest and most productive mines.

At Cape Mountain no practical distinction is made between the first and the second modes of occurrence. The largest amount of prospecting has been done along the granite-limestone contacts because some rich pockets of tin ore have been discovered in tourmalinized granite along the contact and because of the distinctive character of the contact-metamorphic rocks (pyroxene hornfels). It can not be positively asserted that cassiterite occurs in the contact-metamorphic rock (in fact, all observations have been to the contrary), but it is not improbable that some tin ore may occur in the tourmalinized limestone adjoining tourmalinized granite.

Some of the dikes cutting the limestone show margins which are strongly tourmalinized and considerably impregnated with cassiterite. Large masses of bluish tourmaline occur, and these carry rich pockets of tin ore of a light-brownish color. The limestone adjoining the dikes has here and there been converted into coarse white spar, in which numerous prisms and columns of tourmaline are embedded. Where tourmalinization has been complete it may be difficult to distinguish tourmalinized limestone from tourmalinized dike rock. The tourmalinization, either of granite or limestone, however, appears to be purely local and erratic in occurrence. Furthermore, the tourmaline rock, although, as already stated, locally rich in cassiterite, is in general quite barren.

Along the periphery of the main granite mass local tourmalinization of the granite has taken place, accompanied by an introduction of cassiterite and pyrite. The pyrite has largely been oxidized, and in this way heavy red porous masses, consisting chiefly of iron oxide, with tourmaline and cassiterite, have been produced.

The contact rocks adjoining the large granite stock and some of the granite sills have been prospected at a number of places. A heavy green rock, showing in places finely disseminated pyrrhotite, has been regarded as tin ore, but microscopic and chemical analysis fail to reveal any tin. The green rock is locally known both as "greenstone" and as "tinstone." It is a finely granular rock, consisting of pyroxene, probably hedenbergite, and fluorite in equal proportions. This rock is well exposed in a cut on the Canoe claim, where a few feet of it directly overlies a granite sill, 8 feet thick. At other points on Cape Mountain, notably one-half mile north of the Lucky Queen property, the pyroxene is embedded in calcite. The pyroxene, which is unusually well developed for a contact-metamorphic rock, is of brown color and does not look unlike cassiterite, especially cassiterite which shows a macroscopic cleavage. It is true that cassiterite has a more splendent luster, but the distinction is not one that carries conviction. Where the presence of tin is suspected in such rocks, only assays can give reliable information.

The statements regarding deposits of contact-metamorphic origin made for the Ear Mountain region are equally applicable to Cape Mountain. In addition, the highly irregular nature of the granite contact makes prospecting for such deposits difficult and would entail heavy—probably unwarrantable—expenses in mining them.

Up to the present time a single narrow quartz vein has been found in place, cutting the granite on the north side of Cape Mountain at an altitude of 1,850 feet. The vein is accompanied by some alteration to greisen and partial tourmalinization of the adjoining granite—changes characteristic of tin-bearing veins. At other points on Cape Mountain cassiterite, accompanied by tourmaline, is found as an impregnation of the granite adjoining slips or fault planes. This type of occurrence, in the opinion of the writer, holds out greater possibilities for the future of the district as a tin producer than the other two. Unfortunately, exploratory work has been mainly confined to the contact deposits.

DEVELOPMENTS.

At the time of visit two properties only were being actively prospected at Cape Mountain—those of the United States Alaska Tin Mining Company and the Bartels Tin Mining Company. The former property is situated near the summit of the mountain, on the north side. Developments up to the end of July, 1907, consisted of a shaft reported to be 22 feet deep, now filled with water, and a 7-foot tunnel, 270 feet long. The company has also erected a 10-stamp mill near the beach at Tin City. Four men were employed at the time of visit. The shaft is sunk on a quartz ledge, 1 foot thick, striking N. 45° W. (magnetic) and dipping 80° E. The tunnel, whose altitude at the portal is 1,600 feet, according to aneroid measurement, is driven in a direction S. 40° W. through hard, firm granite, and is expected to tap the ledge 250 feet below the collar of the shaft.

The principal development work by the Bartels Tin Mining Company has been done on the North Star property. Eight men were employed during the summer of 1907. The main tunnel, with its drifts and winzes, aggregated 750 feet in length. This tunnel is being driven to catch the granite-limestone contact at a depth of 100 feet below the workings of the Lucky Queen tunnel. About 400 feet from the mouth of the tunnel a band of granite, carrying numerous visible crystals of cassiterite, associated with some tourmaline, was encountered. The width of this band is about 18 inches. The granite is soft and iron stained. The succeeding 3 feet consists of hard gray granite with pyrite disseminated through it. This is succeeded by 15 feet of iron-stained granite. At the time of visit the 18-inch belt of rich tin ore had not been drifted on to prove its persistence. The drifts branching off from the main adit follow the contact of a large limestone block, which was evidently torn from the main limestone mass during the intrusion of the granite. In following this contact, which proved to be of a highly irregular nature, several winzes were necessary. A new tunnel, 67 feet below the North Star tunnel, is being run from the surface to connect with the lowest drifts reached by these winzes. The granite along the limestone contact is charged with numerous radiating groups of tourmaline prisms associated with iron oxide, and locally with pyrite and tin ore. Crushing and oxidation have taken place along the contact, and heavily iron stained gouge matter, a foot in thickness, has been produced. At points where the red clayey material is absent the granite is fresh and the progressive increase of fineness of grain as the contact is approached can be noted.

A considerable portion of the energies of the company has been expended on assessment work on the numerous claims which it holds on Cape Mountain.

On the Carlson & Goodwin property an adit 20 feet long has been driven along the contact of a horizontal limestone and a granitic dike. The dike sends small, irregular tongues into the limestone, and the ends of these tongues have been completely converted into blue tourmaline rock. The limestone has been rendered coarsely crystalline, but evinces no other change. Rock from the dump, however, shows that locally an intense tourmalinization was produced. No stanniferous rock was seen in place.

On the northwest side of the mountain, on Village Creek, some drill holes have been put down to the granite contact, but the results are not known.

BROOKS MOUNTAIN.

Brooks Mountain, the dominant peak of the York Mountains, lies in the watershed of the Bering and Arctic drainages. It is easily accessible from the coast by way of Lost River, a distance of 9 miles. The mineral deposits are of contact-metamorphic origin, and though no cassiterite-bearing rock has been discovered on the mountain, yet the character of the mineralization here allies it to that of the tin region, of which Brooks Mountain is geographically a part.

An intrusive granite mass, 2 miles long by two-thirds of a mile wide, forms the southern flank of the mountain. The granite is characterized by the presence of numerous large porphyritic orthoclase crystals, commonly an inch in diameter, and large idiomorphic crystals of smoky quartz exceeding peas in size. The matrix consists of a coarsely granular assemblage of orthoclase and subordinate oligoclase ($Ab_{80}An_{20}$), with quartz and biotite in small amounts. The rocks surrounding the granite are chiefly limestones of the Port Clarence formation, and are highly crumpled throughout much of the region. Along the periphery of the granite they have been marmorized, and an extensive variety of contact-metamorphic minerals have been produced in the immediate vicinity of the contact.

At the west end of the granite stock a horizontal pegmatite about 8 inches thick traverses the white marble. It consists of orthoclase, quartz, and biotite, generally segregated in separate masses, the biotite in plates one-half inch in diameter forming selvages 1 to 2 inches thick. Thin sections cut from equidimensional portions of the pegmatite show, in addition to the three constituents already named, a small amount of plagioclase, some faint-colored bluish-green mica, accessory corundum, and probably topaz. The structure is allotriomorphic granular. The pegmatite is overlain by 1 foot of finely granular, heavy green rock, resembling that adjoining the pegmatite selvages on Cape Mountain. This rock is composed of vesuvianite, hedenbergite, and fluorite in approximately equal proportions.

Vesuvianite is the commonest mineral in the metamorphic aureole of the granite mass. Along the headwaters of Yankee Creek the impure crumpled Port Clarence limestone is brought into contact with the intrusive stock, and a thorough recrystallization has ensued. Crystallographically perfect vesuvianite in prisms up to three-fourths inch in length occurs scattered in great profusion through a matrix of coarse white calc spar. The vesuvianite is noteworthy as containing 0.88 per cent B_2O_3.[a] Where this mineral has not individualized into large crystals the metamorphosed rock consists of a fine equigranular aggregate of vesuvianite, calcite, and possibly garnet, interspersed with minute plates of phlogopite. The growth of the large crystals has produced a clarification, as it were, of the carbonate rock, and the boron content of the vesuvianite shows that this process was promoted by pneumatolytic agents. In this connection it is significant that an energetic tourmalinization of the granite has taken place at a number of points in the vicinity of this portion of the contact.

At the west end of the Brooks Mountain granite mass a prospect trench discloses a body of argentiferous galena ore, occurring 20 feet from the granite contact in a coarsely crystalline white limestone. The strike of the ore body, as revealed in the open cut, is N. 15° W. (magnetic), and the dip 65° toward the granite. A thickness of 3½ feet of solid ore is exposed, consisting of galena strongly admixed with a lustrous black zinc blende which, as analysis shows, contains 19 per cent of ferrous iron. Some pyrrhotite is also present, but this mineral is comparatively rare. Where any gangue mineral is visible it consists of fluorite. The ore body is frozen to both walls. The hanging wall shows a belt of finely granular fluorite several inches thick, succeeded by extremely coarse calcite containing scattered crystals of diopside and some galena. The grain of the calcite decreases away from the ore body. A thin section of rock taken from a point near the hanging wall is composed of calcite, fluorite, diopside, calcic plagioclase (Ab_2An_3), an unknown positive uniaxial mineral, and a small amount of colorless mica, with sporadic grains of the ore minerals. Assays of the ore made in Nome yielded 34 per cent of lead

[a] This determination was made by Prof. Edgar F. Smith, of the University of Pennsylvania, according to two new methods for the estimation of B_2O_3 that he has recently discovered.

and 11 ounces of silver per ton. Other assays were reported to give ore values ranging from $17 to $44 per ton.

In the vicinity of the galena prospect there is some contact-metamorphosed limestone containing a fibrous green magnesia-iron boron mineral (ludwigite?) intercrystallized with galena. Loose masses of paigeite hornfels are also present. Some rock containing abundant honey-yellow crystals of chondrodite and numerous minute octahedra of spinel, embedded in a mesostasis of calcite with accessory magnetite, occurs near by.

In the same general locality some contact masses of vesuvianite have been prospected for nickel. The vesuvianite is in part finely granular and gives the rock a general green color. This feature and the unusual weight of the rock (that is, compared to quartz) doubtless caused the nickel prospecting. No indications of nickel are present, and it may be added that such a mode of occurrence is totally unknown for nickel. On microscopic examination small amounts of calcite, deeply pleochroic biotite, and hedenbergite are found associated with the vesuvianite.

In the canyon below the galena claim some assessment work has been done on a showing of contact-metamorphic minerals near the granite contact. The deposit is interesting from a scientific standpoint, inasmuch as a hitherto unknown boron-tin mineral has been discovered in it, but nothing of great commercial importance has been found here. The minerals comprise brown garnet, showing rhombic faces, green or yellowish-green vesuvianite, and abundant magnetite closely associated with the new mineral—a magnesia-iron tin borate which has been named hulsite.[a] These various minerals are all included in a matrix of coarse white spar (Pl. III, *B*). On account of the low percentage of tin in hulsite (approximately 10 per cent) the deposit can have no economic value.

At the head of the same canyon other contact-metamorphic deposits have received attention. Here, at an altitude of 2,000 feet, a small prospect hole exposed a mass of metamorphic minerals occurring in a white marble a few feet from the granite contact. Tourmaline, fluorite, calcite, arsenopyrite, brilliant black sphalerite, pyroxene, and axinite occur confusedly intergrown. The ore body is 4 feet thick and penetrates the marmorized limestone in irregular tongues a few inches thick. Some galena was noted in the ends of these tongues, which were examined microscopically and found to consist almost exclusively of monoclinic pyroxene. A few hundred feet north of this occurrence the pure white marble gives way to a highly metamorphosed impure limestone, consisting essentially of vesuvianite, calcite, biotite, and accessory tourmaline. Some of this rock contains sphalerite

[a] Am. Jour. Sci., 4th ser., vol. 25, 1908, p. 323.

and other sulphurets, which on oxidizing give it a gossan appearance. High gold assays were claimed from this type of rock. Ledoux & Co., of New York, report on an assay sample submitted by the Survey: "Gold, trace; silver, 0.23 ounce."

On the north side of Brooks Mountain, at an altitude of 1,850 feet, is a small galena prospect. The galena occurs in a gossan, the skeleton of which consists of tourmaline. The iron oxide of the gossan contains lead and traces of bismuth, the lead probably as carbonate and the bismuth as oxide.

LOST RIVER.

LOCATION.

Lost River is a small stream rising in the heart of the York Mountains in the western part of Seward Peninsula. It flows southward into Bering Sea through a comparatively broad and open valley, except for a short stretch near its mouth, where it flows in a narrow canyon. It has a total length of 9 miles. The region is nearly destitute of vegetation, even Arctic mosses being scarce. The tin prospects are on Cassiterite Creek (see fig. 7), a branch of Lost River, 6 miles from the coast, and are easily accessible by a good wagon roadway. A tungsten-silver prospect, a copper prospect, and some galena prospects are also situated in this region.

GENERAL GEOLOGY.

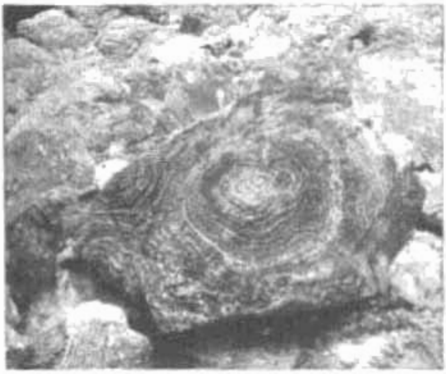
The rocks.—The general geologic features of the region are simple. The bed rock consists of the Port Clarence limestone, dipping northward at an angle of 20°. Near the head of Cassiterite Creek the limestone is intimately banded with argillaceous laminæ, and intensely crumpled (Pl. II, *B*). Locally the formation is fractured and brecciated, and shear zones of white marble have been formed.

On Tin Creek, another tributary of Lost River, a small granite boss, a third of a mile in diameter, is intruded into the limestone. The granite is a medium-grained aggregate of feldspar, quartz (which is partly idiomorphic, smoky, and conspicuous), and scattered foils of biotite. The principal effect of this intrusion has been to marmorize the surrounding limestone, though locally some large masses of contact-metamorphic minerals have been formed.

A considerable number of vertical quartz porphyry dikes pierce the limestone, but only one has been found extending into the granite area. They are fairly persistent, and can be traced for several miles across the country. They are not all strictly contemporaneous intrusions, as certain dikes have been found to intersect each other. The quartz porphyries are light-colored rocks containing small glassy quartz and feldspar crystals embedded in an aphanitic matrix. The

A

B



C

D

A. ORBULE PRODUCED BY CONTACT METAMORPHISM.
B. REVERSE SIDE OF ORBULE SHOWN IN *A*.
C. MAXIMUM ORBULE. DIAMETER, 8 INCHES.
D. IRREGULAR ORBULES.

main tin prospects of the region occur in a few highly altered dikes of this character, but several of the other dikes have received separate names and have been more or less prospected, on what encouragement, however, it is difficult to understand. They are usually unmineralized, except for sporadic cubes of pyrite, and there is no known reason why they should become tin bearing in depth.

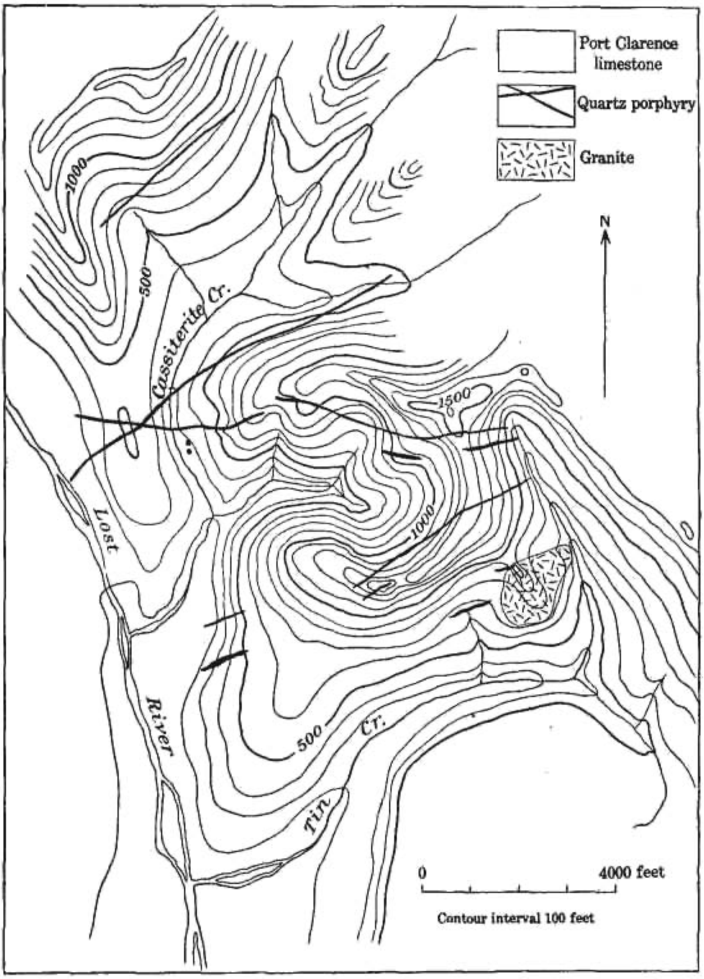


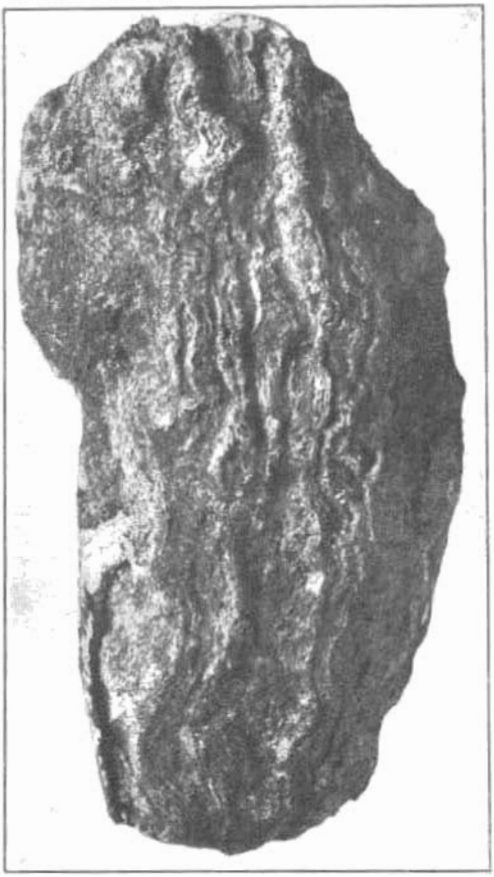
FIG. 7.—Geologic sketch map of Cassiterite Creek and vicinity. Topography by Adolph Knopf. Elevations determined by aneroid barometer.

Orbicular contact metamorphism.—The limestone surrounding the granite boss of Tin Creek has been converted into a coarse white marble. Near the contact loose blocks showing orbicular forms are common (Pls. IV, V, VI, *B*). The orbules are composed of an alternating succession of concentric black and white bands, commonly a millimeter or so in breadth. As shown in the photographs, the orbicular structure is brought out in detail by the etching action of the weather. Many of the sections through the orbules are perfect circles, a maximum diameter of 8 inches being noted, but elliptical forms, due to the interference of contiguous orbules, are common. In some places small orbules occur in the outer bands of large orbules and cause a wrinkling of the even banding. Where several small independent orbules have formed around closely spaced centers highly intricate structure resembling that of contorted gneiss has been evolved.

The minerals composing the orbules, named in their order of abundance, are fluorite, hornblende, vesuvianite, plagioclase (Ab_8An_7), and magnetite. The hornblende is a deep-colored variety, the pleochroism ranging from brown to strong greenish blue. The vesuvianite has a tendency to form radial groups of short, stout columns. Under the microscope the banded structure is not as distinctly apparent as would be expected from inspection of the weathered surface of the orbules. The light-colored bands consist of mutual intergrowths of fluorite and plagioclase; the dark bands consist of fluorite with hornblende or vesuvianite, or with both together, and commonly some magnetite. The presence of fluorite in both dark and light colored bands causes them to contrast less emphatically under the microscope than they do macroscopically. Examined in thin section the central portion of one of the orbules was found to consist of calcite anhedra in which are embedded vesuvianite, fluorite, and green amphibole inclosing considerable magnetite. This central area is surrounded by a ring of magnetite. Other centers are composed chiefly of fluorite and vesuvianite with intergrown hornblende. An unusual type of orbule is one composed of garnet, pyroxene, and fluorite, with narrow black bands of magnetite.

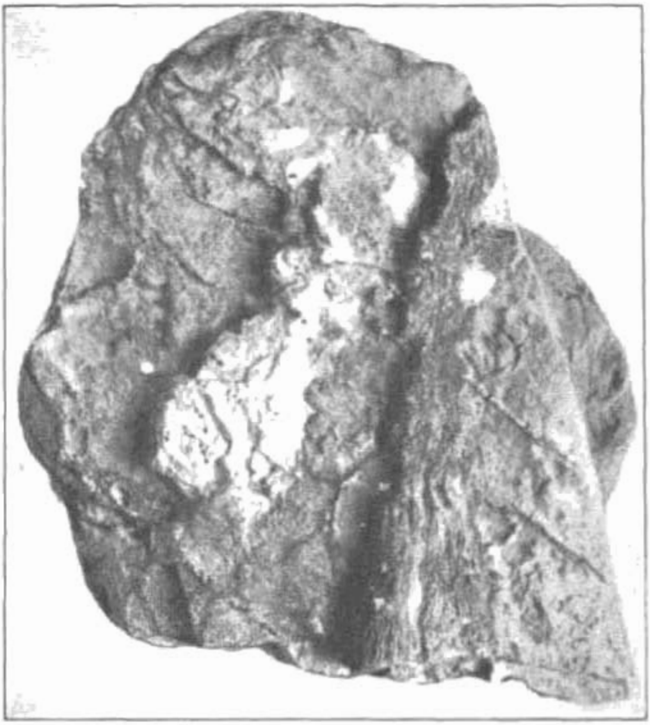
A single exposure outcropping beneath the talus near the granite-limestone contact throws light on the genesis of these remarkable forms. Curious veins, symmetrically banded, traverse the marmorized limestone in irregular fashion. The bands are only a fraction of a millimeter in thickness and simulate the sinuous flow lines of certain acidic volcanic rocks (Pl. V). Small tongues, a few inches in length, project into the marble, and these also are symmetrically banded. In irregular expansions of the veins orbicular structures have been developed (Pl. VI, *B*). The veins are composed of fluorite and calcic plagioclase (Ab_1An_2), with pyroxene, green mica, hornblende, and accessory arsenopyrite, cassiterite, and scheelite. They therefore resemble the orbules in mineralogical constitution to a considerable extent.

The orbicular material is cut by quartz porphyry, thus fixing the period of its formation, although not very closely. The only quartz porphyry dike penetrating the granite shows strong marginal chill-



BANDED VEIN; A SUPPLY DUCT FOR THE ORBULES.

Natural size.



A. BANDED APOPHYSIS FROM GARNET-VESUVIANITE MASS ON TIN CREEK.

Natural size.

B. ORBULES IN MARBLE MATRIX, SHOWING MODE OF ORIGIN.

ing, indicating, therefore, a considerable interval between the intrusion of the granite and the injection of the dikes. How nearly contemporaneous were the solidification of the granite and the metamorphism is an open question.

A mass of metamorphic minerals 50 feet wide is exposed on the bank of Tin Creek, 1,000 feet from the visible contact of the granite and limestone. It consists of solid masses of radial and arborescent vesuvianite and of brown garnet showing dodecahedral faces. The microscope reveals in addition small amounts of interstitial fluorite and calcite and accessory pyroxene, hornblende, and plagioclase. The dark mass of metamorphic minerals has injected apophyses, as it were, into the adjoining limestone (Pl. VI, *A*). These are arranged in black and white bands, a fraction of a millimeter in thickness. The microscope shows that these apophysal veins are composed of fluorite, strongly pleochroic from brown-green to blue-green hornblende, vesuvianite, and calcite, with accessory magnetite and arsenopyrite. These features ally this occurrence with the orbicular contact metamorphism and suggest that the heavy vesuvianite-garnet masses were produced by magmatic solutions traveling outward along fissures in the limestone.

Forms similar to the orbicular structures have not previously been recorded. Trüstedt [a] has recently described some curious occurrences ("Erzschlauche," he terms them) from Pitkaranta, in Finland, which in their essential aspects resemble the banded veins serving as the supply ducts for the Alaskan orbules. Cross sections of the ore arteries resemble sections through the orbules and, moreover, show a similarity in mineralogical constitution and similar alternating bands composed of magnetite and fluorite-vesuvianite with sporadic garnet. The explanation advanced for the ore arteries, which anastomose through a limestone, is that they are crustification structures produced by juvenile waters subject to rapid changes in composition and temperature. The circular pipes along which the deposition took place were produced by the corrosive action of earlier solutions. This hypothesis does not fit the Lost River phenomena. The mode of growth of the orbules—outward from centers—their common interferences, and their position adjoining the banded veins preclude an origin by crustification. Their essential similarity to the banded veins and their parasitic habit show that the two features are identical phenomena, which, as already indicated, are allied to the formation of the vesuvianite-garnet masses. The explanation which the writer would suggest for this related set of phenomena is that it was produced by magmatic emissions traveling outward under great pressure along fissures in the limestone; that the flow of the solutions was im-

[a] Trüstedt, O., Die Erzlagerstätten von Pitkäranta am Ladoga-See: Bull. Comm. Geol. de Finlande, No. 19, 1907, p. 226.

peded; that at points of stagnation the wall rock was thoroughly permeated and a local intense metasomatism was produced. The solutions contained large amounts of fluorine, aluminum, silicon, iron, and sodium. The formation of fluorite (CaF_2) caused the expulsion of an equivalent quantity of CO_2 from the limestone and, owing to the absorption of this gas, the capacity of the solutions to dissolve lime was increased to a high degree.

It is probable that the channels of circulation were enlarged by this process and that the vein filling as now seen consists of minerals formed from the lime of the wall rock and fluorine, aluminum, silicon, iron, and sodium derived from the magmatic solutions. In such veins formed in limestone under conditions of high pressure and temperature it appears to be impossible to discriminate between metasomatically altered wall rock and the filling of the original channels of circulation. The banding was produced either by processes similar to those which have given certain igneous dikes their banded character or by phenomena similar to those operative in the formation of Liesegang's rings. If a drop of $AgNO_3$ solution be placed upon a gelatin plate impregnated with $K_2Cr_2O_7$ a series of concentric rings consisting of $Ag_2Cr_2O_7$ will be formed, becoming progressively wider spaced with increasing distance from the center. The explanation given by Ostwald [a] is that as the soluble silver salt diffuses outward a periodic precipitation of insoluble silver chromate will take place at the loci of supersaturation. Morse and Pierce [b] have investigated this phenomenon in some detail, using tubes, however, instead of plates, and have shown incidentally that gelatin is not essential to the production of the rings and bands. Among other substances employed were $FeCl_3$ and Na_2CO_3, and a recurrent evolution of CO_2 was noted. This reaction proceeds as follows:

$$2FeCl_3+3H_2O+3Na_2CO_3=3CO_2+6NaCl+2Fe(OH)_3.$$

When the attempt is made to fit this explanation to the natural conditions the problem becomes greatly complicated on account of the complex character of the solutions, the unknown state of combination of the various elements, and their different rates of diffusion. As abundant fluorine was present in the solutions, a reaction analogous to the preceding may be formulated as follows:

$$2FeF_3+3H_2O+3CaCO_3=3CO_2+3CaF_2+2Fe(OH)_3.$$

The fluorine was thus fixed as fluorite and the iron separated as magnetite or was taken up by the production of amphibole. Enough

[a] Lehbruch allegemeinen Chemie, 2d., Band 2, Teil 2, p. 778.
[b] Zeitschr. physikal. Chemie, vol. 45, 1903, p. 589.

has been indicated to show that an explanation involving diffusion and supersaturation is at least as plausible as one involving crustification and is in closer harmony with the phenomena observed in the field.

CASSITERITE PROSPECTS.

Lodes.—At Tin Creek a few thin quartz stringers carrying cassiterite have been found in the granite. Collier [a] has shown that some pyritiferous granite from the same locality contains 0.3 per cent of tin. No cassiterite is visible in this granite to the unaided eye, so on account of the prevalence of sulphides he assumed that the tin occurs in the form of tin pyrites (stannite). A cut has been opened on this occurrence and shows a number of narrow bands of hard quartzose granite containing finely disseminated pyrites, chiefly of iron and arsenic. Under the microscope the rock is seen to be composed of quartz, topaz, and sericitized feldspar, with accessory pyrite, arsenopyrite, and cassiterite in small amount.

The principal tin prospects of the region are located on Cassiterite Creek, and occur in the quartz porphyry dike known as the Cassiterite lode. This dike is 6 to 10 feet thick and can be traced from the head of Tin Creek in a northwesterly direction to Lost River, a distance of 9,000 feet. Near Lost River the dike rock contains a multitude of angular limestone fragments and is really a limestone breccia cemented by quartz porphyry. The characteristic feature of the Cassiterite lode dike rock, where nonstanniferous, is the abundance of sharply defined quartz phenocrysts embedded in a white aphanitic matrix. Thin sections cut from the least-altered portions of the dike show numerous phenocrysts of quartz, orthoclase, and sodic plagioclase embedded in a cryptocrystalline groundmass. The nonlamellated feldspar is opaque from kaolinization, but the plagioclase is unaltered. Sporadic crystals of clear and limpid plagioclase lie inclosed in turbid orthoclase phenocrysts. Fluorite is common in the groundmass and patches of topaz occur also. More highly altered phases of the dike merely show quartz phenocrysts lying scattered in a matrix of scaly white mica, fluorite, and quartz. Along a portion of its course the white quartz porphyry dike has broken through an older dike, a gray feldspar porphyry, which is particularly conspicuous on account of the multitude of dull white phenocrysts that it contains.

The tin-bearing portion of the dike is 3,000 feet long, but the whole of this length can not be considered ore rock; intermittent barren stretches occur, and the ore is probably localized in irregular shoots. The limestone in the vicinity of the stanniferous portion of the dike

[a] Collier, A. J., Tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, 1904, p. 22.

is seamed with innumerable veinlets which reticulate the surface of the country rock in every conceivable direction (Pl. VII, *A*). These vary in thickness from a film's breadth to several inches. An energetic metasomatic alteration has accompanied the veinlets, and cassiterite is locally observed in them, but nothing in the nature of a stanniferous stockwork has been formed.

The tin ore found in the quartz porphyry dike is associated with irregular seams and stringers of quartz and lithia mica. Cassiterite occurs both in the stringers and as an impregnation of the altered dike adjoining the stringers. Where the veinlets are absent the quartz porphyry contains no cassiterite, and is hard and barren. Wolframite is commonly associated with the cassiterite and, though no actual tests have been made, it is probable that the tungsten content of the lode is as valuable as the tin. Pyrite and arsenopyrite accompany the tin ore and more rarely sphalerite and galena are found. Locally the dike rock contains some molybdenite. The commonest gangue mineral is fluorite, with zinnwaldite next in order of abundance. Thin sections show also the presence of topaz in radial aggregates. Where alteration has been most intense large drusy masses of cubical fluorite and mica occur, and from such localities magnificent specimens of cassiterite in black splendent crystals have been obtained. The usual type of ore, however, is a soft kaolinized porphyry, stained red with iron oxide, and impregnated with cassiterite, wolframite, and sulphides. The dike is intensely and irregularly slickensided and clay gouge is common. The limestone wall rock, however, is firm and hard. It is considerably impregnated with fluorite, which glows with a greenish light when struck with the pick. Thin sections of wall rock immediately adjacent to the dike show that it consists of fluorite and radial topaz, with some colorless mica. Cassiterite occurs to a small extent in the wall rock in narrow veinlets (1 inch thick) consisting of divergent columnar topaz. In the vicinity of these veinlets the fluoritized limestone contains patches of coarse fluorspar and rosettes of topaz.

A few hundred feet north of the Cassiterite lode is another quartz porphyry dike, known as the Ida Bell lode. It is about 35 feet thick on the summit of the hill between Lost River and Cassiterite Creek. The rock is dense and fine grained. In the vicinity of Cassiterite Creek quartz stringers an inch or so in thickness, carrying cassiterite with some wolframite, cut the dike, but along its eastern extension only sporadic cubes of pyrite can be seen. The alteration that is so characteristic a feature of the Cassiterite lode is conspicuously absent from the Ida Bell quartz porphyry dike. The petrographic similarity which a number of other quartz porphyry dikes in the Lost River basin bear to this dike has occasioned considerable useless prospecting.

A. RETICULATE SEAMING OF LIMESTONE IN VICINITY OF CASSITERITE LODE.

B. SURFACE EXPOSURE SHOWING OCCURRENCE OF FLUORITE-SILICATE ROCK ADJOINING VEINLETS IN LIMESTONE.

One mile north of the Cassiterite lode is another tin-bearing porphyry dike named the Dolcoath lode. It is from 2½ to 3 feet thick, strikes N. 50° E. (magnetic) and dips 65° NW. This dike differs from the two previously described both in its mineralogy and in the mode of occurrence of the tin ore. It is so highly altered and mineralized that its original igneous character is not everywhere readily apparent. Least-altered phases show a dark-gray fine-grained rock containing numerous dull feldspar phenocrysts and a few quartz crystals. The feldspars prove to be near labradorite in composition, and the groundmass is largely obscured by secondary minerals, such as tourmaline, quartz, pyrite, mica, chlorite, and others. Some movement has taken place along the walls of the dike, especially the hanging wall, forming a crushed zone 1 to 6 inches thick. The dike rock is heavily charged with arsenical pyrites and tourmaline and contains some cassiterite disseminated through it. Locally the dike has been converted into large masses of danburite containing radial groups of tourmaline and an abundance of arsenopyrite. Cassiterite is inclosed in these three constituents, but is visible only under the microscope.

The wall rock of the dike is the dense-textured banded argillaceous variety of the Port Clarence limestone. The calcareous portion has been converted into coarse white spar containing random prisms of tremolite; the argillaceous bands have been converted into matted aggregates of tremolite fibers. Finely crystallized cassiterite occurs embedded in the coarse calc spar and locally is extremely abundant. Topaz in square prisms is found in the limestone to some extent. Cassiterite also occurs in the wall rock intimately intergrown with pocket-like masses of danburite, which is a calcium borosilicate related to topaz. The danburite is of light pinkish-gray color, with a peculiar vitreous greasy luster, and occurs as rude ill-defined columns in rough radial arrangement. Examination of the danburite-cassiterite ore in thin section shows that the cassiterite, which is finely idiomorphic, lies embedded in the danburite, and contains innumerable microlites of tourmaline. The danburite incloses some small patches of calcite, and may, like the cassiterite, inclose great numbers of minute tourmaline prisms. These bands of wall rock, which carry tin ore and show marmorization with accompanying development of danburite, topaz, and tremolite, occur on both foot and hanging walls of the dike, though nowhere more than 6 inches thick. Tremolite, however, persists to great distances from the dike, though in lesser abundance. Arsenopyrite has apparently replaced the wall rock to some extent also, as solid lumps of it containing only tremolite fibers have been found. The association of danburite and cassiterite is unique in the literature of tin deposits. To establish the identity of the danburite beyond question the following approximate partial analysis was made by W. T. Schaller on the purest material that could be obtained:

Analysis of danburite from Dolcoath lode, Lost River region.

SiO_2	47.54
Al_2O_3, Fe_2O_3	3.43
CaO	21.02
MgO	1.57
B_2O_3	[a]24.03
	97.59

Specific gravity, 2.98.

Developments.—At the time of visit five adits had been driven on the Cassiterite lode, three of which were open and could be examined. Tunnel B, 260 feet above Cassiterite Creek, was 180 feet long. The tunnel follows the southern margin of the dike, and is partly in limestone. At 45 feet from the mouth a drift has been run 10 feet to the north, crosscutting the lode. Tunnel A, 1,170 feet above the creek, was 80 feet long. The dike is soft and can be augered, so that an advance of 4 feet a day (single shift) is easily made. Both these adits are on the east side of Cassiterite Creek. Tunnel E, driven on the Cassiterite lode 10 feet above the creek level on the west side, is 100 feet long. A crosscut 9 feet long has been driven 50 feet from the mouth of the adit. The Ida Bell dike has been explored by an adit 55 feet long, at the end of which a winze 69 feet deep was sunk. This is now filled with water.

A few hundred feet south of the Cassiterite lode some open cuts and adits, now caved in, were opened on a porphyry impregnated with cassiterite. No surface croppings of this porphyry body are visible, for the porphyry is buried under the mantle of slide rock covering the steep slopes of the region. A shaft 50 feet deep was sunk on this occurrence, but was flooded at the time of visit. A number of open cuts have partly exposed some thin but rich quartz veinlets in the limestone. A shaft reported to be 18 feet deep was sunk near such a vein on the Jupiter claim, and a drift 44 feet long was run to the ledge, but both were also under water.

The developments on the Dolcoath dike consist of four cuts opened at intervals along a length of 3,000 feet. An assay of ore from one of the crosscuts was reported to have yielded 1.15 per cent of tin.

Seaming of the limestone.—The most striking feature in the vicinity of the Cassiterite lode is the vast multitude of veinlets that interlace the limestones in every direction (Pl. VII, *A*). The area thus affected extends for 1,000 feet or more on both sides of the stan-

[a] Two determinations made with concordant results by Messrs. Chapin and Wherry under the direction of Prof. Edgar C. Smith.

niferous portion of the dike. On the basis of dominant mineralogical composition five types of veinlets can be discriminated—fluorite-amphibole, plagioclase-fluorite, zinnwaldite-topaz, topaz-fluorite, and tourmaline-mica. The pure types occur, but innumerable intermediate and transitional forms are found also.

Veinlets (Pl. VII, *B*), only one-half inch thick, consisting of fluorite and radial amphibole, are paralleled on both sides by altered wall rock, 2 inches wide, sharply delimited against marmorized limestone containing minute fibers of tremolite. The wall consists of fluorite, amphibole, vesuvianite, and green mica irregularly intergrown. Where embedded in fluorite the amphibole is a deep-colored variety, pleochroic in tones of brown-green and blue-green.

Allied to the veinlets just described are dense white veinlets consisting essentially of fluorite and plagioclase. Locally they contain hornblende and scattered grains of pyrite and arsenopyrite. They are inclosed by dark-green rock, which is very delicately banded by thin white bands running parallel to the central veinlet. The larger bands are a millimeter in width, but the most of them are narrower, and some are as narrow as 0.1 millimeter. These features are most strikingly apparent on weather-etched surfaces. Small seams branching from the central veinlet cut across the banded rock. The metasomatically altered wall rock is thus elaborately banded at but few places; more commonly it is a structureless green rock. In thin section the central veinlet is seen to be composed of an intimate intergrowth of fluorite and calcic plagioclase (as calcic at least as Ab_1An_1), with scheelite as an accessory mineral. The inclosing rock is formed of fluorite, hornblende, and vesuvianite, but green mica, pyroxene, and calcic plagioclase also occur, and arsenopyrite and cassiterite are present as rare accessories. The hornblende and vesuvianite are prone to form small radial groups. The narrow white bands are composed of intergrowths of fluorite and plagioclase. The macroscopic appearance of the banded rock immediately recalls the orbules and banded veins of Tin Creek, and this external resemblance is confirmed by the similarity of mineralogical constitution as revealed by the microscope. The chemical origin of the banding is here more obviously apparent.

Veinlets of zinnwaldite up to 1 inch in thickness are common in the limestone. Under the microscope the zinnwaldite forms radiating fanlike groups diverging from the vein walls. The mica is dirty greenish and somewhat pleochroic at the points of attachment. Elsewhere it resembles muscovite. Some topaz occurs as an interstitial filling, and cassiterite and wolframite are rare accessory minerals. In the specimen examined optically the wall rock is a cryptocrystalline limestone exhibiting only a feeble alteration. Others, however, show an energetic fluoritization and notable increase of granularity. An analysis of the zinnwaldite has been made by W. T. Schaller[a] in the laboratory of the Survey, and is quoted here to illustrate the elaborate composition of this mica.

Analysis of zinnwaldite in limestone near Cassiterite lode, Lost River region.

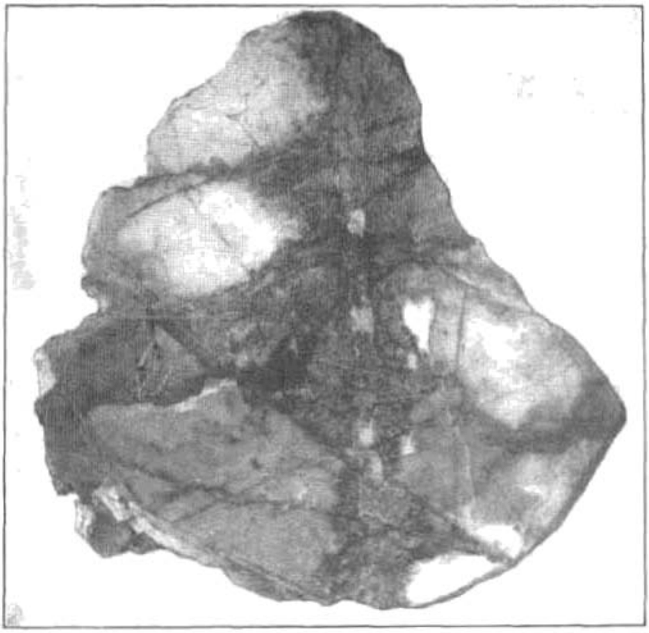
SiO_2	46. 80
Al_2O_3	24. 50
Fe_2O_3	. 50
FeO	6. 35
MnO	1. 38
CaO	. 24
Na_2O	1. 73
K_2O	9. 20
Li_2O	3. 73
H_2O	. 88
F	8. 63
	103. 94
Less O=2F	3. 63
	100. 31

Topaz-fluorite veinlets, carrying cassiterite and tabular crystals of wolframite, have produced both fluoritization and topazization of the adjoining limestone.

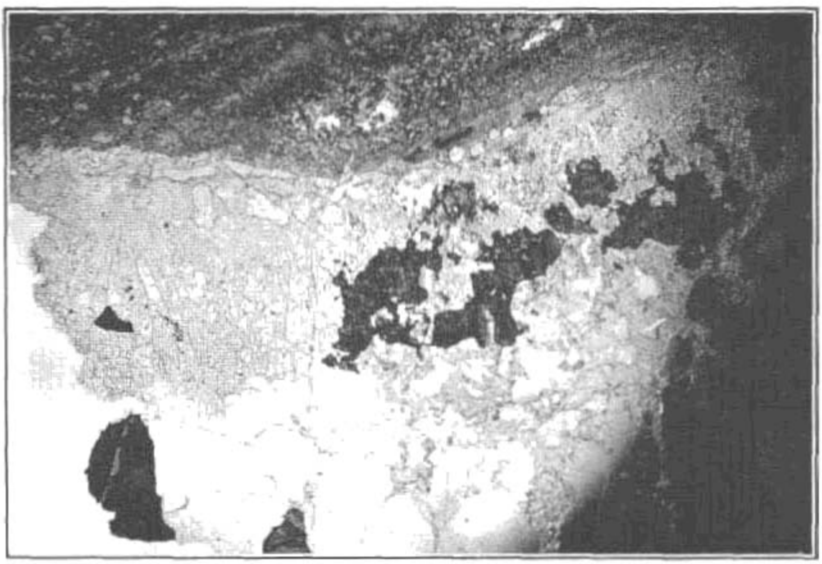
On the south side of the Cassiterite lode tourmaline veinlets are common in the limestone, though no tourmaline occurs in the tin ore of the dike rock. The cause of this peculiarity is not known. This type of veinlet is composed of white mica, blue tourmaline, and fluorite. Some carry visible cassiterite, but these are rare. Microscopic examination of a stanniferous veinlet (one-half inch thick) showed that the cassiterite is intergrown with scheelite, calcite, and mica (zinnwaldite?) and embedded in a gangue of mica, tourmaline, and fluorite. The limestone adjoining the tourmaline stringers has been converted into a confused intergrowth of green and indigo-blue tourmaline, fluorite, and magnetite, with accessory calcite, vesuvianite, green mica, and amphibole, forming a rock indistinguishable, texturally and mineralogically, from the contact-metamorphosed limestone of Ear Mountain.

A feature allied to the seaming of the limestone by the veinlets is found in an outcrop on the creek 200 feet below the Cassiterite lode, in which a zone of brecciated limestone has been recemented by various dark-colored minerals which here and there form large radial groups 3 to 4 inches in diameter. The cement or binding material when examined optically is found to consist chiefly of blue-green hornblende, vesuvianite, calcic plagioclase (Ab_1An_2), fluorite, minor amounts of calcite, and accessory scheelite.

[a] Am. Jour. Sci., 4th ser., vol. 24, 1907, p. 158.



A. POLISHED SURFACE OF SEAMED LIMESTONE SHOWING INTENSE METASOMATISM ACCOMPANYING THE VEINLETS IN LIMESTONE AND NUMEROUS SUBSIDIARY VEINLETS BRANCHING FROM MAIN VEINLET.



B. THIN SECTION OF CASSITERITE ORE.

Magnification 12 diameters. Radial topaz diverging from vein wall.

To sum up briefly: In spite of the diversity of mineral composition of the various veinlets it is found that all are accompanied by similar intense alterations of their wall rocks (Pl. VIII, *A*). They appear to be of practically synchronous origin, except, perhaps, the tourmaline veinlets, and the smaller seams represent leakages along subsidiary fractures. A more complete interchange of material between wall rock and solution was apparently possible in the minor seams, for vesuvianite and garnet appear in them, whereas these minerals occur only in the metasomatically altered wall rock of the larger veinlets.

Cassiterite and wolframite quartz veins.—It is a notable feature that, although the quartz stringers cutting the porphyry dikes contain cassiterite and wolframite together, those cutting the limestone contain either cassiterite alone or wolframite alone, and in large proportions. Veinlets of such diverse composition occur not many hundred feet apart. They average only a few inches in thickness and, so far as is now known, 30 or 40 feet in length.

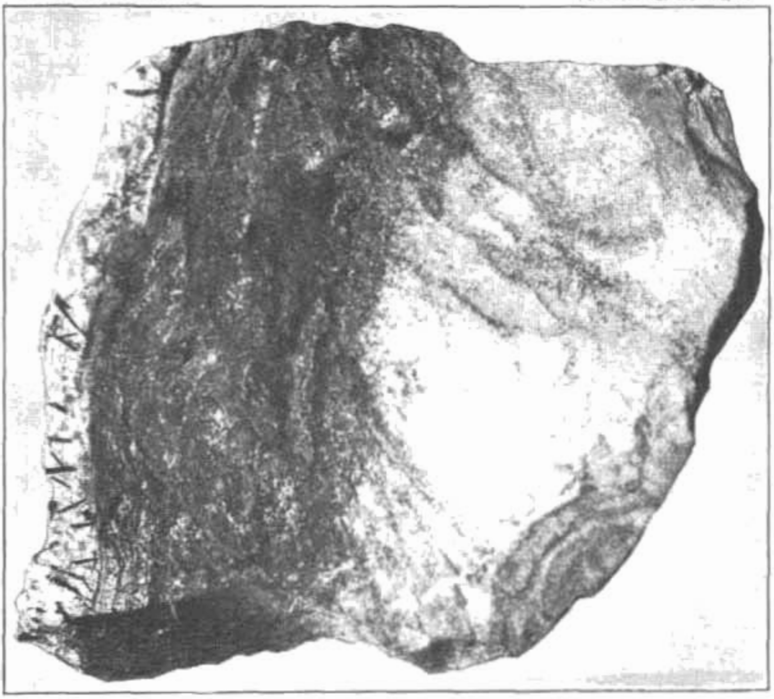
The cassiterite-quartz veins, while rare and of no great persistence, are extraordinarily rich in tin. Cassiterite, complexly twinned, occurs in crystals up to an inch in size. The predominant gangue mineral is quartz, with which are associated subordinate amounts of fluorite, feldspar, and white mica. The cassiterite is concentrated near the sides of the vein, which is frozen to the wall rock. Locally a thin band, one-eighth inch thick, of delicate radial topaz intervenes between the quartz gangue and the altered wall rock. Thin sections cut from this portion of the ore show groups of topaz prisms diverging from the wall of the vein (Pl. VIII, *B*). Closely associated with them are fluorite, white mica in well-defined plates, quartz, and cassiterite. The wall rock consists of a fine-grained aggregate of fluorite, topaz, and mica. Farther away from the vein the limestone is marmorized and transfixed with tremolite needles. The filling of the veinlets branching off from the cassiterite-quartz vein is not quartz, but is chiefly white mica. In the country rock adjoining the cassiterite-quartz vein, veinlets consisting essentially of white mica and lamellated plagioclase are common, and some of these are metalliferous. In their central portions they carry small amounts of galena, chalcopyrite, pyrrhotite, and sphalerite. The wall rock adjoining these veinlets, which average perhaps one-fourth inch in thickness, is altered to fluorite and aggregates of scaly green mica.

Some quartz stringers carrying considerable wolframite have been found cutting the limestone. The gangue material is dominantly quartz, but fluorite, white mica, and albite also occur. The altered wall rock consists of fluorite, green-blue hornblende, vesuvianite, green mica, and garnet, with scheelite and cassiterite as rare accessory minerals (Pl. IX, *B*). Sphalerite and chalcopyrite occur disseminated through the metamorphosed wall rock, though absent from the quartz veins themselves. The zone of metasomatism is sharply bounded by white saccharoidal limestone containing sporadic prisms of tremolite (Pl. IX, *A*).

The cause of the segregation of the cassiterite and wolframite into separate veinlets is not known. On the hill between Lost River and Cassiterite Creek a prospect trench has opened a tin-bearing veinlet 1 inch to 6 inches thick for a length of 30 feet. At one end the veinlet can be seen to pinch out. Throughout its length it is unusually rich in cassiterite and carries some wolframite and arsenopyrite. The gangue is composed essentially of topaz, fluorite, and zinnwaldite, arranged in a rudely banded structure. The middle band is the most distinctly defined, though only one-half inch broad, and consists chiefly of topaz imperfectly interlocking along a central line. The wall rock of this veinlet is highly altered and is impregnated to some extent with chalcopyrite, pyrite, and sphalerite. The study of this occurrence suggests that the simple quartz veins are due to a sort of differentiation from the primary solutions that deposited fluosilicates, and that, accompanying this change, a segregation of cassiterite from the wolframite may have taken place.

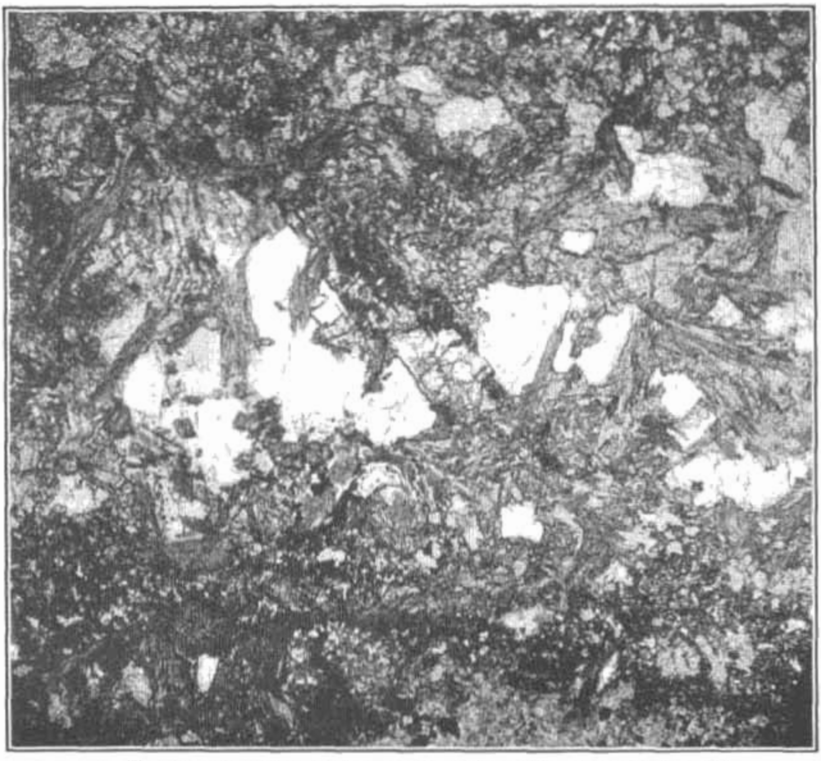
Metasomatic processes.—The Lost River occurrences throw some light on the metasomatism produced by stanniferous solutions acting on a nearly pure limestone. In the zone of most intense activity fluorine has effected a complex expulsion of the carbon dioxide with the production of abundant fluorite. On the assumption that the calcium remains constant and is combined as fluorite, this means a loss in volume of 34 per cent. This shrinkage appears to have been amply compensated for by the production of topaz, hornblende, vesuvianite, mica, plagioclase, and garnet, all of which involve an introduction of material, chiefly alumina and silica, with some FeO, Na_2O, K_2O, and Li_2O. Beyond the zone of fluoritization the limestone has been marmorized and some tremolite produced. The transition between the two zones is abrupt, and the difference of the amphiboles in them is a characteristic feature. The colorless tremolite, which is less abundant than the deep blue-green hornblende, has doubtless been produced by the recrystallization of impurities in the original limestone. Where the stanniferous solutions contained boron, alkali tourmaline has commonly been developed as a metasomatic mineral. At the Dolcoath dike the solutions appear to have been unusually rich in boron, and extensive danburitization has taken place, with accompanying development of cassiterite, tremolite, tourmaline, and topaz. Marmorization, too, has locally been intense, with the production of calcite individuals up to an inch in size.

The metasomatic processes outlined in the preceding paragraph are of a synthetic nature and have caused the formation of various



A. POLISHED SURFACE OF WALL ROCK ADJOINING WOLFRAMITE-QUARTZ VEIN.

Showing marked contrast between the marmorized limestone and the metasomatically altered limestone.



B. THIN SECTION OF WALL ROCK ADJOINING QUARTZ-WOLFRAMITE VEIN.

Magnification 32 diameters. Showing an intergrowth of hornblende, vesuvianite, and fluorite.

complex silicates, some of which, like topaz, danburite, vesuvianite, and hornblende, have not been described previously as alteration products in limestone adjoining fissure veins. Topaz, according to Rosenbusch,[a] is characteristic of the pneumatolytic contact zones of many granites. Danburite has recently been described as a constituent in some of the numerous contact-metamorphic deposits of Japan.[b] Vesuvianite is a typical contact-metamorphic mineral, and hornblende is common in the metamorphic aureoles of many granites. Tremolite, a common contact-metamorphic mineral, has, however, been recorded by Lindgren[c] from the Clifton-Morenci district as a metasomatic product in limestone adjoining fissure veins, and the unusual and significant character of this alteration has been pointed out. Tremolite, as has been shown, is one of the commonest products of the metasomatic activity of stanniferous solutions circulating in limestone, but only in the zone of least intense activity. To sum up briefly, the metasomatic alteration accompanying cassiterite veins in limestone, as exemplified by these Alaskan occurrences, is closely allied to contact metamorphism. The wall rock immediately adjoining the vein is characterized by the addition of material and the formation of fluo-, boro-, and alumino-silicates. This zone passes outward into one showing the features of simple thermal metamorphism—marmorization with the production of sporadic tremolite.

Wolframite-topaz lode.—A unique mineral deposit is exposed opposite the mouth of Tin Creek in an open cut on the ridge between Lost River and Left Fork. The surface indications show that the mineralization has taken place along a fault, running approximately east and west, which has brought two slightly dissimilar limestones into juxtaposition. Some brecciation is apparent along this line. The open cut shows stringers of ore occurring in a belt 1 foot thick, forming a stringer lode. The ore minerals consist of wolframite, galena, and stannite, and are embedded in a gangue of radial topaz associated with some deep-purple fluorite. The stannite is usually intercrystallized with the galena and is of a brown-black color. It reacts for tin, copper, zinc, iron, and sulphur. The topaz forms fine spherulitic aggregates, which may in places attain a diameter of half an inch, but as a rule are very small and are crystallized in delicate radial groups. The high specific gravity of topaz (3.5) gives the ore rock an unusually heavy weight. The surface ore is stained black by manganese minerals produced by the decomposition of wolframite. Some azurite is present also, and is doubtless derived from the copper

[a] Mikroskopische Physiographie, vol. 1, pt. 2, Stuttgart, 1905, p. 139.

[b] Beiträge zur Mineralogie von Japan, No. 3, Tokyo, 1907, p. 102.

[c] Lindgren, W., Copper deposits of Clifton-Morenci district, Arizona: Prof. Paper U. S. Geol. Survey No. 43, 1905, p. 176.

in the stannite. An assay[a] of a sample of this ore submitted by the Survey gave a return of 22.9 ounces of silver to the ton.

The gangue material was identified optically as topaz from its similarity to that associated with the tin ore on Cassiterite Creek. This determination was confirmed by an approximate quantitative analysis made by W. T. Schaller, with results as follows:

Analysis of topaz from wolframite-topaz lode, near Tin Creek.

SiO_2	30.27
Al_2O_3	54.66
CaO	1.16
MgO	Trace.
F	17.26
H_2O, alkalis	Not det.
	103.35
Less O=2 F	7.27
	96.08

The wall rock of the topaz lode consists of a dense cryptocrystalline limestone which shows no evidence of metasomatic alteration. The topaz lode is remarkable in two respects—it is the first recorded instance of topaz as a fissure-vein filling and as the gangue material of sulphide minerals. Topaz is common in the greisen adjoining cassiterite veins and in certain metasomatically altered quartz porphyry dikes, but has not hitherto been noted as a vein-forming mineral. It is regarded by Vogt[b] as distinctive of the cassiterite veins in contrast with the ordinary sulphide-ore veins (filons plombifères). The absence of metasomatic alteration in the limestone adjoining the topaz lode is noteworthy, but it will be recalled that some of the zinnwaldite-topaz veinlets in the vicinity of the Cassiterite lode show a similar lack of action on their wall rocks.

The stannite in the above-described wolframite-topaz lode is the only known verified occurrence of this mineral in the Alaskan tin region. Stannite is not a valuable tin-ore mineral, both on account of its relatively low tin content (30 per cent compared to 78 per cent in cassiterite) and its difficult metallurgical treatment. It is a rather favorite object of search with the prospector, chiefly because of the fascination which its unknown character exercises; and in consequence pyrite and pyrrhotite are commonly mistaken for stannite. It is, however, a mineral whose identity can be established only by careful chemical examination.

OTHER MINERAL DEPOSITS.

Alaska Chief property.—The Alaska Chief claim is situated about 4½ miles from Bering Sea, on Rapid River, the large western branch

[a] Made by Ledoux & Co., of New York.

[b] Genesis of ore deposits; special publication of Am. Inst. Min. Eng., 1902, p. 666.

of Lost River. The workings are on a small gulch tributary to Rapid River. The country rock is a tough, fine-grained limestone of the Port Clarence formation, lying nearly horizontal. Locally the strata are buckled and show crushing in the crest of the buckles. A fault breccia 15 feet wide, consisting of small angular fragments of limestone cemented together by white calc spar, is exposed in the creek one-third mile west of the mine. Basalt, in the form of a narrow dike 1 foot thick, is the only other rock known to be in place in the near vicinity of the mine. A few thousand feet to the east a number of quartz porphyry dikes can be seen cutting the limestone.

The original shaft was sunk in a heavy body of porous red iron oxide containing galena, reported to be 12 feet thick. At a depth of 35 feet work was suspended. An adit 143 feet long driven 85 feet below the collar of the shaft encountered the same ore body 50 feet below the bottom of the shaft. The ore was still oxidized. About 7 feet of low-grade galena ore was exposed.

On the east side of the gulch a devious tunnel, about 600 feet in length, was driven to catch another body of galena indicated on the surface. The tunnel follows a zone of crushed limestone, bounded in many places by fine walls marked with striæ. The "ledge matter" consists of small fragments of limestone bound together by coarse calc spar, clay, and red iron oxide. No ore was encountered. The tunnel on the west side of the gulch was then commenced, and the ore body already mentioned was struck late in August, 1907.

Idaho claim.—A few hundred yards below the mouth of Tin Creek a copper prospect has been opened on the edge of the 15-foot bench fronting Lost River, and at the time of visit enough work had been done to expose the face of ore at this point. The deposit occurs in an irregular shattered zone in the limestone, 15 feet wide and including numerous horses of unmineralized limestone. The ore mineral is chalcopyrite, associated with abundant pyrrhotite (magnetic iron pryites), and occurs in a gangue of calcite, fluorite, and small fragments of slickensided rock. Some of the fluorite is rose-tinted and is locally known as ruby quartz. Stripping has shown that the same ore body extends at least 50 feet to the east, where a strong gossan has been uncovered. The relatively great width of the deposit, combined with the low chalcopyrite tenor and the abundance of pyrrhotite, reduces the copper percentage to a small figure.

On Tin Creek a galena prospect has been opened on some gossan croppings at an altitude of 1,100 feet, 800 feet above the bed of the creek. The deposit occurs in a fracture zone in the limestone, which has been coarsely recrystallized in the immediate vicinity, forming spar crystals up to an inch in size. The gossan consists of honeycombed masses of iron oxide containing abundant galena and numerous white and colorless crystals of cerusite (lead carbonate). It was planned to prove the value of this deposit during the winter of 1907 and 1908.

A small trench, 650 feet below the galena prospect, has been dug in the effort to locate the bed-rock source of some loose bowlders composed of arsenopyrite flecked with a small amount of cupriferous pyrite. Assays made in Nome are reported to have yielded $12 to the ton in gold. Some stibnite in a gangue of purple fluorite has been found in the saddle at the head of Tin Creek.

ORIGIN OF THE ORES.

The injection of the quartz porphyry dikes represents the final intrusive activity of an underlying granite magma, of which a portion is now exposed by erosion on Tin Creek. Fracturing of the dikes, accompanied by shattering of the adjacent limestone, took place after their consolidation, and an energetic mineralization ensued. As shown by the vein fillings and metasomatic alterations the ore-depositing solutions were characterized by their richness in fluorine, aluminum, silicon, calcium, tin, tungsten, iron, manganese, arsenic, sulphur, lithium, potassium, and sodium, but contained also copper, lead, and zinc, and locally boron in abundance. The state of combination of the various elements in solution is not known. The vein material includes various silicates, such as topaz, zinnwaldite, tourmaline, and albite, and proves that conditions unusual in the formation of the ordinary types of veins prevailed. Albite and tourmaline are commonly regarded as indicative of the magmatic derivation of vein-forming waters, and topaz and zinnwaldite are the two most characteristic of the so-called pneumatolytic minerals. The presence of topaz in the vein matter itself is somewhat unusual, inasmuch as this mineral, although common in the greisen adjoining quartz-cassiterite veinlets in granite as a replacement of feldspar, is comparatively rare as a fissure filling. Of the minerals contained in the veinlets as Cassiterite Creek all, with the notable exception of quartz, have also developed metasomatically in the limestone. It is noteworthy that cassiterite, though present in large proportions in many of the veinlets, appears only in insignificant amounts in the intensely altered wall rock. In addition hornblende, vesuvianite, garnet, and others were formed, and prove that conditions allied to those obtaining during contact metamorphism prevailed. The stanniferous solutions were therefore presumably of magmatic origin and at high temperature and pressure.

The abundance of fluorine compounds—fluorite, topaz, and zinnwaldite—is in harmony with Daubrée's generalization [a] that fluorine is the active agent in the formation of tin deposits. According to

[a] Daubrée, A., Géologie expérimentale, p. 38.

his theory cassiterite is produced by the mutual decomposition of the vapors of water and stannic chloride reacting as follows:

$$SnCl_4+2H_2O=SnO_2+4HCl.$$

He was actually able to synthesize cassiterite in this way.

According to analogy we would expect—.

$$SnF_4+2H_2O=SnO_2+4HF.$$

Cassiterite has been produced at red heat by Deville and Caron [a] in conformity to this equation. Quartz can be synthesized according to an analogous reaction. In recent years Vogt [b] has been a vigorous exponent of the pneumatolytic or gas-aqueous origin of cassiterite deposits. He conceives that hydrochloric and hydrofluoric acids acting on a cooling granite magma effect an acid extraction of tin and the various elements associated with it. Gaseous conditions are therefore considered as dominant during the formation of cassiterite bodies, and the final individualization of the minerals is held to be due to the reactions of Daubrée's experiments.

Certain facts in the Lost River area suggest that fluorine is not, however, absolutely essential to the formation of cassiterite. On the Dolcoath dike some of the richest ore is intergrown with danburite ($CaB_2(SiO_4)_2$) and the limestone shows no fluorite, although the latter is common in the vicinity of the Cassiterite lode. Moreover, the cassiterite includes multitudes of tourmaline microlites, so that there is obviously a closer association of the tin with boron than with fluorine. On the other hand, the wolframite-topaz lode, with its content of galena and stannite, proves that tin and abundant fluorine may coexist in the same solution and cassiterite not be formed.

PLACERS.

BUCK CREEK.

Developments subsequent to 1905 have revealed few new facts of interest in regard to the placers of Buck Creek. The gravels have a length of about 4 miles and are shallow. Work below the mouth of Sutter Creek has shown that the gravel in that part of the stream is from 120 to 160 feet wide, averaging about 125 feet. The width of the pay streak is not known. A pit having a mean depth of 5 feet, from which 48 tons of concentrates have been extracted, has demonstrated that the gravel may run as high as 25 pounds per cubic yard. The gravel is a comparatively fine wash and bowlders are rare, the

[a] Compt. Rend., vol. 46, 1858, p. 764.
[b] Zeitschr. prakt. Geologie, 1895, p. 475.

largest noted consisting of greenstone about a foot in diameter. The richest gravel rests immediately upon bed rock and is exceedingly clayey and toughly bound together. It gives difficulty in washing, the clay having a tendency to roll up in balls and carry cassiterite nuggets over the sluice boxes. The bed rock is a broken shale or slate, very clayey, but contains no cassiterite. On Sutter Creek, the large southern branch of Buck Creek, there is a considerable body of gravel, and the discovery of stream tin has recently been reported on it. The other tributaries, gulches, and "benches" of Buck Creek contain little or no gravel, at least in amounts sufficient to warrant an outlay for the purpose of placer mining.

The stream tin of Buck Creek is clearly derived from the erosion and concentration of the cassiterite occurring in the quartz stringers so abundant throughout the area. This source was partly supplemented by the cassiterite occurring in the actinolite rock, and to a lesser extent by that contained in the quartz porphyry dikes. As these bed-rock sources are known to occur in place on the summit of the hills at the head of Buck Creek, it is probable that some of the creeks flowing into Lopp Lagoon carry stream tin. But whether cassiterite is present in these streams in payable quantities is purely a matter of accurate sampling, and not of opinion or theory—an idea which prevails in certain quarters to the detriment of the region.

Two companies were in operation on Buck Creek during 1907, but on account of a number of adverse circumstances the yield was less than was expected. Placer mining was confined to a small strip just below the mouth of Sutter Creek, and the total output of the year was approximately 50 tons of concentrates.

At the beginning of the season the American Tin Mining Company was working its ground by means of an automatic scraper and belt conveyor operated by a 35-horsepower oil-burning engine. Early in August, however, extortionate freight rates on the transportation of crude oil from Nome to York and the imperfect adaptation of the scraper to the character of the gravel necessitated a change in the method of working. Shoveling in was then adopted, with results at least more satisfactory than those attained with machinery. The other company also employed the shoveling-in method, and the tailings were removed by a horse and scraper.

GROUSE CREEK.

During the summer of 1907 assessment work was done on a number of claims on Grouse Creek and two of its tributaries, Sterling and Skookum creeks. The results are not known. Some gold sifted out of the stream-tin concentrates from Sterling Creek was flat, coarse, and not greatly waterworn, and had quartz still adhering to it.

FAIRHAVEN DISTRICT.

A sample of black-sand concentrates from Humboldt Creek sent in to the office for determination proved to be a rich tin ore containing less than $5 per ton in gold. About two-thirds of the sample was pyrite. Another sample of concentrates sent in from Kougarok River was found to contain considerable cassiterite, but far less than the Humboldt Creek sample. It carried, however, 85 ounces of gold per ton and contained 66 per cent of pyrite and about 10 per cent of magnetite. As the headwaters of Humboldt Creek drain the Hot Springs granite area, the tin was probably derived from that region. Collier states that samples of tin ore purporting to come from it were brought to Nome late in the season of 1902.

RÉSUMÉ AND CONCLUSIONS.

Four localities in the western part of Seward Peninsula are being prospected for lode tin at the present time. From one stream—Buck Creek—placer tin is actually being extracted, and an output of approximately 50 tons of concentrates was attained in 1907.

The sedimentary rocks of the York region comprise a series of slates of unknown but probably early Paleozoic age, a thick volume of thin-bedded limestone of Ordovician age (Port Clarence limestone), and crystalline limestone of Carboniferous age. At Ear Mountain contorted limestones and lime-mica schists prevail. These rocks are intruded by a number of granite masses, which, though appearing in isolated stocks, show by the many features that they possess in common that they belong to the same irruptive magma. The granites are coarse-grained types with large porphyritic feldspars and quartz which is commonly of a conspicuously smoky character. They were unusually rich in volatile constituents, among which boron, fluorine together with chlorine, and iron were the most prevalent, and they are therefore characteristically surrounded by pneumatolytic contact aureoles. Large amounts of the magmatic emanations were retained by the limestones in such minerals as tourmaline, axinite, ludwigite, hulsite, paigeite, boron vesuvianite, magnetite, hedenbergite, fluorite, scapolite, and chondrodite.

Complementary contact phenomena occur at Cape Mountain, where giant granite selvages are overlain by fluoritic and scapolitic pyroxene hornfels containing accessory scheelite. These phenomena are regarded as showing on the one hand the effect of the mineralizers on the crystallization of the magma, and on the other hand their effect in producing intense metasomatic action on the adjoining limestone. Essentially similar metasomatism was produced by a pegmatite intrusive in the marble surrounding the granite stock of Brooks Mountain. Along Tin Creek a novel type of contact metamorphism which has produced perfect orbicular forms has occurred. The orbules are allied in their origin to garnet-vesuvianite masses, which have injected small banded apophyses, as it were, into the inclosing limestone. The supply ducts for the orbules consist of curious banded veins composed of fluorite, calcic plagioclase, and pyroxene, with accessory arsenopyrite, cassiterite, and scheelite.

The tin deposits are genetically associated with the granitic intrusives. Cassiterite occurs in a variety of ways:

(1) In a tourmaline-axinite hornfels.

(2) In beds of actinolite rock which are probably interstratified with slates.

(3) In tourmalinized margins of granite masses and granitic dikes.

(4) In mineralized quartz porphyry dikes.

(5) In quartz veins cutting granite and accompanied by impregnation of the adjoining granite.

(6) In quartz stringers cutting slates and limestones.

In addition, tin is found to be present as paigeite (an iron-tin borate) in lime-silicate hornfels.

At Ear Mountain cassiterite occurs in a contact-metamorphosed limestone consisting essentially of tourmaline, axinite, and actinolite, but it is not found in any of the other pneumatolytic contact rocks of the region. This is a fact of considerable interest from the standpoint of ore genesis. The stanniferous granite magma was rich in halogens and boron, and theoretically the limestones are favorable loci for the precipitation of cassiterite. By the action of stannic chloride ($SnCl_4$) vapor on lime Daubrée[a] was able to synthesize cassiterite. The limestone contacts might therefore be expected to show this mineral. But as a matter of fact the contact rocks, although rich in pneumatolytic minerals, are as a rule barren of tin. The advent of the cassiterite was postponed to a later stage, and where evidence can be obtained as to the relative ages of intrusion and mineralization the latter postdates the injection of the quartz porphyry or rhyolitic dikes. This would appear to indicate that a long period of preliminary concentration was taking place in the cooling magma.

The rarity of cassiterite as a contact-metamorphic mineral the world over is anomalous. As far as the writer is aware the only deposit in which it is unequivocally of contact-metamorphic origin is that in the Dartmoor Forest, Devonshire, England, described by Busz.[b] At this locality hornfels adjoining the granite contact consists essentially of light-colored mica, quartz, and tourmaline with innumerable grains and minute crystals of cassiterite scattered throughout the rock.

[a] Compt. Rend., vol. 39, 1854, p. 138.

[b] Busz, K., Neues Jahrb., Beil. Band 13, 1899, p. 100.

At the St. Dizier mine,[a] in Tasmania, cassiterite occurs in a magnetite-silicate rock of the Kristiania type, but it is not entirely clear whether the cassiterite is contemporaneous with the other constituents. According to Twelvetrees[b] the tin-bearing rock at the Stony Ford mine, Tasmania, is a band of quartz-chlorite rock, charged with pink garnets, pyrite, some blende and chalcopyrite, and cassiterite. This is regarded as probably resulting from the contact metamorphism of slates and sandstone. At Pitkaranta, Finland, cassiterite occurs lining druses along a definite formation consisting of lime-silicate rock ("skarn") that was produced in early pre-Cambrian time by the contact metamorphism of a limestone. The tin ore, however, is connected with the intrusion of the Rapikiwi granite of late pre-Cambrian age, and is regarded as of contact-metamorphic origin, being due to magmatic solutions flowing along pervious contacts. This conception[c] of the genesis of the deposits would practically extend the term contact metamorphism to all deposits formed by juvenile waters of high temperature.

A remarkable similarity, both mineralogic and geologic, exists between these deposits and those of Schwarzenberg in Saxony,[d] where cassiterite occurs as a secondary impregnation in a salite-tremolite rock which at some distance from the contact encircles a granite mass. Dalmer, however, would include these deposits as a phase of contact metamorphism, using that term in its largest sense. From this review it would appear that stanniferous contact deposits of the Kristiania type are of extremely rare occurrence. One such deposit of commercial importance has yet to be found. This is certainly a surprising fact in view of the commonly accepted theory of the pneumatolytic origin of the majority of tin-ore deposits.

The Alaskan tin deposits exhibit a number of unique features. These include the association of cassiterite and arsenopyrite in a gangue of actinolite; the intergrowth of cassiterite with the rare calcium borosilicate, danburite; and the occurrence of an argentiferous wolframite-topaz lode containing galena and stannite. An opportunity has been afforded by the prevalence of limestones in the region to study the metasomatism connected with cassiterite veins in such rocks, and the study has shown that it resembles contact metamorphism in its dual aspect—that is, metamorphism both with and without addition of material.

[a] Waller, G. A., Tin-ore deposits of Mount Heemskirk, Govt. Geol. Office, Tasmania, 1902, p. 46.

[b] Twelvetrees, W. H., Tin mines of the Blue Tier, Govt. Geol. Office, Tasmania, 1901, p. 29.

[c] Trüstedt, O., Die Erzlagerstätten von Pitkäranta am Ladoga-See: Bull. Comm. Geol. de Finlande, No. 19, 1907, p. 316.

[d] Beck, R., Erzlagerstätten, 2d ed., Berlin, 1903, p. 444.

In general, the tin shows the intimate association with fluorine and boron observed in most tin deposits the world over, an association that is emphasized by the discovery of the new iron-tin borates as essential constituents of lime-silicate contact rocks in the metamorphic aureoles of granitic intrusives.

PRACTICAL DEDUCTIONS.

Developments in this region have been sufficient to demonstrate, at least, that the granite-limestone contacts are not favorable places to hunt for commercial bodies of cassiterite ore. Although a great variety of contact-metamorphic rocks have been produced around the peripheries of the granites only a few that are stanniferous were found, and in only one was even a small amount of cassiterite detected. The bunchy and erratic character of contact-metamorphic ore bodies has been repeatedly emphasized in the preceding pages, and attention has been drawn to the difficulty of mining such deposits occurring along irregular contact surfaces. The same drawbacks pertain also to tin ore found in the tourmalinized borders of the granite stocks. In view of the widespread belief in Seward Peninsula that contact deposits are likely sources of tin ore, it is worth while to review here what is known of cassiterite contact-metamorphic deposits in other parts of the world. There has been an actual production of tin from two only—Pitkaranta in Finland and Schwarzenberg in Saxony—and in amounts that are relatively small. The ore at these localities contains pyroxene and other minerals common in the Alaskan contact-metamorphic deposits, but the ore formation is confined to certain definite strata that were evidently favorable to the precipitation of the cassiterite. Some tin ore deposits of probable contact-metamorphic origin have been reported from the Stony Ford mine [a] and St. Dizier mine [b] in Tasmania, but they have not entered the ranks of large producers.

Quartz porphyry dikes, locally known as lodes, or even as quartz veins, have been prospected to some extent, owing to the fact that the original discovery of lode tin in Alaska was made on a mineralized and altered dike of this character. The value of any such dike depends on the number of cassiterite stringers which it contains and the closeness with which they are spaced. Of itself, a quartz porphyry dike has no value. The unwelcome fact should be speedily realized that few of these dikes hold out any inducements whatever as prospective tin producers.

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[a] Twelvetrees, W. H., Tin mines of the Blue Tier, Govt. Geol. Office, Tasmania, 1901, p. 29.

[b] Waller, G. A., Tin ore deposits of Mount Heemskirk, Govt. Geol. Office, Tasmania, 1902, p. 46.

Most of the developments throughout the region are still in the prospecting stage, and many of the open cuts have not uncovered solid bed rock. No tonnage of tin-bearing rock, except at one place on Lost River, has yet been blocked out. Small holes in the ground, which give no clew to either dip, strike, or persistence of the ore rock, are held at enormous figures. The great need of the country is less desultory prospecting. The slate area deserves more careful examination, as it is possible that valuable quartz veins may exist within its confines. The distribution of stream tin in Anikovik River and its tributaries proves that the stanniferous mineralization is not limited to the region at the head of Buck Creek, but is more widely spread throughout the slate belt.

It is probable that a great granite mass, of which the stocks at Brooks Mountain, Tin Creek, and Cape Mountain are protruding bosses, underlies the entire York region. As shown by the prospects of tin, tungsten, copper, lead, and zinc, and probably gold, this magma was capable of effecting a varied mineralization. As the region becomes better known and more thoroughly prospected, additional discoveries will probably be made from time to time.

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