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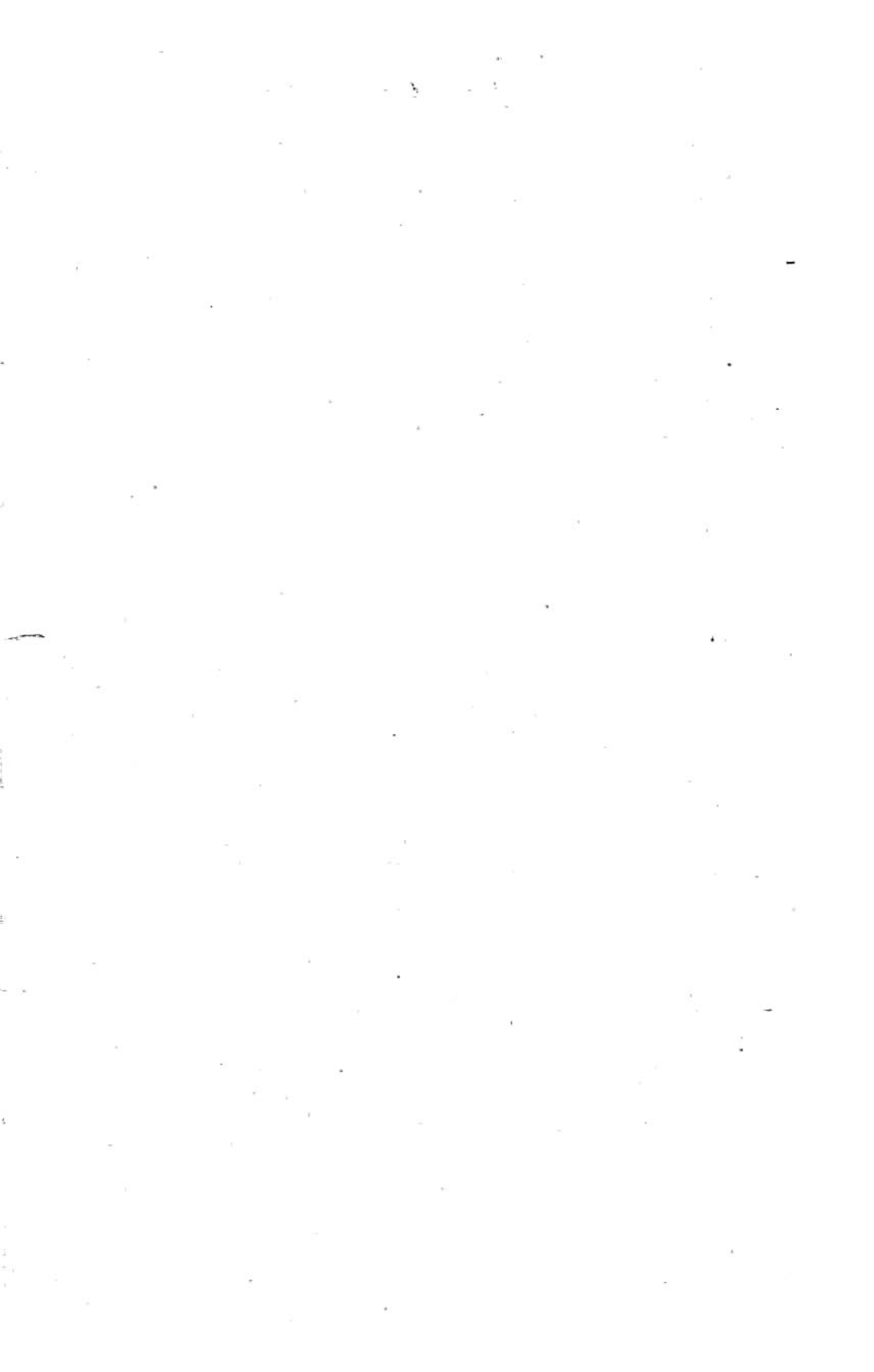
T H E  
  
TIN DEPOSITS OF THE YORK REGION, ALASKA

BY

ARTHUR J. COLLIER



WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1904



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## LETTER OF TRANSMITTAL.

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DEPARTMENT OF THE INTERIOR,  
UNITED STATES GEOLOGICAL SURVEY,  
*Washington, D. C., March 2, 1904.*

SIR: I have the honor to transmit herewith a report entitled "The Tin Deposits of the York Region, Alaska," by Mr. Arthur J. Collier, and to recommend its publication as a bulletin.

Placer tin was discovered in this region in 1900, and since that time active prospecting has been going on to determine the extent and distribution of the stream tin, and also to locate its source in bed rock. Though the occurrence of tin-bearing lodes had been previously reported, the first authentic discovery of this kind was made by Mr. Collier during the last season, and this find has awakened great interest in the district. The demand for authentic information regarding these occurrences has led to the preparation of this report, which is based on a very hasty field examination. The aim has been to summarize all the information in regard to the occurrence of tin which might be of value to the prospector, and for this reason a brief description of the better known tin deposits of the world has been included. The publication of the geologic results of these investigations is deferred until a more complete study of the notes and specimens has been made.

Very respectfully,

ALFRED H. BROOKS,  
*Geologist in Charge of Division Alaskan Mineral Resources.*

HON. CHARLES D. WALCOTT,  
*Director United States Geological Survey.*





OUTLINE MAP OF SEWARD PENINSULA, ALASKA, SHOWING POSITION OF YORK REGION.

# THE TIN DEPOSITS OF THE YORK REGION, ALASKA.

By ARTHUR J. COLLIER.

## INTRODUCTION.

The known occurrences of tin in Alaska are close to the westernmost point of the American continent, in the York region of Seward Peninsula, the land mass which projects from the west coast of Alaska to within 60 miles of the coast of Asia. The peninsula as a whole has become famous in recent years on account of its gold placers, and every summer it is the objective point of a fleet of vessels loaded with prospectors following the ice pack in its northward retreat. The city of Nome, its most important mining camp, is the metropolis of Alaska. North of Seward Peninsula the Arctic Ocean stretches away toward the pole, while on the south Bering Sea, icebound for half the year, extends for 700 miles to the open water of the Pacific Ocean.

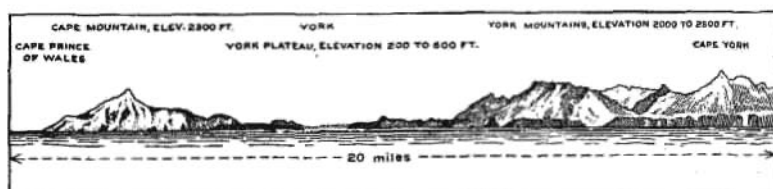


FIG. 1.—Sketch of the coast from Cape York to Cape Prince of Wales.

*Geographic position of the York region.*—The York region, which derives its name from Cape York, an ill-defined promontory on Bering Sea, about 100 miles northwest of Nome, comprises that portion of the peninsula west of the entrance to Port Clarence, thus including Cape Prince of Wales, the westernmost point of the American continent. Its general geographic position is shown in the outline map, Pl. I.

Reference to the topographic map, Pl. II, will show that the region has the general form of an isosceles triangle, with its apex at Cape Prince of Wales and its two sides formed by the shore lines of the Arctic Ocean and of Bering Sea. The southern coast line is, in the main, inhospitable and unbroken by inlets or harbors. The land usually presents abrupt escarpments rising from narrow rocky beaches and giving it a forbidding character, well shown by the sketch reproduced

in fig. 1. On the north the slopes toward the Arctic Ocean are more gentle, and the coast is characterized by barrier beaches that cut off broad lagoons from the open sea. Such a one is Lopp Lagoon, a large body of water that is unfortunately too shallow for any but light-draft boats. The large bay known as Port Clarence, 20 miles southeast of York, is the only good harbor in the region.

The York Mountains occupy the southeastern part of the triangle and culminate in Brooks Mountain, 2,900 feet in altitude, the highest point in this part of the peninsula. These mountains have rugged crest lines, their continuity being broken by several broad streams and river valleys, but when seen from a distance their summits have an even sky line from 2,000 to 2,900 feet above the sea. To the north and west of this mountain group stretches the so-called York Plateau, a comparatively smooth upland surface 200 to 600 feet above sea level that comprises the greater part of the region under discussion. The smaller streams crossing this plateau flow in sharply cut V-shaped canyons, while the larger streams occupy comparatively broad valleys containing large accumulations of gravel. On the south the plateau presents an escarpment to Bering Sea, but on the north it slopes gently downward to a coastal plain dotted with lakes, through which the rivers and streams meander to the Arctic Ocean.

The drainage of the region runs either northward or southward, but the watershed lies much nearer Bering Sea than the Arctic Ocean.

*History of recent exploration and development.*—The chief settlement of the region is York, a collection of cabins and tents on the open coast of Bering Sea at the mouth of Anikovik River, about 10 miles east of Cape Prince of Wales and 5 miles west of Cape York.

Previous to the discovery of gold at Cape Nome very little was known regarding the York region. A mission had been established for a number of years at Cape Prince of Wales, where one of the Government reindeer herds was maintained. After the first rush to Nome prospectors rapidly extended their search to all parts of the peninsula, and as early as the fall of 1899 some placer gold had been found in the Anikovik River Basin.<sup>a</sup>

In 1900, A. H. Brooks, of the United States Geological Survey, during his investigation of the southern part of the Seward Peninsula, spent several days in the York region and brought from the placers of Anikovik River and Buhner Creek, one of its tributaries, some concentrates, which proved to contain stream tin.<sup>b</sup>

In July, 1901, the writer spent a number of days in the York district,

<sup>a</sup> Schrader, F. C., and Brooks, A. H., Preliminary report on Cape Nome gold region, Alaska: Special report on Alaska, U. S. Geol. Survey, 1900, pp. 25-26.

<sup>b</sup> Brooks, A. H., An occurrence of stream tin in the York region, Alaska: Mineral Resources U. S. for 1900. U. S. Geol. Survey, 1901, pp. 267-271. A new occurrence of cassiterite in Alaska: Science, new ser., vol. 13, No. 328, 1901, p. 593. A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900; special report on Alaska, U. S. Geol. Survey, 1901, pp. 132-139.

before the news of the discovery had been disseminated among the miners, and it was possible only to verify the facts regarding tin ore reported by Mr. Brooks. A reconnaissance geologic map of the region was prepared and published in the report of the season's work, together with some suggestions in regard to the possible occurrence of tin ore.<sup>a</sup> In the latter part of the season, a great many prospectors searched the York region for tin, and before winter they had located promising deposits of stream tin on Buck Creek, a tributary of Mint River, about 20 miles north of the town of York.

In 1902 the search was continued and the first real attempts to mine the tin-bearing gravels were made on Buck Creek. The nature of this occurrence and the mining conditions which existed there at that time have been described by Mr. Rickard.<sup>b</sup>

In 1903 the writer was detailed to continue investigations of the mineral resources of the Seward Peninsula, and Mr. F. L. Hess was assigned to his party as field assistant. The party also included two experienced camp hands, and was equipped for traveling inland with a pack train of five animals. Nearly all the important placer mining camps of the peninsula were examined during the course of the work. Though a visit to the York region had not been contemplated, it was found upon arrival in the field that the interest in the tin deposits at York had not subsided, and that developments since 1901 justified further investigations, though there was little time available for this purpose. The party reached Teller in the latter part of July and there met a number of prospectors who had been searching for tin in the York region, and who desired to have their specimens examined, since they were unable to identify tin ore. Among these specimens only one piece of tin ore was found, but it had been obtained in a new locality and consisted of cassiterite crystals still in the matrix, indicating that its original source might easily be found.

On the following day Mr. Hess and the writer, accompanied by two prospectors, started from Teller in a small sailboat en route to the scene of the tin prospecting operations in the York region. During the following week Lost River, Buck Creek, and Cape Mountain were visited and the tin deposits at these places were examined. This work had to be done with such haste as to make the results in many respects unsatisfactory, since the work in other districts comprehended in the writer's instructions was sufficient to consume the whole season. The examination of the Lost River locality was made by Mr. Hess and the writer jointly, while Buck Creek was visited by Mr. Hess and Cape Mountain was visited by the writer.

<sup>a</sup> Collier, A. J., Reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 49.

<sup>b</sup> Rickard, Edgar, Tin deposits of the York region, Alaska: Eng. and Min. Jour., vol. 75, 1903, pp. 30-31.

*Purpose of this bulletin.*—It is the purpose of this bulletin to combine the results obtained by the United States Geological Survey parties that have visited the region, together with the information derived from a study of specimens of tin ores and associated minerals recently brought from the York region by outside parties, and to present such facts in regard to the occurrences and value of the metal as may be of assistance to those interested in the development of the field. Throughout the field and office work the writer has had the efficient aid of Mr. Hess, who has devoted special attention to the compilation of the literature referring to tin deposits. The work of Mr. Eugene C. Sullivan, chemist of the Survey, who elaborated a method of analyses by which minute traces of tin could be detected, and who also made assays of the material from the York region, has added greatly to the value of the report.

### GENERAL GEOLOGY.

The geology of the York region, as has been shown, has been subject to investigations during the years 1900, 1901, and 1903, but all of this work was of a reconnaissance character, and the results have not yet been correlated with the latest work in other parts of the peninsula; hence it has been thought best to defer their publication for the present.

A sketch map (fig. 2) is here introduced to show the relative distribution of the more prominent rock types, without attempting, however, to subdivide them into formations or to indicate their stratigraphic and structural relations. In this map the horizontal distribution of four different rock types is indicated. These include slates and limestones, probably of Paleozoic age, and some granular intrusives, chiefly of a siliceous character. The slates and limestones form belts of irregular outline extending north and south, while the igneous rocks are found in intrusive stocks and dikes, the former outcropping in more or less circular areas. Besides these hard rocks, Pleistocene and Recent sands and gravels form the surface deposits of the northern coastal plain, and are also found in the valleys of many of the streams.

### SEDIMENTARY ROCKS.

It is seen in fig. 2 that the larger part of the area surrounding the York Mountains is occupied by limestone. This limestone has an ash-gray color and exhibits little evidence of metamorphism. It is characterized by low dips and comparatively simple structure. This formation has been called the Port Clarence limestone,<sup>a</sup> and has been definitely traced over an area of about 1,400 square miles, extending

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

eastward from Cape York. The Port Clarence limestone is known to be of upper Silurian age, and it is safe to presume that a large part of the sedimentary rocks of the York region are also upper Silurian. The continuity of this limestone is interrupted by several small

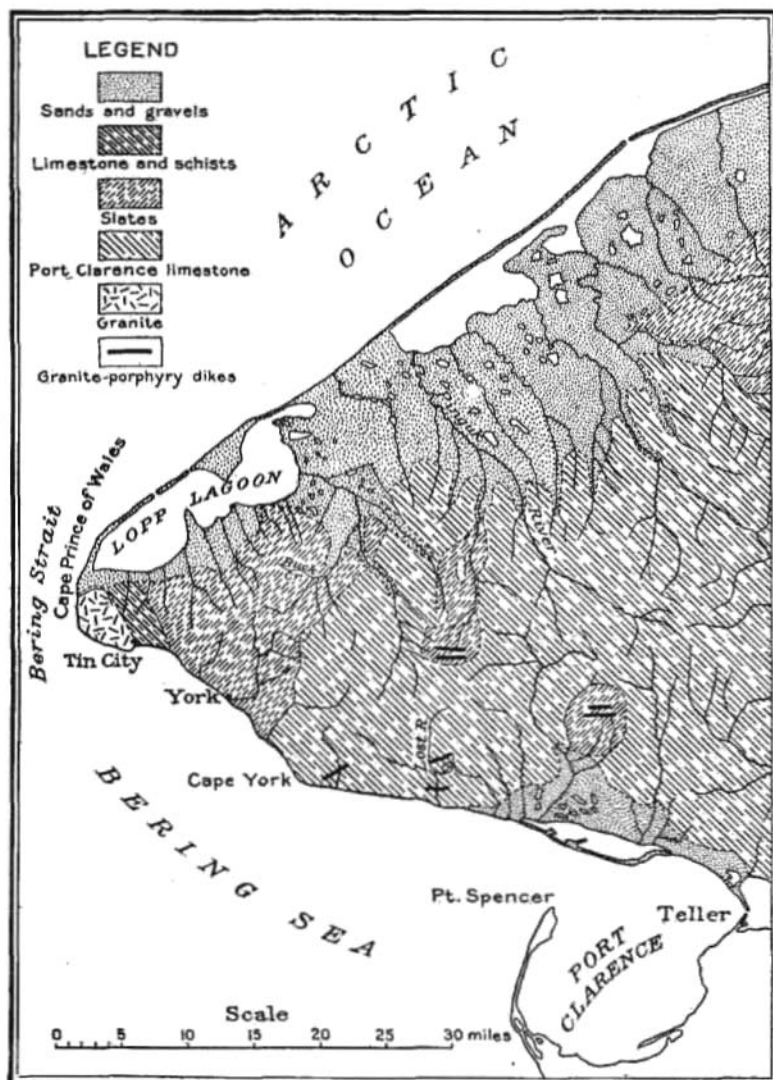


FIG. 2.—Geological sketch map of the York region.

slate areas of irregular outline, and a large belt of these rocks lies to the west of the York Mountains, forming the mass from which the greater part of the York Plateau is cut. These rocks, often so altered that they might more properly be called schists, are of a graphitic,

arenaceous, and sometimes calcareous character, and are of very fine texture. They are much jointed and broken by lines of cleavage into rhombohedral blocks and pencil-shaped fragments. The bedding is often obscured and sometimes obliterated by the highly developed joint structures. The age of these slates has not been determined. In 1900 they were correlated by Brooks<sup>a</sup> with the so-called Kuzitrin slates, which outcrop along the northern base of the Kigluaik Mountains. The work of the writer in 1901 pointed to the conclusion that they are older than the Port Clarence limestone, but this fact has not yet been definitely established. There is some indication of faulting along the contact of this slate belt and the limestones to the southeast.

West of the slates there is a narrow belt of highly altered limestone or marble more or less interbedded with micaceous schists. This belt, about 4 miles in width, lies between the slates on the east and a large mass of granite on the west, the latter forming the peak known as Cape Mountain. Some obscure fossils collected during the past season indicate that these limestones are either of Devonian or Carboniferous age. The stratigraphic relations of this limestone to the slates on the east have not been definitely determined.

#### SURFICIAL DEPOSITS.

The unconsolidated gravels and silts form the youngest group of sediments of the region. On the sketch map these deposits are shown mantling an area bordering the Arctic coast. This is the western end of a very extensive gravel deposit which covers the low Arctic coastal plain of Seward Peninsula from Cape Espenberg to Cape Prince of Wales.<sup>b</sup> These deposits extend to the base of the hills and in the valleys merge with the stream gravels with which they probably have common origin. In the southern part of the York region these surficial deposits are confined to the creek beds and narrow strips along the coast, and are usually too small to be shown on the map. All of these gravels are water-laid deposits, there being no evidence of glaciation. They form a part of the great Quaternary mantle that is so extensively developed in Seward Peninsula and adjacent portions of Alaska. The gravels, which are of economic interest because they locally contain concentrations of stream tin, will be described in another part of this paper.

<sup>a</sup> Brooks, A. H., Richardson, G. B., and Collier, A. J., A reconnaissance of the Cape Nome and adjacent gold fields of Seward Peninsula, Alaska, in 1900: Special report on Alaska, U. S. Geol. Survey, 1901, p. 133.

<sup>b</sup> Collier, A. J., Reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 25.

## IGNEOUS ROCKS.

Two distinct types of igneous rocks are present, one of which is basic while the other is acidic. The first group includes basic dikes and sills, all more or less altered and sometimes schistose, which may be grouped together under the general name of greenstones. The greenstones and greenstone-schists include a number of more or less altered intrusive masses, and occur most frequently in the slates near the contact with the limestone which forms the York Mountains. Boulders of this rock are widely distributed in the gravels of the region. Under the microscope they appear, for the most part, to be altered gabbros. They are often called granite by the miners, but can readily be distinguished from the true granite by a general green color and the absence of quartz. This distinction is of importance, for, so far as known, no tin deposits have been found in association with the greenstone.

The second group consists of more acid rocks and includes a number of large masses of granite together with dikes of a fine-grained, porphyritic rock containing prominent quartz crystals. These dikes often form a fringe surrounding the larger granite masses, of which they are probably offshoots. Granite masses of the same type occur in occasional outcrops from Cape Prince of Wales northeastward for over 100 miles, and form a zone which also finds a western extension in the Diomed Islands and possibly in the granites on the Siberian coast.

In the York region these rocks find their greatest development in Cape Mountain, where a great stock of granite is intruded into the limestone. The Cape Mountain granite is coarsely crystalline, somewhat porphyritic, and consists essentially of quartz, microcline, and biotite, but contains as accessory minerals, albite, muscovite, zircon, apatite, tourmaline, pyrite, and fluorite.

At Brooks Mountain, which is largely made up of slates, a number of dikes of granitic and rhyolitic rocks were observed, but these have not yet been studied microscopically. A few miles to the south, near Lost River, a number of granite and rhyolite intrusions in the limestone have been examined and will be described in some detail in connection with the Lost River tin deposits. The granites of this region, and especially those at Lost River, have been considerably altered and have taken various forms to which the name "greisen" has been applied because of their similarity to the vein rocks of the tin deposits of Cornwall and Saxony. The typical greisen of Saxony is a granite made up of quartz and lepidolite, or lithia mica, with fluorite, tourmaline, topaz, and cassiterite in small amounts.

The distribution of the granite intrusives is of the greatest economic importance, since many of the known lode deposits of tin occur in granite dikes. The prospectors of the region have readily recognized this and have made careful search along these contacts.



## ECONOMIC GEOLOGY.

## GENERAL STATEMENT.

Tin is known to be irregularly distributed in the York region over an area of about 450 square miles, embracing the western end of the peninsula. Its occurrence in alluvial deposits has been verified by the United States Geological Survey at three localities, and the existence of tin-bearing lodes has been observed at two points. The extreme points known are 25 miles apart. In addition to these, prospectors report the occurrence of tin at a great many other places, either in lode or placer form, and though it has not been possible to confirm these reports, there is reason to believe that they indicate a more extensive distribution of the tin ores. Many of the reported discoveries lie beyond the limits of the York region and indicate that the tin districts extend 100 miles or more to the northeast.

The tin ore is almost all cassiterite (tin oxide), though some stannite (sulphide of tin, copper, and iron) has been found. In the bed rock two essentially different types of deposits are represented. The ore occurs in veins cutting phyllites or metamorphic slates, and is disseminated through more or less altered granitic dikes. The lode deposits of the latter type give promise of commercial importance. Lode deposits of the former type have not been discovered in place, but the occurrence of tin-bearing quartz veins in slates is inferred from the distribution of the placer tin and from pebbles of slate containing small tin-bearing quartz veins, which have been observed in the gravels. It should be noted that no granite has been found in the slate area, and there is no positive evidence that the tin there has any genetic relation to granite intrusives.

No discussion of the genesis of these various ore bodies will be presented in this report, since the fieldwork has all been of a reconnaissance character. From a comparison of the evidence at hand with the facts known with regard to the older tin-bearing districts, it seems to be at least possible that the tin lodes of both types are connected with intrusive granite bodies, some of which have been exposed by erosion, while others are still deeply buried. These granites, which probably were all intruded at about the same time, mark a zone of plutonic activity extending from the Diomed Islands northeastward, parallel with the Arctic coast, for 100 miles or more. The localities from which tin ore has actually been obtained by United States Geological Survey parties and which have been examined in some detail will be described under the headings "Lost River," "Cape Mountain," "Buck Creek," "Buhner Creek," and "Anikovik River." The streams from which placer tin is reported by prospectors will be mentioned under the heading "Reported occurrences of stream tin," and

the localities from which prospectors have reported "ledge tin" will be described under the headings "Brooks Mountain," "Ear Mountain," "Hot Springs," "Asses Ears," and two other localities worthy of investigation will be mentioned under the headings "Diomedes Islands" and "Don River."

#### LOCALITIES WHERE LODE TIN HAS BEEN FOUND.

##### LOST RIVER.

Lost River enters Bering Sea at a point about 15 miles southeast of York, 25 miles west of Teller, a town on Port Clarence, and 10 miles northwest of Point Spencer, at the entrance to Port Clarence. A view of the valley of this river, taken from the coast, is shown on Pl. III. The river has a length of about 10 miles and drains the central part of the York Mountains. The mountains constitute a nearly circular area of rugged land forms, about 15 miles in diameter. The summits rise to a general level of about 2,500 feet, and, as noted, reach a culmination of 2,900 feet in Brooks Mountain, near the north side of the area, which is the highest point in the northern part of Seward Peninsula. Along the southern edge of this mountain mass there is a well-defined bench from one-half mile to 4 miles wide. This bench was cut from the rocks by wave action and then raised, but so unequally that at the mouth of Lost River it has an elevation of 600 feet, while eastward it gradually declines until at Port Clarence it is practically at sea level.

The writer has referred to this feature in a previous paper as the Cape York bench.<sup>a</sup> It was produced during the same period of erosion as the York Plateau.

On the seaward side the Cape York bench is bounded by steep bluffs, which at places front directly on Bering Sea (see fig. 1) and at other points rise from a lower and younger bench nearly at sea level. This lower and newer plane is well developed from the mouth of Lost River eastward to Port Clarence, and has a width varying from one-half mile to 3 or 4 miles. It is, in part, a rock bench similar to the Cape York bench, and, in part, a gravel-built coastal plane. Immediately north of Port Clarence the lower coastal plane is fringed by a wide lagoon, cut off from Port Clarence by a sand spit.

The York Mountains are generally devoid of the tundra vegetation which covers so much of the Seward Peninsula; and along Lost River, from the coast to the tin deposits, can be found an exceptionally good roadbed for this part of Alaska. For one traveling on foot it is as firm as an ordinary macadamized road, and owing to the ease with which the trip up the river is made the distances are likely to be underestimated by persons who have traveled in other parts of Seward

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

Peninsula. Lost River forks about  $1\frac{1}{2}$  miles from the coast, one branch continuing in a nearly due north direction, while the other drains a country to the west that has not been examined by geologists.

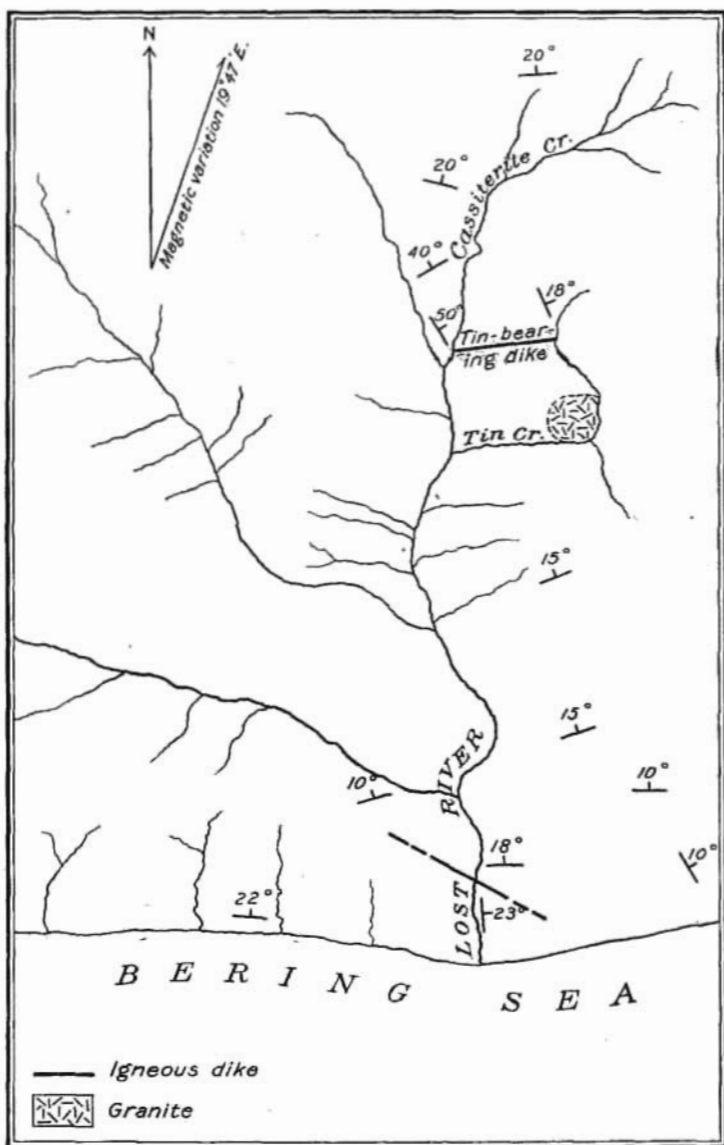


FIG. 3.—Sketch map of Lost River. Scale,  $\frac{1}{4}$  inch=1 mile.

About 4 miles from the coast the north fork of Lost River divides. The eastern branch is Cassiterite Creek; the western, which is somewhat larger, rises about 3 miles to the north, in the slopes of Brooks Mountain.

The Lost River tin deposits are located on the east side of the north fork of Lost River. (See fig. 3.) The ore has been found on Cassiterite Creek and on another eastern tributary, known as Tin Creek, which enters Lost River about a mile below the mouth of Cassiterite Creek. The latter stream has a length of about 3 miles; its head is within 1 mile of Cassiterite Creek, and after flowing parallel with Cassiterite Creek for about 1 mile it turns westward and enters Lost River from a deep canyon cut in the limestone of the York Mountains. At its mouth Cassiterite Creek is about 100 feet above the sea. In the latter part of July, 1903, Lost River carried approximately 1,000 miner's inches of water.

The York Mountains, in which the Lost River Basin lies, are composed almost wholly of ash-gray limestone of Silurian age, the Port Clarence limestone. Along Lost River the limestone shows little general metamorphism, and as a rule dips at low angles. From the coast to Tin Creek the strata generally dip to the north, and unless there are faults, which were not detected, a thickness of over 5,000 feet of limestone must be exposed. Near the mouth of Lost River a section of these limestones lying nearly horizontal is exposed in a mountain, called by prospectors Saddleback, which has an elevation of more than 2,000 feet above sea level. Dikes of igneous rock cut this limestone at several places along Lost River, and a number of these were readily traced across the limestone by a growth of moss and other vegetation which formed over them, the limestone itself being utterly devoid of vegetation. Microscopic examination shows that these dikes are of rhyolitic nature.

On Tin Creek, which enters Lost River from the east about  $4\frac{1}{2}$  miles from the coast, a large body of granite was found intruded in the limestone. This granite outcrop is believed to be nearly circular in outline and probably one-half mile in diameter. Around its margin the limestone was found to be considerably altered, and some small dikes of fine-grained pegmatite, probably apophyses from the main mass, were found cutting the limestone, apparently parallel with the contact of the limestone and granite.

Under the microscope the granite from the main mass is found to consist essentially of quartz, biotite, hornblende, orthoclase and acidic plagioclase feldspars with fluorspar, either accessory or secondary, and a few small grains of a mineral resembling zircon and believed to be cassiterite. Apparently the rock has been slightly crushed or sheared, producing streaks of fine-grained fragmental material of the same character as the original grains.

In Tin Creek, which flows for some distance along this contact, many boulders and pebbles, some of considerable size, were found to contain minerals, which are the result of contact metamorphism.

The main tin-bearing ledge outcrops nearly half a mile north of this

granite boss. It is a white, porphyritic dike, cutting the Port Clarence limestone, and striking nearly east and west. It has been traced from Tin Creek westward across the mountain to Cassiterite Creek, a distance of about 1 mile, but has not been found beyond these streams in either direction. All of this rock has been more or less altered, so that it is practically a greisen having crystals of cassiterite disseminated through it. Specimens collected near Tin Creek appear, in the hand specimen, to be a white aplite or porphyry with some small spots and large patches of purple. Under the microscope many of the original minerals are seen to have been replaced by fluorite, to which the purple color is due. Pseudomorphs of fluorite take the place of most of the feldspar crystals and of some of the quartz grains. (See Pl. V.) In specimens which are still more altered, collected from the same dike, near Cassiterite Creek, probably very few of the original minerals remain. The rock here is found to consist of calcite, fluorite, lithia mica, and quartz, proportioned in the order named. The limestone, on the south side of the dike, is altered for several hundred feet, and contains many greenish minerals, among which epidote and garnet have been identified. The limestones north of this dike are reported to contain many small stringers of tin ore for several hundred feet. The ore obtained from the main ledge varies considerably in general appearance and character. Some of the weathered ore from the croppings is highly siliceous, and has the appearance of weathered, iron-stained vein quartz with small black cassiterite crystals disseminated through it, while other specimens show clearly their granitic origin and contain comparatively little vein quartz. In the ore of the latter type the cassiterite occurs both as disseminated crystals varying in size from that of a pin head to that of a walnut and as veinlets and irregular masses. (See Pl. VII, B.) The granitic ore consists principally of calcite, fluorite, quartz, and large crystals of lithia mica; and in addition to the cassiterite, tourmaline, topaz, pyrite, garnet, and galena were observed in small amounts. Quantitative analyses of the lithia mica present made by W. T. Schaller, of the United States Geological Survey, show that it has the composition of zinnwaldite. In the float of this dike large specimens of galena, wolframite, and some malachite were collected, and in the altered limestone near the contact some large specimens of garnet were obtained. The siliceous ore mentioned above, when examined with the hand lens, sometimes showed spangles of free gold. A sample of this ore assayed<sup>a</sup> for gold and silver gave 0.36 ounce of gold per ton and a trace of silver. The piece assayed was a picked specimen, and not a commercial sample. Assays made for other parties are reported to show smaller amounts of gold in all cases. The occurrence of so much gold associated with the cassiterite seems to be unusual in tin ores, and merits further investigation.

<sup>a</sup> Assay by E. E. Burlingame & Co., Denver, Colo.

Among the loose material from the croppings of the ledge a large piece of galena coated with yellowish alteration products was found. This may have come either from the ledge or from the altered limestone near the contact. An assay shows that it contains 0.08 ounce of gold and 7.76 ounces of silver per ton. Both on Tin Creek and on Cassiterite Creek tin ore in angular, unworn crystals is reported to have been found in the gravels of the stream beds. One specimen of placer tin of this kind obtained near the cropping of the large dike on Cassiterite Creek consists principally of crystals of cassiterite, but contains also wolframite and garnet.

The tin-bearing dike is readily followed from Cassiterite Creek eastward over a mountain having an elevation of about 1,000 feet to Tin Creek, a distance of about 1 mile. At the time the ledge was examined, in the latter part of July, 1903, no excavation had been made on it, and it was impossible to measure the exact width at any point, but surface débris indicated a width of about 100 feet. Since that time crosscut trenches have been made on the ledge near Cassiterite Creek, and the above estimate is reported to represent the facts.<sup>a</sup> The cassiterite was found to be distributed through the whole width of the dike.

No attempt will be made to give an estimate of the value of the deposit. The development on the ledge has not, as yet, gone far enough to allow systematic sampling, and until further excavations have been made the grade of the ore and the size of the deposit can not be determined. Picked specimens showing as high as 17 per cent metallic tin have been assayed, and still higher assays could be obtained by careful sorting. From the tests thus far made an average of 6 per cent for the whole width of the ledge is claimed.

The following assays of ore collected on this lode by Governor Hutchinson were made by Ledoux & Co., of New York:

*Assay of tin ore from Lost River.*

	Per cent tin.
Sample of ore marked "Dyke".....	5.08
Sample of ore marked "Float".....	15.70
Sample of ore marked "Greisen".....	4.13

A partial analysis of one sample of the ore is as follows (No. 7451):

*Partial analysis of tin ore from Lost River.*

	Per cent.
Gold and silver.....	None.
Lead oxide (lead, 0.028 per cent).....	0.030
Copper oxide (copper, 0.085 per cent).....	.106
Arsenic oxide (arsenic, 0.38 per cent).....	.580
Tin oxide (tin, 4.46 per cent).....	5.74

<sup>a</sup> For information regarding developments subsequent to July 31, 1903, the writer is indebted to Gov. J. H. Hutchinson, a mine operator, who bonded several of the claims here in September, 1903. The facts as given by him are corroborated by others who have visited the locality.

	Per cent.
Manganous oxide (manganese, 0.424 per cent) .....	.548
Zinc oxide (zinc, 0.257 per cent) .....	.320
Nickel and cobalt oxides .....	Traces.
Silica .....	28.52
Alumina .....	33.55
Ferric oxide .....	8.31
Lime .....	6.75
Magnesia .....	.25
Lithium oxide .....	.09
Potassium oxide .....	.91
Sodium oxide .....	.36
Water, carbonic acid, etc .....	6.48
Sulphuric oxide (sulphur, 0.04 per cent) .....	.10

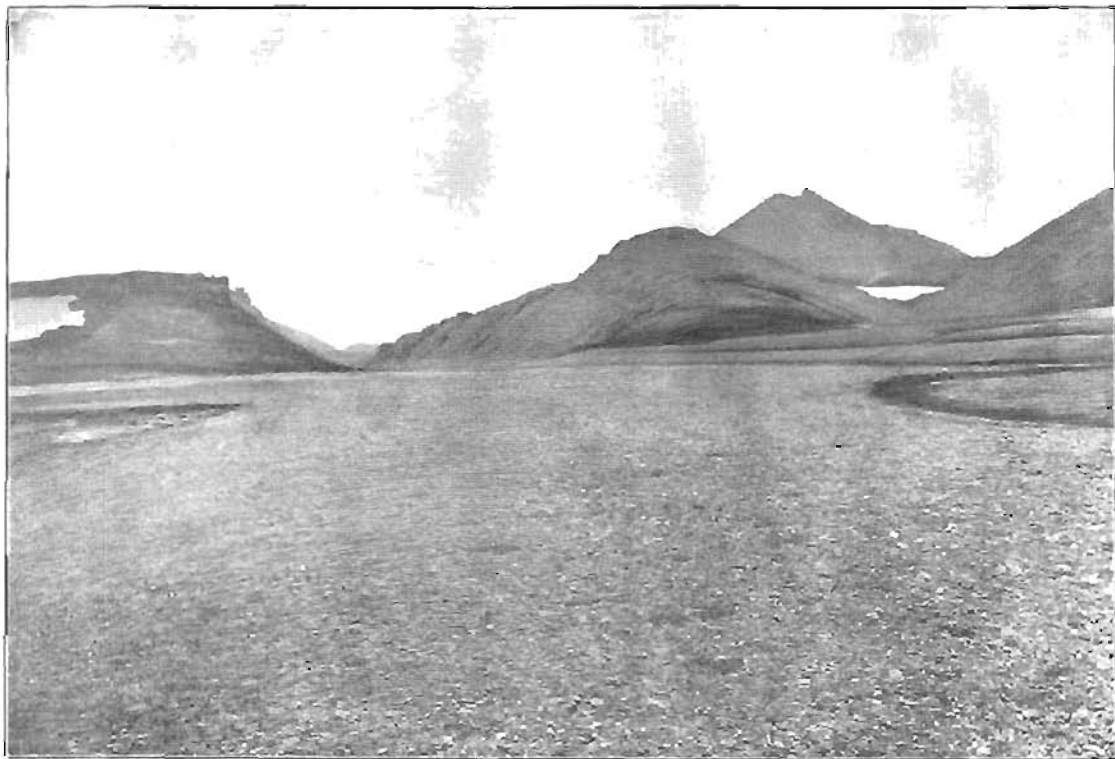
The alumina, etc., may contain titanitic acid. The magnesia and alkalis require confirmatory determinations.

Tin ore in the form of stannite or tin pyrites has been found on Tin Creek at the upper contact of the large granite area which has been described, and about half a mile below the cassiterite ledge. Specimens of mineralized granite were collected at this place, which, on examination in the laboratory of the Survey, are found to contain a small amount of tin in the form of stannite, together with other sulphide minerals. A sample of this ore assayed by Mr. E. C. Sullivan contained 0.3 per cent tin. Mineralized granite of this character appears to cover a considerable area, but the ore is probably of little value, except as showing the distribution of tin through the granites of the region.

In 1898 a party of disappointed prospectors, returning from Kotzebue Sound, were shipwrecked a few miles east of the mouth of Lost River, and were obliged to camp at that point during the winter. A cabin built largely from wreckage of their schooner is still standing, and is known as the Kotzebue cabin. These prospectors probably first applied the name Lost River to this stream.

In the succeeding summer a mining district was organized by survivors of this expedition, with headquarters located on King River, which enters Bering Sea between Lost River and Cape York. The Lost River region was included at that time in the King River recording district. No discoveries of gold were made, however, and the region was abandoned by prospectors. In 1901 the writer, in company with Mr. D. C. Witherspoon, topographer, of the Geological Survey, made a hasty examination of Lost River, but did not discover any indications of tin ore.

In the winter of 1902 prospectors again turned their attention to this region in the search for tin ore. Granite-porphry dikes, which occur in the limestones near the mouth of Lost River and also near King River, first attracted their attention, and many specimens of this material containing dark colored or smoky quartz phenocrysts, which



VALLEY OF LOST RIVER, FROM THE COAST.







CAPE MOUNTAIN, FROM YORK.



were mistaken for "tin crystals," were sent to various assayers, from whom widely divergent reports were obtained.

Early in the summer of 1903 Charles Randt, Leslie Crim, and W. J. O'Brien discovered the interesting minerals above referred to in float boulders in Tin Creek, a tributary of Lost River, and made a thorough search for tin ore in that vicinity. They made a large collection of minerals, which was referred to the writer when he arrived in Teller in July, 1903. Metallic tin was readily obtained from one small specimen by aid of a blowpipe, while the larger part of the collection<sup>a</sup> was shown to contain minerals of no value. The collection was of sufficient interest to tempt the writer to examine the locality in detail. Mr. Hess and the writer proceeded to Lost River and were there able to trace the tin ore which had been seen in Teller to the granitic dike on Cassiterite Creek, and also to obtain specimens of stannite ore from Tin Creek.

Since this examination the dike described has been called "Cassiterite ledge" in location notices, and it has been definitely traced through a group of four claims. A crosscut trench has been made near the Cassiterite Creek end of the ledge, which, it is reported, shows that the ledge has a width of 100 feet and that cassiterite is disseminated throughout the rock. It is also reported that other discoveries of tin-bearing ledges in this neighborhood have been made since July, 1903. The claims located on Cassiterite ledge have been purchased by an experienced mine operator and will be developed next summer.

#### CAPE MOUNTAIN.

Cape Prince of Wales, the most western point of Seward Peninsula, is marked by a high peak known as Cape Mountain. At the southeast base of this mountain a settlement called Tin City has grown up within the last year. The Eskimo village of Kingegan, the Congregational Mission, and Wales post-office are located on the north side, facing Bering Strait. From the summit of the mountain East Cape and other points on the Asiatic coast, only 60 miles distant, are plainly visible on clear days. On its west and south sides this mountain slopes down to bluffs that drop perpendicularly into the sea. On its southeast side, near Tin City, the coast recedes northward, making a bight, which affords some protection from west winds, but for the prevailing south winds of summer it is practically an open roadstead with landing facilities, little, if any, better than those at Nome or York. The nearest good anchorage is about 40 miles distant, on Port Clarence, from which there are several practicable railroad routes. A view of this mountain as seen from York, about 12 miles distant, is shown in Pl. IV.

<sup>a</sup> A chemical analysis of one of these samples made by Mr. E. C. Sullivan, of the United States Geological Survey, shows no trace of tin. This sample consists mainly of tourmaline.

The greater part of the York region is occupied by the York Plateau, which is from 200 to 600 feet above the sea and is a result of erosion occurring during the period in which was produced the bench described in connection with the Lost River deposits.<sup>a</sup>

This plateau is trenched by the streams which drain the region, and the valleys have V-shaped cross sections, characteristic of newly established drainage. At the base of Cape Mountain, which rises to an elevation of 2,300 feet, the York Plateau has an elevation of about 300 feet above the sea. The interbedded schists and limestones above described form the bed rock of the plateau surface surrounding Cape Mountain, but the mountain itself is composed almost entirely of a granite boss intrusive in the limestone. The contact relations of the granite and limestone have not been studied in detail, but from data gathered in the hasty reconnaissances it appears that the granite cuts across the bedding of the limestone. This granite has already been described under the heading "Igneous rocks."

The writer's visit to this locality was of necessity a very hasty one, and work was hampered by exceedingly rainy weather, so that his observations were limited. Specimens of tin ore, however, were obtained from surface débris, which undoubtedly came from the granite of the mountain, though the ore was not definitely traced to its position in the solid rock. It is reported that tin ore has been found in at least three distinct places on this mountain, and that it occurs in somewhat irregular deposits which have an east-west trend. Several short tunnels have been driven into the mountain, but are reported not to have reached any ore bodies. The granite from some of these tunnels is partially altered to greisen and justifies the belief that the ore bodies may be not far distant. A sample of this granite, analyzed by Mr. Sullivan, of the Survey, was found to contain a few hundredths of 1 per cent tin.

The ore obtained at Cape Mountain differs in general appearance from that seen at Lost River. Large pieces of nearly pure cassiterite, one of which weighed fully 9 pounds, are said to have been found on the surface of the mountain. A specimen which the writer obtained weighs approximately 2 pounds and is nearly pure cassiterite, showing few crystal faces, but embedded in it and surrounding it are long, slender needles of tourmaline. While in this vicinity the writer saw a number of large, nearly colorless crystals of cassiterite which were practically transparent. Near the end of the season a large amount of supposed tin ore was collected on the flanks of Cape Mountain and shipped to Seattle, where it was examined by the writer and from it samples were selected for study in the laboratory. This supposed ore contains very little tin, but several dark crystalline minerals which

<sup>a</sup> Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, pp. 36-39.



A



B

## THIN SECTIONS OF ALTERED PORPHYRITIC DIKE NEAR TIN CREEK.

- A. Magnified 80 diameters: *a*, feldspar; *b*, fluorite; *c*, fine-grained sericitic minerals; *d*, groundmass of fine-grained quartz, fluorite, sericite, and calcite.
- B. Magnified 54 diameters: *a*, quartz phenocryst; *b*, groundmass, consisting mainly of fluorite and secondary quartz; *c*, zinnwaldite mica.



have been mistaken for cassiterite. A sample assayed for tin by Mr. Sullivan, of the Survey, contained a trace of tin, a few hundredths of 1 per cent. The principal constituent is tourmaline, in slender black or brown needles, and wolframite or scheelite are probably present, if, as reported, a considerable amount of tungsten was found.

Tin ore was discovered on Cape Mountain in July, 1902, by Mr. W. C. J. Bartels. In the fall of 1902 he brought out a large collection of specimens, which on examination by chemists and assayers, was found to include some tin ore. Extensive developments were planned for the season of 1903, and a well-equipped prospecting plant was sent to Cape Mountain. A large dynamo driven by a gasoline engine was to be placed near the beach at the point now known as Tin City, and from this dynamo wires to several points on the mountain were to supply power for electric drills. By the use of these drills it was expected that tunnels could readily be extended into the heart of the mountain and crosscut the ledges from which has come the float ore.

After spending nearly the whole of the season of 1903 in getting the machinery in place and establishing the winter camp it was found that the engine for driving the dynamo was defective, and the plan for development work during the winter of 1903-4 was necessarily suspended.

No work is now in progress on Cape Mountain, so far as is known, and very little advance has been made in revealing the nature of the ore deposits since the float ore was first discovered. This work, however, will undoubtedly be resumed in the summer of 1904, and it is to be expected that by the end of that season more definite information will have been obtained.

#### LOCALITIES FROM WHICH LODE TIN HAS BEEN REPORTED.

The discovery of tin ore in ledges has been reported by prospectors from many other localities in Seward Peninsula, some of which deserve notice, since the geologic conditions are known to be promising, and they will be described in some detail.

#### DIOMEDE ISLANDS.

These islands, which lie in Bering Strait, midway between Alaska and Siberia, are reported to be composed of granite, though they have not been examined by geologists. It is probable that they represent an intrusion similar to that at Cape Mountain. It is reported that copper ore has been found on them, and should the tin ore found on Cape Mountain develop commercial importance they may merit investigation.



## BROOKS MOUNTAIN.

This mountain lies about 11 miles north of the mouth of Lost River. The locality can easily be reached by a road up Lost River from the beach, or by a road following up Don River from Port Clarence. Wagons have been driven over both these routes. By the latter route the mountain is probably 20 miles from deep water of Port Clarence. The bed rock exposed on the mountain consists of highly altered limestones, and black slates which resemble the slates near York.<sup>a</sup>

The sedimentary rocks are cut by a number of granite and rhyolite dikes, which are believed to strike approximately east and west. All of the streams which head in Brooks Mountain, namely Lost River, Don River, York River, and Mint River, carry granite boulders that have been derived from the mountain.

In 1901 the writer observed in this vicinity some of the minerals that have been found associated with tin in the ledges seen within the past season, and in the winter of 1901 a prospector, who had spent considerable time in this same region, sent a collection of these minerals to the Geological Survey Office. This collection contains a great deal of tourmaline and garnet, both of which are associated with tin ore on Tin and Cassiterite creeks, about 4 miles south of Brooks Mountain. This locality seems promising for the occurrence of tin-bearing veins, though so far as is known to the writer no tin ore has yet been identified.

## DON RIVER.

On the west side of Don River there is a ridge of high hills composed, in part, of slates like those found near York.<sup>b</sup>

These slates are cut by intrusive dikes of quartz-porphry and granite resembling the intrusives of Brooks Mountain and Lost River. Some of the minerals often associated with tin ore have been found here, and the region is worthy of some investigation. This region lies about 10 miles east of Lost River and 9 miles north of Port Clarence.

## EAR MOUNTAIN.

Ear Mountain is 50 miles north of Teller and 10 miles southwest from Shishmaref Inlet, a large, shallow body of water, not navigable for ocean vessels. Should the reported discoveries of tin be verified, and the ore occur in commercial quantities, a railroad not over 50 miles in length could be built to Port Clarence.

This mountain is an isolated upland mass that has an altitude of

<sup>a</sup> Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 30, Pl. III.

<sup>b</sup> Collier, A. J., *Idem*, pp. 46-47.



A



B

## THIN SECTIONS OF PORPHYRITIC DIKE ON EAR MOUNTAIN.

- A. Magnified 23 diameters: *a*, pyrrhotite; *b*, tourmaline; *c*, quartz; *d*, feldspar; *e*, groundmass of quartz and feldspar.
- B. Magnified 23 diameters: *a*, pyrrhotite; *b*, tourmaline; *c*, kaolin and calcite pseudomorph after feldspar; *d*, groundmass of secondary calcite.



2,308 feet above the sea. It stands on a well-marked plateau surface that has an elevation of 1,000 feet. This plateau has been correlated with the Kugruk Plateau, and is due to an earlier era of erosion than that which produced the York Plateau.<sup>a</sup>

The sedimentary rocks surrounding Ear Mountain consist mainly of quartzites and dark slates, which resemble the slates near York and have been correlated with them. The core of the mountain is a granite boss or stock intruded in these slates. Radiating from the main granite mass there is a fringe of intrusive quartz-porphry and rhyolite dikes which are regarded as offshoots from the main intrusion.<sup>b</sup>

The granites of the main mass are coarsely crystalline and consist essentially of quartz, orthoclase, and biotite. A specimen from one of the smaller bodies, examined microscopically, is made up essentially of quartz and of orthoclase and plagioclase feldspars. A narrow dike from the same region was found to consist essentially of quartz and feldspar, with muscovite, largely secondary, and a secondary growth of feldspar surrounding the larger orthoclase crystals. In Ear Mountain a platy structure brought out by the weathering gives the rock a stratified appearance.

Tin ore has been reported to occur in this region, and it is probably true that some cassiterite has been brought out by prospectors. The specimens of supposed ore which were submitted to the writer contained, however, only traces of tin, though some of the minerals often associated with its ores were present. On the north side of the mountain quartz-porphry dikes can be traced for considerable distances. Several specimens of these rocks have been carefully examined in the laboratories of the U. S. Geological Survey. Apparently they were originally rhyolites or quartz-porphyrines, but in thin sections they show considerable alteration. In one case the porphyritic texture of rhyolite remains, but the minerals, especially the feldspar phenocrysts, are partly replaced by tourmaline and pyrrhotite or magnetic pyrite, as shown on Pl. VI. In this case the tourmaline was probably first introduced and was followed by the pyrrhotite. No cassiterite has been identified in the section. In another section the original texture is completely obliterated and the rock consists essentially of tourmaline in radiating groups of crystals surrounded by a groundmass made up principally of calcite with some quartz (Pl. VII, A). Magnetite and biotite seem to be present in small amounts, and probably also cassiterite, though it has not been detected in the thin sections. This specimen resembles in texture the luxullianite<sup>c</sup> from Cornwall, but differs from it in composition, since the groundmass of the typical

<sup>a</sup> Collier, A. J., Prof. Paper U. S. Geol. Survey No. 2, p. 35.

<sup>b</sup> Collier, A. J., op. cit., p. 30.

<sup>c</sup> Harker, Alfred, Quart. Jour. Geol. Soc. London, 1895, vol. 51, p. 141. Rosenbush, H., Mikroskopische Physiographie der Massigen Gesteine, vol. 2, pt. 1, p. 50. Kemp, James Furman, Handbook of Rocks, p. 32.

luxullianite consists largely of feldspar and quartz, while in this rock it is largely calcite.

Four samples of rock from the north side of Ear Mountain were assayed for traces of tin by Mr. Sullivan of the Survey. While none of them carry tin in commercial quantities, traces of tin, estimated at a few hundredths of 1 per cent, were found in all of them. A prospecting shaft, it is reported, was sunk on one of these dikes, and samples obtained from considerable distance below the surface were found to be largely made up of dark mica and tourmaline. It is also reported that stream tin has been found in several of the creeks that head in Ear Mountain.

#### HOT SPRINGS.<sup>a</sup>

This locality is 70 miles northeast from Port Clarence, about 30 miles southeast from the head of Shishmaref Inlet, and 30 miles from deep water on Goodhope Bay. It takes its name from a group of hot sulphur springs, well known to prospectors and miners, around which there is usually a small village of tents.

In summer time the usual route of travel to this locality is by way of Imuruk Basin and the Kuzitrin and Kugruk rivers. If tin deposits of value should be discovered in this vicinity a road would probably be constructed to Goodhope Bay. The general bed rock of this vicinity is graphitic mica-schist, but at Hot Springs this schist is intruded by a large body of granite several miles across. The granite is of the same general type as that of Ear Mountain, but it has not been examined microscopically. In Professional Paper No. 2 two characteristic landscapes within this granite area are shown on Pls. VIII and IX.

Since the discoveries of tin ore were made in the granites of the York region, prospectors have turned their attention to this area, and samples of tin ore purporting to come from it were brought to Nome late in the season of 1902.

#### ASSES EARS.<sup>b</sup>

Near the headwaters of the western tributaries of Pinnell River, in the region south of the eastern extension of Kotzebue Sound, are a number of small isolated areas of granite, surrounded by massive crystalline limestones. These granites have been more resistant to weathering than the limestones, and stand out as prominent hills or buttes. One of these forms the well-known landmark called the Asses Ears, which was so named by Kotzebue in 1816, because "its summit is in the form of two asses' ears." A few miles to the north-

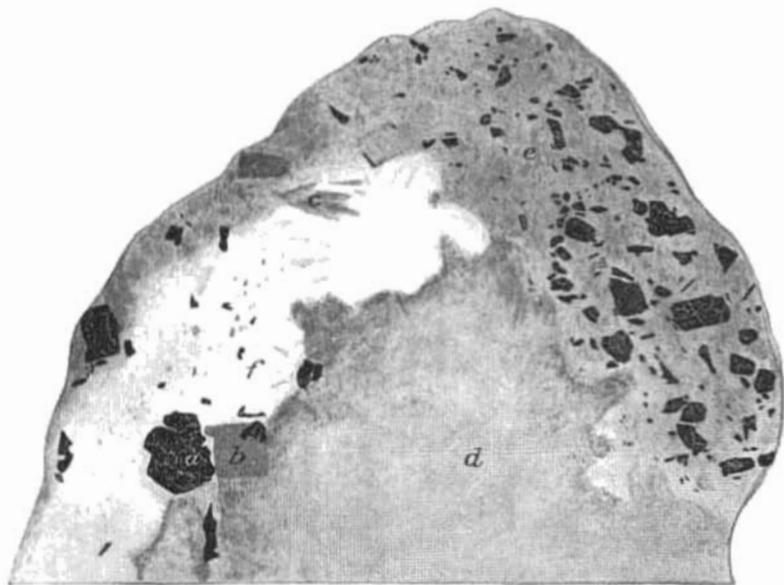
<sup>a</sup> Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: Prof. Paper U. S. Geol. Survey No. 2, 1902, p. 55

<sup>b</sup> This note is furnished by Mr. Fred H. Moffit, in advance of his report on "A reconnaissance of the northeastern portion of Seward Peninsula."



A. THIN SECTION OF LUXULIANITE FROM EAR MOUNTAIN.

Magnified 80 diameters: *a*, tourmaline; *b*, groundmass of secondary calcite.



B. POLISHED SURFACE OF TIN ORE FROM LOST RIVER.

*a*, Cassiterite; *b*, gray pyrite; *c*, zinnwaldite mica; *d*, fluorite; *e*, groundmass of fluorite and calcite; *f*, groundmass, chiefly kaolin.



west is another granite area, smaller and much less prominent than that forming the Asses Ears. These two localities are situated south of the Sound and, since they are not favorable places for placer gold, have been rarely visited. A third granite area makes up the central mass of the elevated watershed between Kiwalik and Buckland rivers. This range extends from Kotzebue Sound to within a few miles of Koyuk River, a distance of about 40 miles. Here the granites are found only in the higher central part of the mass, and are surrounded by later eruptives, including andesitic rocks and lavas which form the lower hills.

These granites are all variable in their texture, and often have an extremely coarse, pegmatitic appearance. Twinned orthoclase feldspars, 2 or 3 inches in length and three-fourths of an inch thick, are not uncommon, and hornblende crystals of large size are found in places. Locally, quartz seems to be absent and the rock becomes syenitic in character. Fluorite was seen in joint planes in the granites northwest of the Asses Ears, suggesting the possible presence of tin ores such as occur with this mineral in the western part of Seward Peninsula.

Dr. Cabell Whitehead, of the Alaska Banking and Safe Deposit Company, reports the presence of cassiterite in the form of fine sand in gold taken from Old Glory Creek, which heads up toward the limestone area in which the previously mentioned granite masses of the Asses Ears region occur.

#### LOCALITIES WHERE STREAM TIN HAS BEEN FOUND.

##### BUCK CREEK.<sup>a</sup>

Buck Creek was the scene of the first actual mining of tin ore in Alaska, and is the present center for tin-placer mining activities. This settlement is on the Arctic slope of Seward Peninsula, about 20 miles northeast from York, and 4 miles from tide water on Lopp Lagoon, an inlet from the Arctic Ocean. It is reached by a wagon road from York, which follows the bed of Anikovik River for 10 miles, then crosses a low divide to Grouse Creek and follows Grouse Creek to its junction with Buck Creek. This road is fairly good, except for 1½ miles of soft tundra<sup>b</sup> on the divide between Anikovik River and Grouse Creek, where it is almost impassable for heavy wagons. A good road-bed could easily be built here by bringing gravel from Anikovik River. Lopp Lagoon is not navigable for seagoing vessels and affords no harbor for such craft. It is a large, shallow body of water, sepa-

<sup>a</sup>This description of the tin placers of Buck Creek is based on the work of Mr. Frank L. Hess.

<sup>b</sup>The Standard Dictionary gives the following definition of "tundra:" "A rolling plain of Russia and Siberia, covered with moss and at times very moist and marshy." "The 'tundras' of northern latitudes are frozen plains of which the surface is covered with arctic mosses and other plants."—Archibald Geikie, Text-Book of Geology.



rated from the Arctic Ocean by a low sand spit, on the seaward side of which the shallow water is reported to extend out about 2 miles from the coast, so that landing is difficult. For small, flat-bottomed boats, however, this lagoon is navigable, and it is possible that such boats might, but not probable that they ever will, convey tin ore from the Buck Creek mines, out through the inlet, to vessels lying offshore in the Arctic Ocean. It is reported that small boats can be brought up Mint River and Grouse Creek to within 1 mile of the mouth of Buck Creek. These streams, however, are shallow and crooked, and it is not probable that they can be used successfully for conveying ore from Buck Creek to the sea.

The plateau already described extends northward from the town of York on the coast of Bering Sea to the Arctic Ocean. It has an elevation of about 600 feet near York, and slopes to sea level a few miles from the Arctic coast. Buck Creek and the other streams in its vicinity flow in comparatively new valleys cut in this plateau. Above the surface of the plateau there are several buttes, of which Cape Mountain and Potato Mountain<sup>a</sup> are the most prominent. Potato Mountain is a large, cone-shaped mountain, having an elevation of 1,370 feet. From this mountain a range of low hills extends northward for a distance of 3 or 4 miles toward Lopp Lagoon.

Buck Creek is a small stream, about 5 miles in length, which rises in this range of hills and flows southeastward to Grouse Creek. Its waters are then carried northward through Mint River and Lopp Lagoon to the Arctic Ocean. About 1 mile from its mouth Buck Creek receives a large tributary from the south, called Sutter Creek, and about 4 miles above its mouth it again forks, the two branches being known, respectively, as Right and Left forks. Several smaller tributaries are received between Sutter Creek and these upper forks.

The bed rock on which the York Plateau is developed, and in which Buck Creek Valley is incised, is a dark, slaty schist, which has been already described. Along Buck Creek it has the characteristic jointing described in the general discussion of the geology of this region.

The mountains west of Buck Creek, including Potato Mountain, are composed of similar slates. They apparently contain no intrusive, igneous rocks, either of the greenstone or granite type.

Near the mouth of Buck Creek boulders and pebbles of greenstone occur in the gravel deposits. These have not been traced to their source, but they probably came from a group of hills on the east side of Grouse Creek before the present drainage was established. At a number of places along Buck Creek small quartz veins were found cutting across the bedding or running parallel with it through the slate. Some of these quartz veins are as much as 3 or 4 feet thick,

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<sup>a</sup>The name Conical Hill was applied to this mountain by Captain Beechey in 1826. It is said to have been called "Potato Mountain" by the Russians. On the topographic map, Prof. Paper No. 2, Pl. XII, the mountain is called "Cone Hill."

and two of them can be traced for a quarter of a mile or more. Most of the veins are mere stringers, 1 or 2 inches thick and only a few feet long. In one instance a vein of nearly pure pyrite 6 or 8 feet wide was seen. Pebbles of pyrite 2 or 3 inches in diameter, oxidized on the outside, are found in the gravels below this vein.

Mr. Edgar Rickard<sup>a</sup> reports on this deposit as follows:

The source of the cassiterite can be readily traced to the slate of the [Potato Mountain] range, where it undoubtedly occurs in countless small veins and vugs, sometimes associated with quartz and so thoroughly scattered through the mass that the action of the elements has washed it from the hillsides and concentrated it in the streams below in appreciable deposits.

Though specimens obtained from the gravel show that this is true, no veins of this kind were seen by Mr. Hess nor by the number of prospectors who were actively engaged in a search for tin-bearing veins. It is of interest to note that no granitic rocks or acid intrusives of any kind have been found associated with the phyllites, nor have any pebbles of such rocks been found in the gravels. So far as the surface indications show, it appears that the tin ore has its source in veins which are of distinct origin from those found in association with granitic rocks.

The gravel deposits in the bed of Buck Creek are from 10 to 150 feet wide, varying greatly in different parts of the creek.

Cassiterite, in the form of stream tin, is distributed from the mouth of the creek to within a mile of its head, above which point little more than traces have been found. The ore varies in size from fine sand to pebbles weighing 13 or 14 pounds. Several pieces from 5 to 8 pounds in weight were seen by Mr. Hess, though the average size is much smaller. A few of the pebbles are perfectly rounded, but most of them are subangular. The ore from the claims near the mouth of Buck Creek is generally well rounded, while that from near the head is sharp and angular. In general the stream tin grows more angular as the head of the creek is approached.

The color of the cassiterite varies from almost black to a light resin or amber; when crushed, however, it makes a light-colored resinous powder, by which it is readily distinguished from hematite or other iron minerals that are frequently mistaken for it, since they invariably give a distinctly red, brown, or black powder. A number of specimens were obtained with pieces of quartz and slate still attached to them, leaving no doubt as to the local origin of the fragments. Sometimes small pieces of cassiterite are found inclosed between fragments of slate, showing that the ore sometimes occurs as veinlets in the bed rock.

Near the head of Buck Creek Mr. Edgar Rickard,<sup>a</sup> in 1902, tested

<sup>a</sup> Rickard, Edgar, Tin deposits of the York region, Alaska: Eng. and Min. Jour., vol. 75, 1903, p. 30.

the gravels systematically and found that they contain about 8 pounds of 60 per cent ore to the cubic yard. The value per yard on this basis, with tin at 28 cents per pound, would be \$1.34, out of which charges for shipping and treatment would have to be paid.

Mr. Hess saw pannings made at a number of places along Buck Creek, but not enough to test thoroughly the richness of the gravels. The best that were seen came from immediately above the mouth of Sutter Creek, where a drain ditch from 2 to 2½ feet deep was under construction. Seven pans taken from various parts of the gravel thrown out of this ditch gave about 1 pound 6 ounces of concentrates. Estimating 20 pounds of gravel to the pan, this would give approximately 27 pounds of, say, 60 per cent ore to the cubic yard of gravel. Bed rock was here 5½ feet below the surface, and the gravel approximately 100 feet wide. A few good colors of gold were found in the concentrates. At this point there seemed to be no difference in the distribution of the tin ore through the gravels below the surface. It seemed from the evidence of prospectors that this uniform distribution through the gravels prevailed generally along the creek, though at one place it was found to be richer on bed rock.

It is reported that cassiterite has been found in a bench near the upper forks of Buck Creek, but no definite data were obtained concerning the nature of the occurrence.

On Grouse Creek, below the mouth of Buck, the amount of tin ore is reported to be very small, and while Mr. Hess found no evidence of prospecting in this section, and is of the opinion that practically none has been done there, the gravel deposits are more extensive than those on Buck Creek and seem to be worthy of attention. No large amounts of cassiterite have been reported from either Gold Creek, a tributary of Grouse above Buck, or from Sutter Creek, the large southern tributary of Buck, nor has much gold been found there.

To summarize the evidence with regard to the Buck Creek region, tin ore has been found in the gravels of the creek from its mouth to within 1 mile of its head. The pay streak appears to be confined to the present stream-bed and flood-plain deposits. In the present creek bed the ore is found from the surface to the bottom of the gravels. Outside the creek bed, in the flood plain, there is a covering of moss and muck above the pay gravel. No cassiterite is known to have been found on the hillsides surrounding Buck Creek or on the plateau surface in which Buck Creek Valley is incised, though such an occurrence is to be expected. The known pay streak varies in width from 10 to 150 feet, and in thickness from a few inches to 5 feet. Estimates of the amount of tin ore in the gravels vary from 8 to 27 pounds per cubic yard, but very few comprehensive tests have been made.

At the time of Mr. Hess's visit to Buck Creek, near the end of

July, sluicing for tin ore was in progress at only one place. The creek valley still contained great drifts of snow, and mining operations generally were retarded by the lateness of the season.

Stream tin is harder to separate from the gravel than is gold on account of its lower specific gravity, but the methods employed in washing it out were modifications of somewhat primitive processes of gold placer mining. Ten men were shoveling into the one "string"

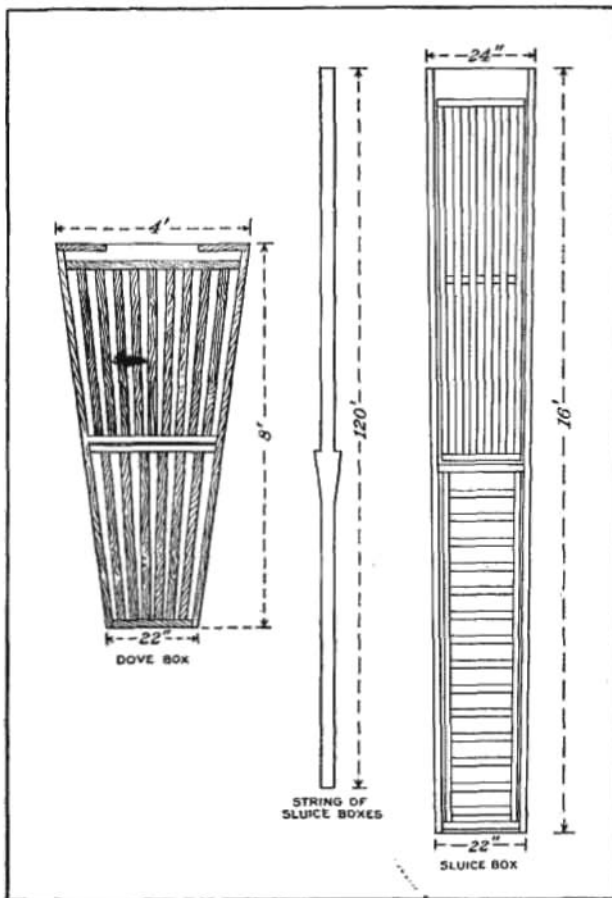


FIG. 4.—Sluice boxes used in washing placer tin in York region.

of sluice boxes and a clean up was made four times a day, so that the work was frequently interrupted. The sluice boxes used were 16 feet long, 24 inches wide at the upper end and 22 inches wide at the lower end, and 7 boxes were used in a "string," making a total length of 150 feet. A "dove box" 8 feet long, 4 feet wide at the upper end and 22 inches wide at the lower end, with riffles, was

introduced between the fourth and fifth boxes from the upper end (see fig. 4). Ordinary patterns of Pole and Hungarian riffles were used, except that they were made of  $2\frac{1}{2}$  by  $1\frac{1}{2}$  inch material, which is larger and heavier than that ordinarily used in sluicing for gold. About 100 miner's inches of water constituted a sluice head for this apparatus. It is reported that the concentrates obtained averaged about 40 pounds per day to the shovel. The concentrates from the sluice boxes were further concentrated by hand by panning in a box 5 feet long by 3 feet wide and 8 inches deep, into which water flowed

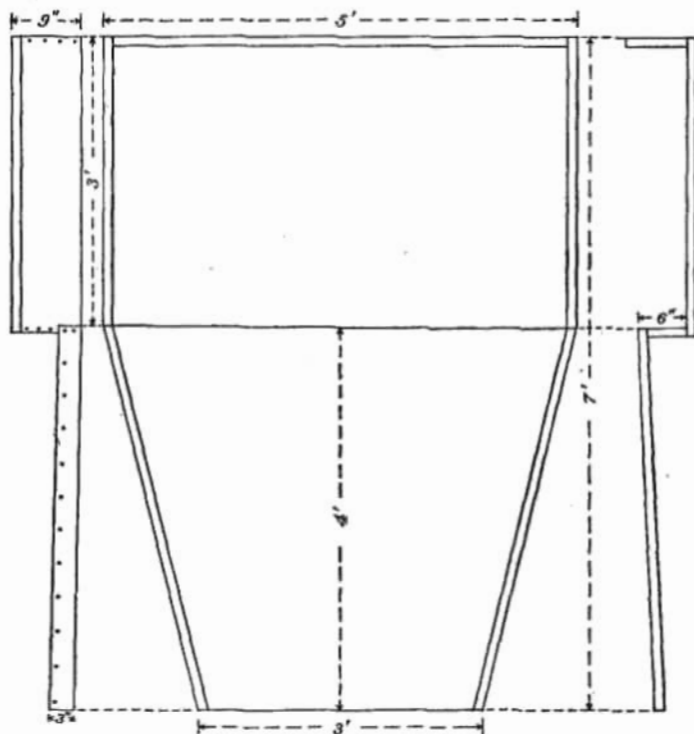


FIG. 5.—Box used in washing stream tin concentrates.

through a canvas hose and flowed out over an apron 4 feet long in a stream about three-quarters of an inch deep, as shown in fig. 5. The concentrated gravel was gradually worked up over the edge of the pan, which was kept just submerged at the upper end of the apron, where the stream of water carried away the lighter portion, while the heavier particles sank in the box. It is reported that concentrates treated in this way averaged about 50 per cent tin. The larger pieces of foreign matter were picked out by hand. The impurities in the concentrates are mainly hematite, magnetite, quartz, and slate.

Later in the season some sluicing for tin ore was done at several

other points on Buck Creek, and altogether a considerable amount of tin ore, estimated at from 30 to 40 tons, was obtained and hauled to York for shipment.

Should further prospecting demonstrate that there are large amounts of stream tin in Buck Creek or any of the neighboring streams, practical mining will require the introduction of more economical methods to overcome the handicap of short seasons and high wages. In other parts of Seward Peninsula hydraulic mining has been practiced with marked success in the gold placers, and the same method can probably be adapted to the tin placers as well. Water for this purpose can be obtained from the streams rising in the York Mountains. The feasibility of collecting water from these streams for working the tin placers of Buck Creek and vicinity will be readily seen from the topographic map of the region (Pl. II), but the question whether or not the deposits will warrant the necessary expenditure can not be settled without further development.

#### ANIKOVIK RIVER AND BUHNER CREEK.

The localities on Anikovik River and Buhner Creek, where tin ore was discovered in 1900, are 2 and 3 miles, respectively, from York. Buhner Creek flows into Anikovik River from the west, a short distance north of the point where Banner Creek enters the Anikovik. The following description of these deposits is quoted from Mr. Brooks:<sup>a</sup>

On Buhner Creek 2 or 3 feet of gravel overlies the bed rock, which consists of arenaceous schists, often graphitic, together with some graphitic slates. This is part of the schist series which has been described. The bed rock is much jointed, the schists being broken up into pencil-shaped fragments. They strike nearly at right angles to the course of the stream and offer natural riffles for the concentration of heavier material. A hasty reconnaissance of the drainage basin of this stream, which includes not more than a square mile of area, showed the same series of rocks throughout its extent. At a few localities some deeply weathered, dark-green intrusives were found, which, on examination by the microscope, were found to consist almost entirely of secondary minerals. In some cases, however, a little plagioclase was still unaltered and a suggestion of ophitic structure remained, so that these are probably of a diabasic character. The slates and schists are everywhere penetrated by small veins, consisting usually of quartz with some calcite, and frequently carrying pyrite and sometimes gold. These veins are very irregular, often widening out to form blebs, and again contracting so as not to be easily traceable.

The stream tin is concentrated on the bed rock with other heavy minerals, and was found by the miners in the sluice boxes. A sample of the concentrate<sup>b</sup> in one of the sluice boxes was examined by Mr. Arthur J. Collier, and yielded the following minerals: Cassiterite, magnetite, ilmenite, limonite, pyrite, fluorite, garnets, and gold. The determination of percentage by weight was as follows: 90 per cent tin-

<sup>a</sup> 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.

<sup>b</sup> The sample of these concentrates from which the first determination of tin ore in Alaska was made was obtained from C. B. Kittredge, who was mining on Buhner Creek. Another sample was obtained from Mr. Trumble, a miner on Anikovik River.

stone; 5 per cent magnetite; other minerals, 5 per cent. The cassiterite occurs in grains and pebbles, from those microscopic in size to those half an inch in diameter; they have subrounded and rounded forms. In some cases there is a suggestion of pyramidal and prismatic crystal forms. The cassiterite varies in color from a light brown to a lustrous black.

A second locality of this mineral was found on the Anikovik River, about half a mile below the mouth of Buhner Creek. Here the cassiterite was also found with the concentrates from the mining operations. One pebble of stream tin obtained from this locality was about 2 inches in diameter.

It will be necessary to make a more detailed examination of this region to determine where this mineral occurs in the bed rock. The facts obtained by the writer point toward the conclusion that its source was in the quartz and calcite veins in which the gold was found. No cassiterite was, however, found in this vein material.

Since 1901 these workings have been abandoned by miners, neither gold or cassiterite having been found in paying quantities. On Anikovik River there are extensive gravel deposits, which may possibly be made to yield fair returns either in gold or tin if economically worked on an extensive scale by hydraulic methods. Sufficient water for this purpose can probably be obtained either from the head of Anikovik River or from Kanauguk River.

#### LOCALITIES FROM WHICH STREAM TIN HAS BEEN REPORTED.

It is reported by prospectors familiar with the Buck Creek deposits that some tin ore has been found in alluvial deposits on Baituk and Kigezruk creeks, flowing into Bering Sea; in Banner Creek, tributary to the Anikovik; several small streams flowing into Lopp Lagoon; Clara Creek, a tributary of Mint River; and in York Creek, a tributary of Pinguk River, all in the York region. Stream tin has also been reported from all parts of Seward Peninsula where gold mining is in progress, but outside of the York region these reports have generally been without foundation. Last summer, however, Mr. Hess obtained from a miner a specimen of stream tin said to have been found on Gold Bottom Creek, a tributary of Snake River, in the Nome district. If this find was genuine it indicates a wider distribution of the tin ore than has heretofore been supposed, and is the only case known in which stream tin has been found in the gold placers near Nome. There is probably not enough tin ore there to have economic value.

The bed rock of Gold Bottom Creek consists of limestones and schists of the Nome series.

#### SUMMARY OF ECONOMIC GEOLOGY.

Tin ore in considerable quantities has been found in the York region at a number of widely separated localities, the extreme points known being 25 miles apart. While the existence of tin ore in sufficient quantities to be worked on a profitable scale has not yet been demonstrated because of the remoteness of the region, the inhospitable

climate and the cost of labor, the probabilities are that further development will prove some of the deposits to have commercial value.

The ore occurs in both alluvial deposits and in ledges. The ore of the alluvial deposits has been traced in some cases to small veinlets and vugs in the slate country rock, where it has no visible connection with intrusions of granite or other igneous rock, and in others to well-defined dikes or veins of greisen. This lode ore is associated with granite or other siliceous, igneous, intrusive rocks, that have been altered to true greisen like that occurring in nearly all productive tin regions.

In one case the cassiterite occurs disseminated through a greisen composed of quartz, calcite, fluorite, and lithia mica. In another case the tinstone is intimately associated with tourmaline contained in veins in the granite.

The granites in which tin ore has been found are intruded in limestones of Silurian age in one case and probably of Carboniferous age in another. Similar bodies occur northeastward from York for a distance of 100 miles. Minerals associated with the tin ore in the York region, such as fluorite and tourmaline, have been found in several of these granite areas, and tin ore has been reported from some of them, but its existence outside of the York region has not yet been proved.

Some of the promoters of mining enterprises have expressed a desire to install immediately a complete outfit for milling and smelting tin ore at some point in the York region. The many fiascos resulting from the building of mills and smelters before the extent of ore bodies had been determined are well known to anyone familiar with the history of mining in the United States, so that the folly of this plan is evident. Even after the ore is proved to exist in sufficient quantities for mining a careful study must be made of the ore itself, and of the conditions as affected by climate, wages, fuel supply, and transportation, before either the proper place or method of treating the ores can be determined. The erection of a smelter at present would seem to be ill advised, if for no other reason than because no estimable supply of ore exists. In estimating the value of tin ores in this northern region several facts must be borne in mind. The region is devoid of timber and is accessible by ocean steamers, at the longest, only from the first of June to the end of October. Harbor facilities are poor, and all supplies and wages are high. On the other hand, the construction of railroads and wagon roads would not be difficult, and, if demanded, would require comparatively little outlay of capital.

#### TRANSPORTATION AND FUEL SUPPLY.

In view of the possible developments of tin mining in this region the questions of transportation and harbor facilities become important.



The coast line of the York region is not broken by any inlet or harbor suitable for seagoing vessels. Such craft are obliged to lie a safe distance offshore, while landings of freight or passengers are made with lighters or small boats through the surf, as at Nome. During much of the time the sea is smooth and such landings are easy, but frequently violent storms continue for several days, which would destroy lighters and endanger the ships themselves. In fair weather vessels could be loaded in safety from piers, but the possibility of maintaining docking or other loading facilities along this coast is questionable on account of the movement of great ice floes that cover Bering Sea during the long winter.

Port Clarence, the only harbor and safe anchorage for large vessels in Seward Peninsula, is a bay 25 miles southeast of York, and, should the tin deposits be worked on an extensive scale, this harbor is easily accessible. It is a large body of comparatively deep water, nearly circular in outline, and cut off from the sea by a long, low sand spit, which terminates in Point Spencer at the entrance to the bay.

Along the north side of Port Clarence there is a shallow lagoon, separated from the bay by a narrow sand spit. This lagoon extends several miles west of the entrance to Port Clarence. It can be made use of for transporting ore in lighters and small boats. The Coast Survey charts show deep water suitable for large vessels along the north shore near the entrance to the bay, and docks and wharves would naturally be built there. On the south side of the entrance, at Point Spencer, a safe anchorage near shore is made use of as a coaling station by whalers en route to the Arctic Ocean. It is reported that the ice leaves this part of Port Clarence first, at the opening of summer, and that vessels have made use of this anchorage before they were able to approach the coast at Nome. It is therefore possible that Point Spencer might be the most convenient shipping point for the York region. The product of the mines could be brought to the coast of Bering Sea by tramroads or wagons, and, in the summer time, ferried across to Point Spencer, or in the winter hauled over the ice either by traction engines or by horses. Should production be sufficient to warrant it a railroad can easily be built from some point on the north shore of Port Clarence to Lost River and up its valley. Should the mines on Buck Creek warrant the building of a railroad the Lost River line could be extended across the divide at the head of Lost River to Mint River, and thence follow around the northern foothills of the York Mountains to Buck Creek. This road could again be extended from Buck Creek to the locality at Cape Mountain. It would probably not be practicable to build a road along the coast from the mouth of Lost River to York.

During the summer season there is sufficient water in the streams of the region to furnish power for all the machinery required in mining

and concentrating, but, obviously, during the winter this source of power is cut off, and coal or other fuel must be used. In Alaska there are two possible sources of coal for the York region. One of these is near Cape Lisburne,<sup>a</sup> about 200 miles northeast of York, on the shore of the Arctic Ocean. There is reported to be an abundance of coal suitable for steaming purposes at this place, but there are absolutely no harbor facilities and there is no wood available for timbering the mines, and, further, navigation on the Arctic Ocean is possible for only two months of the year; so that these coal beds can not be depended on to furnish a coal supply.

The other source of coal is at Herendeen Bay and Port Moller, about 700 miles to the south, on the Alaskan Peninsula, but this coal has not been sufficiently developed to determine whether it exists in commercial quantities. At the present writing it seems that the only certain sources of fuel for the Seward Peninsula are the coals of the State of Washington and those of British Columbia. On account of the difficulty in obtaining fuel and the cost of labor and subsistence in the Seward Peninsula it does not seem possible that the smelting of tin ore in the York region will ever be successfully accomplished. The ore from this region will necessarily be shipped either to the coal mines in other parts of Alaska, to Puget Sound, or to other points for smelting. The freight on ore shipped from Port Clarence to Seattle would probably be very low, since the large number of vessels carrying freight to Seward Peninsula and St. Michael would desire return cargoes.

In the summer of 1902, 98,822 tons of freight were carried to these points.

#### TIN ORES AND ASSOCIATED MINERALS.

*Physical characteristics of tin ore.*—Cassiterite, tinstone, or tin ore, the dioxide of tin, is the most common form in which tin occurs in nature. It crystallizes in four-sided prisms and octahedrons, but twinning is so common that simple crystals are rarely found. The stream tin of the York region usually occurs in rounded pebbles, its color varying from light brown to black; the color of the streak—that is, of the powdered mineral—is pale gray to brownish. Wood tin is cassiterite that occurs in botryoidal and reniform shapes, with concentric and radiated fibrous internal structure, though very compact. Its color is brownish in varying shades, which give it somewhat the appearance of dry wood. A few specimens of wood tin have been found on Buck Creek. Cassiterite has no distinct cleavage visible to the naked eye. It has about the same hardness as quartz, but is very much heavier, having a specific gravity, when pure, of from 6.4 to 7.02.

<sup>a</sup> Schrader, F. C., A reconnaissance in northern Alaska in 1901: Prof. Paper U. S. Geol. Survey No. 20, 1904, pp. 109-114.

Specimens of the ore mined in the York region, which were tested in this office, gave specific gravities from 5.15 to 6.06. Since cassiterite is heavier than most of its associated minerals, it can usually be separated from them by crushing and panning. The most satisfactory test for cassiterite that can be made in the field is with the blowpipe, as follows: The mineral, crushed and finely powdered, is mixed with about equal amounts of powdered charcoal and soda, and heated gently in the reducing flame. Metallic tin is readily obtained in small globules scattered through the assay, but it is more difficult to collect the metal into one globule, and in attempting it an unskilled operator will usually reoxidize the tin.

Stannite, or tin pyrites, is sulphide of tin, copper, and iron with some zinc. Some varieties contain silver, lead, or antimony. Stannite resembles pyrites and other metallic sulphides, and is not easily distinguished in the field. The blowpipe tests are unsatisfactory, since it is impossible to obtain a tin globule from it. This ore, when pure, contains only 27 per cent tin, and is not mined except in conjunction with other ores. It has been found on Tin Creek in the York region.

#### ASSOCIATED MINERALS.

In the York region the most common minerals accompanying tin are quartz, tourmaline, epidote, garnet, rutile, fluorite, wolframite, magnetite, hematite, limonite, and ilmenite. Of these, tourmaline, garnet, rutile, wolframite, magnetite, limonite, and quartz have often been mistaken for tin ore.

*Tourmaline.*—This is a complex silicate of boron and aluminum. In the York region it occurs in slender three, six, or nine sided prisms, brownish black and bluish black in color. These prisms are often arranged in radiating groups. Tourmaline is distinguished from cassiterite by its crystallization and by its specific gravity, which varies from 2.98 to 3.20. Before the blowpipe the tourmaline of the York region is fusible without fluxing, while cassiterite is infusible.

*Garnet.*—In the York region garnet often occurs in massive, granular aggregates, which greatly resemble tinstone. To the experienced eye they are readily distinguishable by slight differences in color. Garnet has a specific gravity from 3.15 to 4.30; in other words, it is a little more than half as heavy as tinstone. It crystallizes in the isometric system, and never forms elongated prisms. Like tourmaline, it fuses before the blowpipe.

*Rutile.*—Titanium dioxide, or rutile, occurs in crystals, which in hardness, specific gravity, and crystallization resemble cassiterite. The crystals, however, are usually slender prisms, striated or furrowed lengthwise. The streak is pale brown. This mineral has not been found in the lodes, but in alluvial deposits it has often been mistaken for tinstone.

*Wolframite*.—This is an ore of the metal tungsten, a tungstate of iron and manganese. It has a submetallic luster, a grayish or brownish-black color, and a black streak. Its specific gravity is 7.2 to 7.5, a little higher than that of cassiterite, but it is readily distinguished from the latter mineral by possessing a perfect cleavage.

*Epidote*.—This complex silicate of calcium, aluminum, and iron is usually of a yellowish-green color. On Tin Creek it is found in prismatic crystals forming divergent groups resembling the tourmaline, which is also found there. In luster, streak, and hardness it resembles cassiterite, but its specific gravity is 3.25 to 3.50, only a little more than half as heavy as cassiterite. Before the blowpipe it fuses easily, and in the closed tube gives water.

*Magnetite and limonite*.—These ores of iron are found in the placers associated with stream tin. They are often mistaken for tin ore, but are readily distinguished by the practiced eye. Magnetite can be distinguished by the use of a magnet, while the red or brown streak of limonite serves to separate it from the tin ore.

*Fluorite*.—This mineral, commonly known as fluorspar, occurs in the bed rock associated with the tin ore wherever found in the York region. It is a simple chemical combination of fluorine and calcium, crystallizing in cubes and having a vitreous luster and usually a white, wine-yellow, greenish-blue, or violet-blue color. Its specific gravity is from 3.01 to 3.18. It is easily scratched with a knife, its hardness being about equal to that of calcite, from which it is distinguished by its cubic crystallization and failure to effervesce with hydrochloric acid.

*Quartz*.—In varying amounts quartz is also associated in the bed rock with the tin ore. Usually it is readily distinguished from the cassiterite, but instances were common last summer where prospectors had mistaken a dark-colored, smoky quartz in small grains for cassiterite. The specific gravity of quartz is 2.65 to 2.66, so that by the panning test the quartz can readily be separated. In powdered form smoky quartz and cassiterite resemble each other so much that the blowpipe test is often required to distinguish them.

#### METHODS OF ASSAYING TIN ORE.

Accurate assays of tin ore by ordinary methods are difficult on account of the readiness with which the tin combines with the various gangue minerals, forming silicates and stannites, which pass off with the slag.

Nearly all writers on the subject of tin assays recommend that only rich ores, practically almost pure cassiterite, be treated by fire assay. Stream tin is ordinarily pure enough to give an approximately accurate result without further concentration, but lode ore, associated as it is

with gangue minerals, must be concentrated. Without such treatment it is impossible to obtain even an approximate estimation by the dry method usually employed, and in an ore containing less than 10 per cent it is probably impossible to obtain any tin at all. A study of the literature regarding tin analyses has convinced the writer that the reports of dry assays of low-grade tin ores, in which the cassiterite can not be recognized by the naked eye or separated by hand panning, are of no value.

For assaying<sup>a</sup> the ore is first pulverized and screened to uniform size, care being taken in the crushing to prevent the formation of slimes, since cassiterite is very brittle. The pulp is then roasted in a muffle to decompose any sulphides and arsenides that may be present. After roasting, and while still hot, it is thrown into cold water, which finely subdivides the ore and exposes a much larger surface to the action of acids. The ore is then boiled with nitrohydro-chloric acid to remove all soluble metallic compounds. This boiling must be continued until iron ceases to dissolve. The ore is then washed with hot water, transferred to a gold pan, and washed free from visible impurities. The ore thus prepared for assay may be treated by either of the two following methods, the first being preferred:

The finely pulverized ore is mixed with five times its weight of chemically pure potassium cyanide, then fused in a clay crucible in a bright fire. A steady fusion is kept up for from 10 to 15 minutes at the highest point to which potassium cyanide can be heated without showing heavy fumes.

Five grams of KCN are rammed into the bottom of the crucible. The charge, consisting of 10 grams of ore mixed with 40 grams of potassium cyanide, is then poured into the crucible, and 5 grams of KCN placed on top of the charge.

A "G" Battersea or Denver crucible may be used for pot-furnace work, and a "B" or 20-gram Colorado crucible will probably do for muffle work.

The following charge is said to be taken from Kerl and Balling.<sup>b</sup>

Five grams of ore are intimately mixed with 0.75 to 1 gram of charcoal dust and charged into a clay crucible. On top are placed 12.5 to 15 grams black flux<sup>c</sup> (or substitute) with 1 to 1.25 grams borax glass, then a salt cover, and finally a piece of charcoal. The crucible is covered, heated in a muffle or a pot furnace at a moderate gradually increasing temperature until the boiling has ceased, and then from one-half to three-fourths of an hour at a white heat. The crucible is removed from the fire, broken when cool, and the tin button weighed.

The salt cover should be about one-fourth inch thick. It would seem that finer charcoal would cover the charge as well as a single piece, for the object is to keep the charge in a reducing atmosphere. These methods are found to give within 0.5 per cent of the results of wet assays when used with well-cleaned minerals.

<sup>a</sup>Hofman, H. O., The dry assay of tin ores: Trans. Am. Inst. Min. Eng., vol. 18, 1890, pp. 3-54.

<sup>b</sup>Kerl, Metallurgische Probirkunst, Leipzig, 1882, p. 412. Balling, Die Probirkunde, Brunswick, 1879, p. 391.

<sup>c</sup>Black flux is 1 part niter ( $KNO_3$ ) and 3 parts argol, deflagrated. Black flux substitute is 2 parts potassium carbonate or sodium bicarbonate and 1 part flour.

All ores must be crushed and carefully concentrated by sizing and panning. For a prospector's field test of ore supposed to carry a small percentage of tin, a practical method would be to crush the supposed tin ore in a hand mortar and concentrate by panning, after which the concentrates can be roasted and cleaned with a magnet and the residue tested with a blowpipe, as has been described.

As small globules of tin, such as are obtained by the blowpipe, are sometimes unsatisfactory, more metal can be reduced by simple means. While at Teller this seemed desirable, and an old teacup was lined one-fourth inch thick with a paste of powdered Wellington coal and baked. The finely pulverized ore was mixed with an equal bulk of powdered coal and twice as much ordinary baking soda; this charge was placed in the cup and covered one-half inch deep with powdered coal and heated for forty-five minutes in an ordinary cook stove with as hot a fire as possible. Although the cup broke upon attempting to remove it from the fire, good-sized buttons of tin, as large as a pea, were obtained. After determining the presence and the relative value of the washed cassiterite, pan assays will be found sufficient for further tests.

Greater accuracy in the assay of tin ores is obtained by wet analysis. Such analyses of eight samples of low-grade tin ores from the Seward Peninsula were recently made in the laboratory of the United States Geological Survey. These ore contained no visible crystals of cassiterite, and were treated without mechanical concentration. The following note in regard to the wet method of analysis is furnished by Mr. Eugene C. Sullivan, of the United States Geological Survey:

The method used in detecting traces of tin was as follows: Two grams were roasted in platinum crucible, fused with potassium bifluoride (KHF), and the melt was twice evaporated with concentrated sulphuric acid ( $H_2SO_4$ ) to insure absence of hydrofluoric acid (HF). The mass was taken up with dilute sulphuric acid ( $H_2SO_4$ ), in which practically all dissolved. The solution was decanted from any slight residue, which was fused as before with potassium bifluoride (KHF) and after driving off hydrofluoric acid (HF) by means of sulphuric acid ( $H_2SO_4$ ) added to the main solution. The solution was nearly neutralized with ammonium hydroxide ( $NH_4OH$ ), and hydrogen sulphide ( $H_2S$ ) was passed through it for several hours. The precipitate was digested for some time with yellow ammonium sulphide, being warmed slightly. The insoluble residue was filtered out, the filtrate acidified slightly with sulphuric acid ( $H_2SO_4$ ), and hydrogen sulphide ( $H_2S$ ) was passed to insure complete precipitation of stannic sulphide ( $SnS_2$ ). The precipitate was filtered out and ignited, again fused with potassium bifluoride (KHF), evaporated with concentrated sulphuric acid ( $H_2SO_4$ ), taken up with dilute sulphuric acid, stannic acid ( $H_2SnO_3$ ) precipitated with ammonium hydroxide ( $NH_4OH$ ), the precipitate dissolved in hydrochloric acid, any residue filtered out, the solution neutralized with ammonium hydroxide ( $NH_4OH$ ) and hydrogen sulphide ( $H_2S$ ) passed for some hours.

Where the tin was present a yellow precipitate of stannic sulphide ( $SnS_2$ ) separated, apparent on allowing the solution to stand for some time. To obtain an idea of the amount of tin present this precipitate, after thorough washing, was ignited and weighed as stannic oxide ( $SnO_2$ ).

## OCCURRENCES OF TIN ORE IN THE UNITED STATES.

The total amount of metallic tin produced from ore mined in the United States has not exceeded 200 tons, though small amounts have been found in no less than 17 States and Territories: Alabama, Alaska, California, Colorado, Connecticut, Georgia, Idaho, Maine, Massachusetts, Missouri, Montana, New Hampshire, North Carolina, South Dakota, Texas, Virginia, Wyoming.

In Alabama, cassiterite occurs in quartz veins in graphitic schists<sup>a</sup> near granite, and as disseminated grains in gneiss.

In California<sup>b</sup> small amounts of float cassiterite have been found in the gold placers at a number of widely separated localities. The ore is found in places at the Temescal mine, 5 miles southeast of Riverside. At this place there is an area of hornblende biotite-granite over 2 miles in diameter which is cut near its borders by dikes of highly quartzose and feldspathic fine-grained granite. The ore occurs in veinlets of tourmaline and quartz aggregates which run northeast and southwest through the granite. A great body of such vein matter, covering an area 300 by 250 feet, and 25 to 30 feet high, crops out in the Cajalco Hill. What is known as the Cajalco vein courses northeast from this outcrop, and the workings extend for 1,100 feet along it. The vein is sinuous, and varies from a minimum of a clay seam to a maximum of 8 feet. There is always a clay gouge on one and often on both walls. Two hundred and ninety-one and fourteen one-hundredths pounds of metallic tin were produced from ore mined at Temescal previous to 1892, when the mines were abandoned.

In the Carolinas a tin belt<sup>c</sup> extends in a northeast-southwest direction for about 31 miles, and lies partly in North Carolina and partly in South Carolina. Tin ore is not evenly distributed through this distance, though the tin-bearing formation, which consists of crystalline schists or gneisses containing pegmatitic dikes, is continuous. The rocks of the tin belt are very much decomposed, and the pegmatite dikes are very thoroughly kaolinized. The tin ore has been found loose in the soil, in the gravels, in bowlders of quartz and mica, and occasionally in the pegmatite dikes. The most promising deposit in the belt is at the Ross mine, near Gaffney, S. C., from which 38,471 pounds of the ore were shipped in 1903.

In Colorado tin ore has been reported near Golden, but little is known of its occurrence.

<sup>a</sup>Phillips, Wm. B., Geol. Survey of Alabama, Bull. No. 3, 1892.

<sup>b</sup>Sixth Ann. Rept. California State Min. Bureau, Sacramento, 1886. Eleventh Ann. Rept. California State Min. Bureau, Sacramento, 1893. Fairbanks, Harold W., Tin deposits at Temescal: Am. Jour. Sci., 4th ser., vol. 4, 1897, pp. 39-42. Rolker, C. M., Production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 536.

<sup>c</sup>This note is furnished by Joseph Hyde Pratt in advance of Economic Paper No. 8 of the North Carolina Geological Survey on "Carolina tin deposits."

In Connecticut tin ore has been found at Haddam, but only as a mineralogical curiosity.

In Georgia tin ore has been reported from Lumpkin County as occurring in granite and chlorite schists, with minute quantities from the gold washings.

In Idaho a few specimens of stream tin have been found on Jordan Creek, in the southwestern part of the State, and in the Coeur d'Alene district.

In Maine<sup>a</sup> cassiterite occurs at Winslow in small veins, which traverse impure limestone, with purple fluorite, mica, quartz, and mispickel. These veins have been prospected to a depth of 100 feet, but have yielded no tin in commercial quantities. Similar occurrences are reported at Paris and Hebron.

In Massachusetts a few crystals of cassiterite have been found with albite and tourmaline at Goshen and Chesterfield.

In Missouri<sup>b</sup> a small amount of cassiterite has been found replacing sphene in granite.

In Montana<sup>b</sup> stream tin has been found in Prickly Pear, French Bar, and Ten Mile creeks, in the "Basin" in Basin Gulch and in Peterson Creek. Light-brown, rounded pebbles of wood tin associated with topaz crystals have been found at one locality.

In New Hampshire cassiterite was found at Lynn and Jackson in 1840 by Doctor Jackson. It occurs with arsenical and copper pyrites, fluorspar, and phosphate of iron in small quartz veins, and mica, slate, and granite near a trap dike.

In South Dakota<sup>c</sup> the Black Hills contain noteworthy deposits of tin ore, which, however, have not yet proved commercially productive. They occur in an area of coarse-grained granite in the central part of the hills. The Etta mine deposit, the only one that has produced any considerable quantity of tin, is a lenticular body of pegmatitic granite, which consists of quartz, feldspar (albite), lepidolite, and spodumene in individuals of great size, up to 8 or 9 feet in dimensions. Cassiterite occurs in association with lithia mica and is accompanied by columbite and tantalite, with which it is apt to be confused. The mine was sold to an English company, which erected a 250-stamp mill, but the ore did not prove profitable to work, and after the first run, which produced 9,385 pounds of tin, the work was closed.

In Texas<sup>d</sup> tin has been discovered in quartz veins occurring in greisen granite in the Franklin Mountains near El Paso, and one small crystal

<sup>a</sup>Jackson, C. T., On the discovery of a new locality for tin ore in Winslow, Me.: Proceedings Boston Soc. Nat. Hist., vol. 12, 1869, p. 267. Hunt, T. S., Remarks on the occurrence of tin ore at Winslow, Me.: Trans. Am. Inst. Min. Eng., vol. 1, 1873, p. 373.

<sup>b</sup>Raymond, R. W., Trans. Am. Inst. Min. Eng., vol. 1, 1873, p. 374.

<sup>c</sup>The writer is indebted to Mr. S. F. Emmons for the note on tin in South Dakota.

<sup>d</sup>Dumble, E. T., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 595, 690, 713.



has been found at another locality. At El Paso,<sup>a</sup> wolframite occurs with the ores, and feldspar is replaced by cassiterite.

In Virginia<sup>b</sup> good tin prospects have been found on the headwaters of Irish Creek, Rockbridge County, in quartz lenses and stringers in granite, which itself is intrusive in metamorphic schists. Associated minerals are wolframite, mispickel, iron pyrites, quartz, and beryl, with small amounts of siderite, limonite, chlorite, muscovite, damourite, and fluorspar.

In Wyoming,<sup>c</sup> at Nigger Hill, in the northwestern portion of the Black Hills, cassiterite has been found in a granitic area that is similar in geological association to that at the Etta mine.

#### CONDITIONS AND METHODS AT THE LARGE TIN MINES OF THE WORLD.

Since the tin from newly discovered sources must come into competition with the product of established mining districts, a comparison with the mining conditions in the older districts will be useful in estimating the value of the newer ones. For this purpose the following notes have been compiled from the most recent publications on the tin deposits of the world, and a brief bibliography of these is presented on pages 55-56.

The greater part of the world's supply of tin is obtained from alluvial deposits. Over three-fourths of it comes from alluvial deposits in the Malay Peninsula, otherwise known as the Straits Settlements, and the islands of Banca and Billiton, off the north coast of Sumatra, the former region producing about half of the tin of the world. A large amount is produced from alluvial deposits in Australia, while in Cornwall, Saxony, and Bolivia most of the tin ore is obtained from vein deposits in the bed rock.

#### MALAY PENINSULA.<sup>d</sup>

The Malay Peninsula, in which the Straits Settlements tin deposits are located, consists of a central axis of rugged hills running north and south, with occasional subordinate or diverging axes and isolated peaks. The whole region is covered by a jungle of tropical vegetation so dense that the roads and trails have to be hewn through. In the tin regions the main range is composed of granitic rocks, occasionally cut by feldspathic and other dikes, while in some places are found gneissic and schistose rocks, with occasional areas of a white, highly crystalline limestone.

Tin ore occurs in nearly every part of the western side of the Malay

<sup>a</sup>Weed, W. H., The El Paso tin deposits: Bull. U. S. Geol. Survey No. 178, 1901.

<sup>b</sup>Rolker, C. M., Production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 523-525.

<sup>c</sup>Rolker, C. M., *cit.*, p. 530.

<sup>d</sup>The following notes regarding the Malay tin deposits are taken almost verbatim from R. A. F. Penrose, Tin deposits of Malay Peninsula: Jour. of Geol., vol. 11, 1903, pp. 135-154.

Peninsula for a distance of 900 miles, but the principal mining district is located about 300 miles northeast of Singapore, and is known as the Kinta district. The district comprises a more or less inclosed valley about 40 miles in length, extending in a north-south direction, about 30 miles in width at its south end and about 5 miles wide at its north end. The valley includes some lower mountains and areas of limestone, surrounded and partly covered with great tracts of alluvium. Much of this alluvium contains oxide of tin, or cassiterite, in particles and fragments of varying size, forming what might be termed "tin placers," in which the tin occurs in different ways. Sometimes it is scattered through it from top to bottom in comparatively uniform quantities; sometimes it is in layers or pay streaks separated by barren ground; sometimes it is richest on the bed rock. As a general rule, however, there is a covering or "overburden" of barren alluvium from 10 to 40 feet or more in thickness above the tin ground. The best ground occurs immediately at the foot of the mountains. Higher up it is often richer, but of small extent, while farther away it is thicker, but of lower grade. The ordinary tin-bearing beds vary from 1 to 30 feet in thickness, though sometimes they reach over 100 feet. In one instance the tin-bearing formations extend from the surface down to a depth of from 5 to 30 feet, without any barren overburden. In another instance large open pits in the alluvium of the river valley show tin-bearing strata, varying from 2 to 10 feet in thickness, with a barren overburden about 40 feet in thickness. In another instance the overburden is from 30 to almost 40 feet in thickness, and the tin-bearing ground below has been penetrated 140 feet vertically without reaching the bottom. In the mountains near its source the ore is angular and in comparatively large fragments, sometimes from an inch to a foot or more in diameter. Farther down the hill it becomes more and more rounded and finer in grain.

Most of the mines are operated by Chinamen, and the labor is performed by coolies from southern China. The tin-bearing alluvium is worked mostly in open cuts or large pits, except where the covering or overburden is very thick, when shafts are sunk to the tin stratum. The average depth of the working is about 40 feet, and the greater depth can not ordinarily be reached on account of water in the pits. It is a common thing to see water raised from these pits by a rude treadmill pump worked by the feet of Chinese laborers.

The pay gravel dug from the bottom of the pit is carried up an incline to the surface in baskets hung on either end of a stick carried on the back of a Chinaman. It is then dumped into wooden troughs, supplied with running water, and, if necessary, stirred with a shovel until washed into the sluice boxes. These boxes are from a few feet to several hundred feet in length, and are built of wood or cut in the sandy clay of the region. In the description of them no mention is

made of riffles being used. After running for some time, the water is shut off and the material in the boxes is cleaned up. This material is further concentrated by hand panning in flat wooden bowls, which resemble the American gold pan. The final process is cleaning by hand picking, by which the magnetic iron and other impurities are removed. Ore treated in this way will average from 60 to 70 per cent tin. In one instance hydraulic monitors are used, but the greater part of the tin ore from this region is produced by the more primitive methods.

#### BANCA.

In the island of Banca,<sup>a</sup> which is under the Dutch Government, the geological conditions resemble those of the Malay Peninsula. The bed rock consists of granite masses flanked by Silurian slates. Tin ore has been found occurring as impregnations in the granite and also as veins in the slate, but these deposits are not worked. The tin wash consists mainly of fragments of granite, "schorl,"<sup>b</sup> and sandstone. The bed rock nearly always consists of granite more or less decomposed. A section of an average stream-tin deposit shows above the bed rock 3 feet of tin-bearing gravel, overlain by red sand, followed by red clay, then coarse sand with pockets of clay, layers of fine sand with a little fine tin ore. The average overburden is from 25 to 35 feet; shallow diggings are prospected by pits, deeper ones by systematic borings. In 1891 and 1892, according to the United States Bureau of Statistics, 7,982 men were employed in the mines of Banca and produced 5,753 tons of tin, a yearly product per man of seventy-two one-hundredths of a ton. There is water for working in the lower valley diggings but eight months each year, and for only five months in the upper diggings.

#### BILLITON.

In Billiton, also under the Dutch Government, the geologic conditions resemble those in Banca. There are granite masses surrounded by quartzites, schists, and slates of Silurian age. Some tin is obtained from ledges that occur both in the granite and in the quartzite, but the greater part of the tin comes from alluvial deposits. In 1891-92 8,690 men were employed here, the output averaging per man a little over seven-tenths of a ton of tin. The prospecting is done very systematically, and is in charge of a corps of European engineers who test the fields in advance of the mining operations by boring first at intervals of, say, 100 yards, and supplementary holes are made from 20 to 25 yards apart to ascertain the course, average thickness, and

<sup>a</sup>Rolker, C. M., Production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 484.

<sup>b</sup>"Schorl" is an old name for rocks composed mainly of tourmaline and quartz.

character of the pay gravel. The contents of each hole is carefully washed and the tin ore weighed, and from these results calculations as to the probable yield of the ground are made. On the basis of this estimate the fields are let to Chinamen.

#### AUSTRALIA.

In Australia tin ore has been found very widely distributed, and is mined in New South Wales, Queensland, South Australia, Tasmania, Victoria, and West Australia. The occurrences present considerable variety, and both alluvial and vein deposits have been worked, though the greater part of the tin is produced from alluvial deposits. The two best-known localities of stream tin are Vegetable Creek in New South Wales, and Bischoff Mountain in Tasmania.<sup>a</sup> All the tin gravels of Vegetable Creek are derived from masses of granite that are permeated by numerous tin veins. The width of the channel deposits of this creek varies from 5 to 15 chains, or from 330 to 990 feet, but the richest portions are reported to be from 1 to 5 chains wide. The average thickness of the deposit is reported to be 7 feet, while the thickness of the pay gravel averages  $2\frac{1}{2}$  feet. The average yield per cubic yard of pay gravel is said to be about 20 pounds of tin ore, equal to about 0.8 per cent. In this district the mining is done by hydraulic monitors and other modern mining appliances.

The tin deposits of the Mount Bischoff region in Tasmania are largely residual gravels derived from decomposition in situ of the bed rock. The bed rock of this mountain consists of Paleozoic clay slates and quartz, and to a less extent of sandstones and dolomites. The slates are traversed by numerous veins of quartz-porphyr. The porphyry and also the slates have undergone great transformations, so that all of the original feldspar and mica, as well as the primary quartz, have been replaced by topaz, tourmaline, secondary quartz, tinstone, and to a less extent by fluorspar, arsenious pyrites, and magnetite. The gravels are sometimes astonishingly rich in tin. In one instance 240 tons of concentrated ore were taken from an area of 66 square feet. Masses containing 6 hundredweight, almost free from the matrix, have been found. The accumulation of tin ore in the gravel is exceedingly patchy, as might be expected in deposits of this nature. Frequently within 60 feet of the richest deposits the wash dirt is found to contain only traces of tin. The ore is first concentrated by sluicing, then crushed and further concentrated; 5,500,000 tons of material handled previous to 1899 is reported to have yielded 44,560 tons of black tin, or 0.81 per cent of the total material treated. The value of a ton of gravel probably averaged about 6s. 10d., or \$1.70. The total cost of mining, crushing, dressing, and bagging the concentrates amounted to 4s.  $2\frac{1}{2}$ d.,

<sup>a</sup>Rolker, C. M., Production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 497.

or about \$1.05 per ton, and the dressing and smelting was covered by a yield of 0.5 per cent tin oxide, equal to about 10 pounds of black tin per ton.<sup>a</sup>

Nearly all the ore obtained in Tasmania is smelted at the Mount Bischoff Company's smelting works in Launcester, Tasmania.

#### CORNWALL.

The tin-bearing district of Cornwall<sup>b</sup> is at the extreme southern end of England and has a length of about 100 miles and a width of from 10 to 30 miles. The bed rock consists of metamorphosed clay slates, called "killas," of Devonian age, intruded by large masses of granite. Both the granite and the slates are cut by dikes of quartz-porphyr, called "elvan courses," whose outcrops form a fringe around the granite areas. Five granite areas of this kind are shown on geological maps of the region, while the Scilly Islands, about 20 miles to the southwest, form a sixth.

The tin gravels of Cornwall were exploited as early as Roman and Grecian times, when the British Islands were called Cassiterides. At present the original tin-bearing gravels have long been exhausted and abandoned. What is called "stream working" at the present day is merely the extraction of tinstone from the tailings of the stamp mills collected in the valley depression. In 1894 about 6 per cent of the total tin production of Cornwall came from the washing of these poor slimes.

The tin-bearing lodes of Cornwall have been worked for many years and afford the best examples of lode mining for comparison. These lodes occur in the granites, slates, or elvans, or in the contacts between them. Nearly all of the mineral wealth occurs within 2 or 3 miles on either side of the boundaries between the slates and the granite.

The granites, especially in their outer portions, are usually more or less altered, and the name greisen is often applied to them. Typical greisen consists principally of quartz and lithia mica, with tourmaline, zircon, topaz, fluorite, and cassiterite in small amounts. In some cases the rock consists very largely of tourmaline and quartz, with fluorite in varying quantities.

The common minerals associated in the veins with the cassiterite are quartz, feldspar, chlorite, and tourmaline, with fluorite, lepidolite, topaz, copper pyrites, and copper glance in varying proportions. Several of the mines have produced both copper and tin ores, and in some cases mines which were opened as copper mines have become tin mines in depth by a gradual increase in the amount of tin ore and corresponding decrease in copper ore.

<sup>a</sup> Rolker, C. M., Production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 505, quoted from Min. Res. of Tasmania, Nov., 1894.

<sup>b</sup> De la Beche, H. T., Report on the geology of Cornwall, Devon, and West Somerset, with map: *Geol. Britain Geol. Survey*, London, 1839.

The metalliferous contents of the tin-bearing lodes appear to be affected not only by the mineral composition of the contiguous rocks, but also, in some degree, by their position and mechanical structure. Whether the rock be granite, slate, or elvan the hardest portions are always quartzose, and in these the lodes are seldom rich.

If, on the contrary, the grain of the rock be neither very fine on the one hand, nor particularly coarse on the other, while the inclosed crystals of feldspar have a greenish, brownish, or pinkish tint and indistinct outlines, quartz, mica, and sometimes schorl being present, the appearance of the rock is considered to be favorable, and lodes inclosed in it may be expected to be fairly productive, especially of tin ore.<sup>a</sup>

The lodes which afford lead ores occur in the slates, usually at some distance from the granite, while the lodes which cut both slate and granite, though they carry both tin and copper, are usually richer in copper where the walls are slate, and richer in tin where the walls are granite.

The walls of the tin-bearing veins are seldom well defined, and generally the ore is disseminated through the wall rock on one side or the other, so that at some distance away from the veins it is rich enough to work. This is especially common when the vein is inclosed in granite, but also happens in the slates and elvans.

All Cornish tin ores can not, however, be distinctly connected with veins. In some instances the deposits are stockworks which consist of a mass of granitic or other rock traversed by a network of small veins interlacing with one another and running through the rock in various directions. Other large deposits in Cornwall, known as "floors" or "carbonas,"<sup>b</sup> are usually connected with well-defined lodes, though in some cases they are surrounded by hard granite and apparently unconnected with any lode or vein. Enormous deposits of this kind have been found in the workings of the St. Ives Consols mine. The Standard lode at this place has been worked to a depth of nearly 200 fathoms and has in the aggregate been very productive, though it does not average more than  $4\frac{1}{2}$  feet in width. Several large carbonas have been found branching off from this lode at various levels, and many of the workings are in the form of enormous caverns from 60 to 75 feet high and equally wide.

The Dolcoath<sup>c</sup> mine is one of the best known of the Cornish tin mines, and in 1902 the lodes had been traced for over 2 miles, while the workings had reached a vertical depth of about 2,100 feet and were still producing large amounts of ore. The main lode of Dolcoath

<sup>a</sup> Phillips, J. A., and Louis, Henry, A treatise on ore deposits, Macmillan & Co., London, 1896, p. 108.

<sup>b</sup> Phillips, J. A., and Louis, Henry, *Idem*, p. 169.

<sup>c</sup> Frecheville, R. J., Great main lode of Dolcoath: *Trans. Royal Geol. Soc. Cornwall*, vol. 10, 1887, pp. 146-156.

varies in width from 12 inches to 27 feet and is richest in tin in the deepest levels, where the ores sometimes average 10 per cent cassiterite. The richest ore occurs where a number of veins intersect and is said to be of a compact, bluish rock, consisting of a mixture of chlorite, quartz, and tourmaline, with stringers of cassiterite running through it. On the north side it passes gradually into a barren granite. From its upper workings, which are in the slate, this mine yielded only copper ores, but from the deeper levels mined at the present time, which are in the granite, only tin ores are obtained.<sup>a</sup>

The average richness of the ore from a number of Cornish mines for ten years, from 1871 to 1881, is given in pounds of black tin per ton, as follows: Dolcoath, 59 pounds; Cook's Kitchen, 43 pounds; Tincroft, 53 pounds, and Carn Brea, 35 pounds.<sup>b</sup> This is approximately equivalent to 1.8 per cent, 1.3 per cent, 1.6 per cent, and 1 per cent, respectively, in metallic tin. During the half year ending December 31, 1902, the average product of the Dolcoath mine was 38.28 pounds black tin per ton, approximately equivalent to 1 per cent, while during the year ending April 24, 1903, the product of the Wheal Grenville Mining Company at Camborne averaged 43.6 pounds black tin per ton,<sup>c</sup> approximately equivalent to 1.1 per cent in metallic tin.

Many examples showing the nature of occurrence and extent of the tin ledges of Cornwall might be cited for comparison, but those given above will probably be sufficient for present purposes, and will show the general resemblance of the occurrence of tin ore in the York region and in Cornwall.

#### BOLIVIA.

The tin mines of Bolivia occur in veins that are regarded as exceptional in that the tin ore is intimately associated with silver ores, bismuth ores, and various sulphides, while the gangue includes barite and certain carbonates. The deposits often occur in trachytes and andesites erupted during Cretaceous or Eocene time.

#### REDUCTION OF TIN ORES.<sup>d</sup>

Tin ore is prepared for smelting by roasting, if necessary, then crushing and concentrating to at least 60 per cent cassiterite. This may be done with ordinary stamp mills and concentrating machinery. In Cornwall both gravity and steam stamps are used.

The earliest and simplest method of smelting was as follows: A hole, about 2 feet in diameter, was dug in the earth, preferably in a bank, in which sticks of wood and well-cleaned ore were piled in alternate

<sup>a</sup> Phillips, J. A., and Louis, Henry, A treatise on ore deposits, Macmillan Co., 1896, p. 211.

<sup>b</sup> Frecheville, R. J., Great main lode of Dolcoath: Trans. Royal Geol. Soc. Cornwall, vol. 10, 1887, p. 154.

<sup>c</sup> Newland, D. H., Tin, the mineral industry, vol. 11, 1903, p. 695.

<sup>d</sup> Louis, Henry, The metallurgy of tin: Mineral Industry, vol. 5, 1896, pp. 533 to 588.

layers and burned; the tin was thus reduced, dropping or flowing to the bottom of the hole. Remains of many such rude furnaces have been found in Cornwall. Afterwards, bellows were introduced to force the fire, and still later charcoal was added. In some parts of the Malay Peninsula small amounts of tin are produced by reducing in this manner, charcoal being used without artificial draft.

For a long while the shaft furnace was used, but it is now almost entirely superseded by the reverberatory furnace. An average furnace of this kind has about the following dimensions: Bed, 10 by 17 feet; fire bridge, 2 by 6 feet; space below fire arch, 3 feet, and below fire bridge, 15 inches. The bed of the furnace is built over a hollow vault and with the hollow fire bridge is cooled by allowing the air to circulate freely beneath it.

In Singapore water has been used below the bed to catch the tin that leaks through, since the metal is very fluid at the high temperature of the smelter.

The bed has a depth of about 6 inches and slopes from all three sides to the tap hole at one end. Opposite the tap hole is a charging door, and there are openings for working the charge at both ends of the furnace. The average charge is about 2 tons of concentrated ore, mixed with from 15 per cent to 20 per cent of powdered anthracite, a small amount of slaked lime, according to the quality of the ore, and sometimes a little fluorspar.

A good heat is raised and the charge kept in a reducing atmosphere at about the temperature of melting cast iron, and after several rabblings is drawn off at the end of from five to seven hours. At Penzance, Cornwall, 16 men working twelve-hour shifts run four such furnaces.

The tin from the reverberatory furnace must be refined, and after it is run into molds it is placed in a liquating furnace, an inclined table under which a fire is built, which raises the temperature just above the melting point of tin. The tin trickles slowly through the tap hole into the "float" or tank for the molten metal, leaving unmelted the more infusible substance in the form of "hardheads," which are alloys of tin with baser metals, such as copper and iron, and these are refined by other methods. The molten tin in the float is allowed to settle a few hours, after which wood is forced down beneath the molten mass, and the steam and gases formed create a strong ebullition. Bismuth, lead, arsenic, and other impurities, and some tin are oxidized and float as a scum on top and are skimmed off to be smelted again with the slags. The same result is accomplished by dipping up the tin in ladles and pouring it back from a height of 2 or 3 feet, but this involves more labor and seems to possess no advantage over boiling.

After boiling, the tin is allowed to settle for two or three hours, and then the uppermost part is ladled into molds and sold as refined tin,



the middle portion is sold as block tin, and the lowest portion must be further refined. Average English refined tin is from 98.64 to 99.76 per cent pure. The cost of refining tin in the Straits Settlements is said to be about \$12 per ton of 2,000 pounds. There is always some loss in smelting tin; slags from the furnace seldom contain less than 5 per cent, and the average loss in smelting is said to be about 9 per cent.

#### PRODUCTION AND VALUE OF TIN IN 1902-3.

During the years 1902 and 1903 the total world's production of tin is estimated at 90,233 and 92,536 long tons, respectively, as shown by the following table.<sup>a</sup>

*Production of tin, estimated on trade statistics.*

	Long tons.		Changes.	
	1902.	1903.	Increase.	Decrease.
Straits (Malay Peninsula) .....	54,062	54,797	735	.....
Australia .....	3,500	4,991	1,491	.....
Banca .....	14,978	15,070	92	.....
Billiton .....	3,951	3,653	.....	298
Bolivia .....	9,000	9,500	500	.....
Cornwall, England .....	4,392	4,150	.....	242
Miscellaneous .....	350	375	25	.....
Total .....	90,233	92,536	2,843	540
Net increase, 2,303 long tons.				

Of this total production only about 30 tons were mined in the United States.

The total consumption of tin in the United States approximated 39,000 tons, or 43 per cent of the world's output. The production of tin last year, as in fact for several years past, has hardly exceeded the consumption, and from some of the older districts, especially Banca and Billiton, there are signs of a diminution in the output. The average price of tin in New York for 1903 was 28.09 cents per pound, or about 1½ cents per pound higher than for 1902. The price varied during the year from 25.42 cents to 30.15 cents per pound. The total amount of tin consumed in the United States was worth at market prices over \$24,500,000.

#### VALUE OF TUNGSTEN AS A BY-PRODUCT.

Tungsten ores in the form of wolframite occur in association with the tin ores in several places in the York region. At present prices these ores in the York region evidently have no commercial value, but

<sup>a</sup>Tin in 1903, Eng. and Min. Jour., vol. 77, Jan. 7, 1904, pp. 18-20.

considering the difficulty which may arise in separating wolframite from cassiterite the following information will be of interest:<sup>a</sup>

Since the latter part of 1903 there has been a very large increase in the demand for tungsten, and it is probable that from October 1, 1903, to October 1, 1904, will see the marketing of about 1,000 tons of tungsten minerals. Where the tungsten mineral is an associate of some other economic mineral that is being mined it should be a valuable by-product. Its value varies with the percentage of tungsten oxide and has been about \$100 per ton for a 55 to 60 per cent ore. As an associate of tin ore it should be of value as a by-product, and could be separated from the tin mineral by an electro-magnetic separator.

As the demand for tungsten is limited there could readily be an overproduction, with a corresponding reduction in price.

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<sup>a</sup>Communicated to the author by Mr. Joseph Hyde Pratt.

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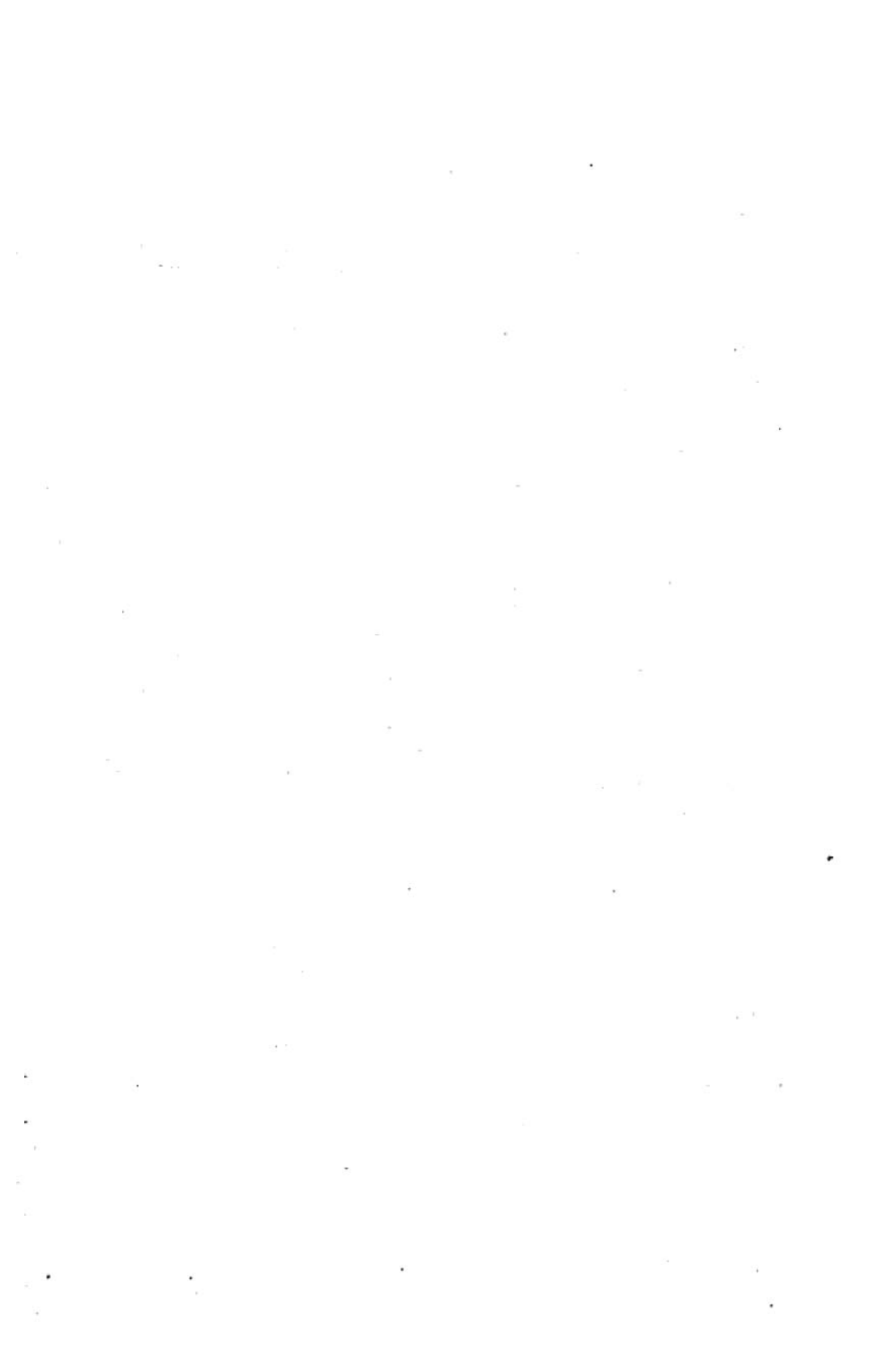
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