RARE METALS.

TIN, TUNGSTEN, AND TANTALUM DEPOSITS OF SOUTH DAKOTA.

By FRANK L. HESS.

INTRODUCTION.

Many articles have been written on the tin deposits of the Black Hills, and an excellent paper by J. D. Irving[a] on the tungsten deposits at Lead was published in 1901. Nothing is known to have been published on the tungsten deposits of the southern Black Hills, but several articles have been written on the deposits of tantalum. Nearly all the papers on these different deposits, however, are a number of years old, and later developments have given several of the deposits an aspect somewhat different from their appearance at the time they were described. It therefore seems well to give a brief account of observations made by the writer during a short reconnaissance trip in September, 1908, together with such reviews of the history and the literature of the region as may seem advisable.

All the known deposits of tin, tungsten, and tantalum in South Dakota occur in the Black Hills, in Lawrence and Pennington counties, in the southwestern part of the State. Although designated as "hills," these elevations reach a height of 7,216 feet in Harney Peak, 500 feet above the highest of the Appalachians (Mount Mitchell, 6,711 feet) and almost a thousand feet above the highest of the White Mountains (Mount Washington, 6,279 feet). They are about 60 to 75 miles long by 50 miles wide, the longer axis lying nearly north and south.

There is a considerable diversity of topography in the different parts of the area to be considered. In the southern part, near Hill City and Keystone, the hills exhibit rounded contours with fairly well

[a] Some recently exploited deposits of wolframite in the Black Hills of South Dakota: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 683-691.

graded valleys, the only jagged or precipitous features being where the harder dikes of pegmatite or coarse granite have resisted erosion, while the more easily weathered schists have worn away.

North of Hill City, in the vicinity of Lead, the hills are flat topped at many places and the valleys are steep sided (though not precipitous), narrow, and deep. The flat tops are given to the hills by approximately horizontal Cambrian sandy dolomites and conglomerates unconformably overlying Algonkian schists which are more easily eroded.

Farther north lies the Tinton area, which resembles much of the country between Hill City and Keystone, though with a somewhat more marked relief, and on the east it is adjoined by the great Spearfish Canyon, which, were it on a great trunk railroad, would be one of the well-known scenic features of the country. The hills are covered with a fair growth of pine except where it has been cut off or burned.

Geologically the Black Hills consist of a central mass of granitic and metamorphic rocks from which dip away on all sides the concentrically outcropping younger rocks of the plains. The granite is a coarse pre-Cambrian pegmatitic intrusive cutting Algonkian schists which are exposed from Tinton to the region south of Hill City. The schists are amphibolitic, staurolitic, andalusitic, and quartzitic, in places containing a great many small garnets. There are also interbedded quartzites. The schists generally stand at a high angle, and on their eroded edges rests a Cambrian conglomerate, though in places the conglomerate is lacking and an overlying quartzite 10 to 25 feet thick takes its place. Above the quartzite are dolomite and shales. These are members of a series of Cambrian rocks which have been eroded from a large part of the area.

The schists are cut by numerous dikes of many kinds of igneous rock. Of these dikes this paper is most concerned with the pegmatites, which are particularly numerous in the Hill City, Keystone, and Tinton areas. A series of quartz veins are closely related to the pegmatites in the Hill City-Keystone area. With these dikes and veins the tin and tantalum deposits are inseparably connected. Tungsten ores are closely associated with them, but at Lead are also found, apparently with other relations. From place to place there is considerable difference in both the physical structure and the mineralogical composition of the pegmatites, especially as concerns the accessory minerals. This is particularly true in the southern hills.

The deposits of tin, tungsten, and tantalum are closely connected, both geographically and genetically, and though workable deposits carrying more than one of these minerals have not yet been proved, this is not out of the range of possibility.

Tin deposits occur in the northern Black Hills at Tinton, and in the southern Black Hills near Hill City, Keystone, Oreville, and Custer.

Tungsten, in the form of wolframite, has been found sparingly at Tinton; in greater quantity at Lead, in the central hills; and at many places near Hill City. Scheelite has been found only occasionally and in small quantity.

Tantalum, in tantalite and columbite, has been found to a very small extent near Tinton and in considerable quantity near Keystone, whence there has been some output.

Tin was first discovered in the Black Hills in 1876, when Richard Pierce, of Denver, recognized cassiterite in placer gold from the northern part of the hills, and in 1877 Fred J. Cross identified it in material from Elk Gulch in the southern hills. It was not discovered in place until in June, 1883, when Maj. A. J. Simmons, of Rapid, sent specimens from the Etta mine, 2 miles south of Keystone, to San Francisco for determination.[a] The Etta claim was at that time being prospected for mica. Shortly afterward tin was found in place at Nigger Hill, since called Tinton, but at that time well known for its rich gold placers, part of which had been discovered by colored men, whence the hill received its name.

Owing to the lack of commercially valuable tin deposits in this country, great interest was awakened among both commercial and scientific men by the discovery. The former soon began plans for the exploitation of the deposits, while the latter studied the minerals and other phenomena connected with the occurrences, and the presence of wolframite and tantalite was soon determined. Companies were formed, and for about ten years there was great activity, though little production of tin. Since 1894 there has been much less done, and only two companies are now engaged in an earnest effort to mine tin, one at Hill City and one at Tinton.

No wolframite is known to have been mined until a number of years after the discovery of tin, when it was found in greatly different association and of much dissimilar appearance at Lead.

The value of tantalum was unknown at that time. In fact, it had little or no value beyond furnishing specimens for collections and material for a small amount of experimental work, so that for a number of years nothing was done toward saving the material except as it occurred in large lumps. The invention of the tantalum lamp gave an impetus to the demand in 1904 and 1905, since which time the market has been light.

[a] O'Harra, C. C., Mineral wealth of the Black Hills: Bull. South Dakota Geol. Survey No. 3, 1902, pp. 62-63. Headden, W. P., Notes upon the history of the discovery and occurrence of tin ore in the Black Hills; Proc. Col. Sci. Soc., vol. 3, 1888-1890, p. 347.

TIN.

GENERAL OUTLINE.

Soon after the discovery of tin at the Etta mine, in 1883, a number of companies were formed to mine the metal. These companies were finally consolidated into the Harney Peak Tin Mining, Milling and Manufacturing Company, with English and American capital. Three million dollars of English money is said to have been sunk in the enterprise, but the amount of American money is unknown.[a] Offices were established at Hill City, and a great number of claims, said to be about 1,100,[a] averaging 10 acres each, with a total area equal to 9 by 15 miles, were purchased over a length of 30 and a breadth of 10 or 11 miles. Apparently all operations and expenditures were on the same extravagant scale. Mills were put up about a mile east of Hill City and at the Etta mine, near Keystone, at a cost of many thousand dollars. The Etta mill alone is said to have cost $235,000.[a]

Shaft houses, boarding houses, or other buildings necessary for large operations were put up on the Etta, Matteen, Gertie, Cowboy, Addie, Mohawk, Coates, and other claims, work was undertaken on a considerable scale, and thousands of tons of pegmatite were broken down. This was easily done, as the pegmatite may be drilled and blasted without difficulty. Lying between the schist foliæ, it breaks with excellent, smooth walls, and the high dip of the dikes makes stoping easy.

Five thousand tons of ore which had been hauled from the various prospects was put through the mill in 1892 and yielded only one-fourth of 1 per cent of metallic tin.[b] This result was in great contrast with the estimates made by various men who had examined the properties, and was attributed to loss through unadjusted new machinery.

Estimates had been made by different examiners as follows:

Results of assays of Harney Peak tin ores.[c]

	Average number of pounds of black tin per long ton of rock.	Pounds of white metal yield per ton of 2,240 pounds.	Percentage of tin.
Prof. W. P. Blake	72.80	36.4	1.625
Prof. G. E. Bailey		134.4	6
E. N. Riotte	67.20		
Prof. H. O. Hoffman (reported test saved)	57.54	39.2	1.746
Estimates of Prof. C. M. Vincent	30	22.5	1
Professor Vincent's 69 samples (selected)		38.8	1.732
Estimates of Capt. Josiah Thomas	40	29.20	1.30

[a] Morse, A. J., The Harney Peak tin mines: Eng. and Min. Jour., vol. 58, 1894, p. 460.

[b] O'Harra, C. C., Mineral wealth of the Black Hills: Bull. South Dakota Geol. Survey No. 3, 1902, p. 67.

[c] Rolker, C. M., The production of tin in various parts of the world: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 533.

The company went into the hands of a receiver in the summer of 1894. At the time the properties were visited (September, 1908) they were still under the control of the court. A large proportion of the claims were allowed to lapse, as they were not considered worth patenting.

During the entire operation of this company probably less than 5 tons of metallic tin was produced, far less than the weight of the gold coin put into the venture. Dr. A. R. Ledoux, the receiver, in a letter dated February 13, 1909, states that a settlement out of court has been effected and that a careful testing of the properties may be undertaken during 1909.

Since the collapse of the Harney Peak Tin Mining, Milling and Manufacturing Company a little tin has been taken out of the placers, both at Nigger Hill (Tinton) and in the southern field. One company—the Tinton Company—has endeavored to work the lode deposits at Tinton, and several companies have attempted to work the Gertie claim at Hill City. Litigation has made an already difficult situation worse, and little in the way of production has been accomplished at either place.

TIN DEPOSITS IN THE SOUTHERN BLACK HILLS.

GERTIE CLAIM.

The Gertie claim is located about half a mile south of Hill City, on the west side of Spring Creek, a short distance, possibly 100 feet, above the floor of the valley and a few hundred feet west of the Burlington Railroad and a public road. At the time visited (September, 1908) it was being operated by E. C. Johnson, who has been connected with the property for a number of years. The Gertie was formerly one of the claims of the Harney Peak Tin Mining, Milling and Manufacturing Company, but title was allowed to lapse and it was relocated by Mr. Johnson.

The basis of the location is in two nearly parallel pegmatite dikes. One of these, whose southeast end is close to the Gertie shaft and which is known as the "vertical" dike, is from a few inches to 4 or 5 feet wide and has a high and somewhat variable dip with a strike of N. 25° W. Although the strike of the dike is the same as that of the schist, it seems to have a steeper dip, so that it probably cuts the schist. Mr. Johnson states that the dike can be followed for three-quarters of a mile. Some prospecting has been done on the dike, and here and there crystals of cassiterite may be seen. In one prospect hole the dike is offset between 3 and 4 feet, almost horizontally, about 30 feet below the surface.

About 20 feet southwest of the southeast end of this dike is the other one, which on the surface reaches a maximum width of about

3 feet. It may be followed readily for about 150 feet, and Mr. Johnson thinks he has found its continuation about a quarter of a mile to the southeast. The dike dips at an angle of 45° S. 78° W. and follows the schistosity.

The Harney Peak Tin Mining, Milling, and Manufacturing Company sunk an inclined shaft more than 400 feet along the dike, ran drifts each way, and stoped great quantities of pegmatite, most of which still lies in the stopes and is held from the levels by fast-decaying timbers. The Gertie Mining and Milling Company report having sunk the shaft to the 500-foot level (on the incline), where the dike was more than 8 feet thick. When visited, the mine was filled with water above the 400-foot level. It is probable that this dike is typical of most of the dikes of the region and that the phenomena which accompany it will be found to be more or less characteristic of others.

The dike was probably injected between the foliæ of the schists in a pasty condition, and the stresses developed through its being forced into place were not equal at all points, so that here and there the schists forming the sides of the dike were pressed almost together and in places met, squeezing out the pegmatite for some distance. This left the dike in irregular lens-shaped bodies. The different phases are excellently shown in the Gertie workings, and a good illustration of the phase in which the dike is wholly parted was printed in an article by Arthur J. Morse.[a] Precisely similar phases are shown diagrammatically in figure 8, drawn from a sketch of a quartz vein in the Forest City mine. That the squeezing took place before the crystallization and solidification of the dike was completed is shown by the fact that there is no noticeable distortion or crushing of the crystals.

The pegmatite, like all the pegmatites of the region, is light colored and fine grained through most of the dike. The quartz is glassy, partly colorless, and partly with a slight smoky tinge. The feldspar is probably albite in the main, though a thorough examination has not been made. The mica is muscovite and is peculiarly clear. In places the small books are almost as transparent as quartz, showing that there has been little or no bending or crushing of the rock since the crystallization of the minerals. Cassiterite and tourmaline occur in small amount as accessory minerals. No others are visible in the specimens collected, beyond a few small bright-green stains in the muscovite and a few rust stains. The dike is in places "frozen" to the walls and silicification extends into the schist an inch or more.

The cassiterite is dark brown in thin section, but appears to be black in the rock. The particles are of irregular shape, but tend to

[a] The Harney Peak tin mines: Eng. and Min. Jour., vol. 58, 1894, p. 463.

elongated tabular forms which vary in size with the texture of the pegmatite. In the fine-grained portions of the dike the cassiterite is in minute particles which may be barely visible. In the coarser portions of the dike the particles reach an inch in length, three-eighths of an inch in thickness, and two-thirds of an inch in width. So far as seen, the tourmaline also is black, and being in small particles it is with difficulty distinguished from cassiterite. It does not seem to accompany the cassiterite in the coarser parts of the dike, but occurs in the finer-grained parts, which makes distinguishment more difficult, particularly as the tourmaline crystals are short and those of cassiterite are elongated as compared with the usual habit of these minerals.

The cassiterite occurs in shoots which are apparently not very continuous in any direction, and no rules are known for their occurrence. In this dike, as in the other tin-bearing pegmatites of the region, many parts seem to be practically barren of tin.

The rock is easily crushed, and aside from the saving of slimed cassiterite probably the greatest difficulty in handling the ore arises from the large amount of mica it contains. A small mill and smelting plant, besides shaft houses, engines, pumps, and air compressor, have been erected.

BLUE BIRD CLAIM.

The Blue Bird claim is located on a short pegmatite dike 1½ miles south of Hill City on the north side of a small stream flowing into Spring Creek, which is nearly a mile to the east. The dike is 14 feet wide at the top and dips 65° E. Cassiterite is carried in veinlike portions of the dike, 1 inch to 2½ inches wide, composed of muscovite and quartz with little feldspar. The mica occurs in narrow aggregates up to one-half inch wide by 1¼ to 1½ inches long, partly perpendicular to the indistinct walls of the veins.

The cassiterite in many places has a tabular form, but is largely anhedral,[a] having been crystallized contemporaneously with the other minerals, quartz, mica, and feldspar. Some particles, however, show their crystal form well, and these were probably the first to crystallize from the mass. Here and there crystals, which are probably twinned, are L-shaped. One specimen has legs that form a right angle and are five-sixteenths and one-half inch long by about one-eighth inch thick. The crystal is broken, so that its width is unknown.

At a depth of 40 feet the dike is crushed and pinches out through faulting, which has taken place since the solidification of the dike. A few feet of sinking and of drifting to the east have not shown the continuation of the dike.

[a] Anhedral = without crystal faces.

OLYMPIA CLAIM.

The Olympia claim, owned by Henry Pettit, is on the south side of the rivulet near which the Blue Bird claim is situated, but a quarter of a mile nearer Spring Creek. The basis of the claim is a pegmatite dike 3 feet thick and several hundred feet long, with a dip of 45° to 55° N. 47° W. The dike is rather fine grained and at one place for a thickness of about 6 inches along the hanging wall contains considerable cassiterite. This portion of the dike is composed mostly of feathery mica and quartz. The mica is in plates an inch or more long by one-sixteenth to three-sixteenths inch wide in overlapping scales radiating in gently curved lines from an axis. The cassiterite is black, partly in tabular forms, reaching three-fourths of an inch in length by one-eighth inch in thickness and a little more in breadth. Most of it is in rather irregular flat grains following the lines of the mica.

The portion bearing cassiterite has been traced for 75 feet. A similar micaceous zone is seen along the foot wall in places, but carries less cassiterite. The middle part of the dike seems to contain little tin. No other accessory minerals were noticed.

TIN PLATE GROUP.

On the Tin Plate group of claims, held by James Angus and lying between the Olympia claim and Oreville (6 miles southwest of Hill City), several pegmatites were examined, of which some were similar in structure to the dike on the Olympia and others were coarser. Only a small amount of cassiterite was seen in any of the dikes. None of the pegmatite had been crushed and panned, however, and this treatment frequently will show cassiterite in some quantity where it is scarcely noticeable on the outside of the rock.

SALLIE CAVANAUGH CLAIM.

On the west side of the summit of a small hill west of Oreville, a collection of possibly a score of houses, Mrs. E. M. McDermott has a claim known as the Sallie Cavanaugh. It is on a coarse pegmatite dike reaching 25 feet in width by 500 feet in length and striking N. 10° E., with a nearly vertical westerly dip.

A rich bunch or short shoot of tin ore, which dips 20°–25° N., is exposed on this claim. The shoot is composed of coarse mica and quartz, with coarse cassiterite. Some of the mica plates are more than 2 inches across, and the cassiterite forms several veinlets one-half inch wide and a foot long. The shoot as exposed is about 2 feet wide and can be seen for only 6 or 7 feet. A few feet to the north

another but less rich shoot was exposed. It was of somewhat greater width, but seemed to be nearly mined out. Almost no cassiterite can be found in other portions of the dike. The large, irregular pieces of cassiterite which occur in such coarse pegmatites are not composed of an aggregate of small crystal individuals which have grown together, as is the case with many large pieces from veins, but of masses which have segregated from the magmas in the same way as coarse quartz or mica, and have formed crystalline individuals either single or twinned.

The dike is somewhat irregular in thickness, and if shafts were sunk it would probably be found to pinch in places. The ore shoots as exposed, though rich, are not large, and their extent is uncertain.

On its lower side the dike rises 20 to 30 feet above the hill slope, and a considerable portion must have been eroded away. It seems probable, therefore, that in the stream bed not over 300 feet below there should be a placer which may be workable and should carry coarse cassiterite.

NAIAD QUEEN CLAIM.

The Naiad Queen claim, held by H. A. Albion, is situated on the north side of a valley one-eighth of a mile south of the Sallie Cavanaugh claim. The valley is possibly due to a fault. The claim is on a pegmatite dike 5 to 6 feet wide, dipping steeply N. 55° W. It has been followed for about 200 feet. A shallow shaft that has been sunk at one place is said to have contained some good ore, and smaller excavations have been made at several other points. The cassiterite is not so coarse or so conspicuous as on the Sallie Cavanaugh claim, and the rock would have to be tested to obtain any adequate idea of its richness.

TIN CITY CLAIM.

Frank Hebert holds the Tin City claim, adjoining the Naiad Queen on the northeast. It is located on what appears to be a lens of pegmatite about 8 feet thick, which shows in the side of a low hill and over which the schists have closed, as described in the notes on the Gertie mine. A short incline which ran into the dike was filled with water at the time visited (September 30, 1908), but good ore could be seen on one side.

LOUISE CLAIM.

The Louise claim, held by E. C. Hunt, is about a mile southwest of Oreville, on the west side of and several hundred feet above the Burlington Railroad and the wagon road which parallels it. Two pegmatite dikes outcrop on the steep hillside, whose general direction (N. 17° E.) they follow, with pinched places here and there, for more

than half a mile toward Oreville. The dikes are about 75 feet apart at the point at which Mr. Hunt was prospecting. The lower dike is 3 to 4 feet thick, with a dip of 55° N. 73° W. Cassiterite is sprinkled through a shoot a foot thick in the middle of the dike. The length of the shoot along the dike was not clear, but could not have been many feet.

The upper dike is of coarser structure, is 5 to 6 feet thick, and shows but little cassiterite. It carries glassy, little-weathered spodumene, the largest crystals of which are from 3 to 8 inches thick by several feet long. The mineral includes some quartz and green tourmaline, and appears to be in two shoots a few feet wide. Apatite and lithiophilite, the latter coated with its decomposition product, purpurite, also occur in the dike.

At several places prospect holes and shallow shafts were dug by the Harney Peak Tin Mining, Milling and Manufacturing Company, or others, and some cassiterite may be seen in the dikes at these points.

FOREST CITY CLAIM.

The claim formerly known as the Clara Bell is now called the Forest City. It is (by road) about 6 miles south of Hill City and 1½ miles east of Oreville. The claim is being worked for gold, but at a depth of 250 feet and about 200 feet northeast of the shaft a tin-bearing pegmatite dike 3 feet 8 inches thick, of light color and fine grain, was cut. The cassiterite is in small pieces with black tourmaline particles of equal size, and is mostly in the outer 3 or 4 inches of the dike. The cassiterite is difficult to distinguish from the tourmaline, as both are black; the grains are small and of equal luster, and their occurrence together makes the dike appear much richer than it really is Feldspar is absent or in minute amount in this part of the dike; quartz occurs in granules, generally of small size, filling the spaces between the mica. The mica in the pegmatite is in narrow blades one-eighth to one-fourth inch across, the books of which are thinner than wide and stand at right angles to the wall.

Alfred Daney reported obtaining 1½ per cent of tin from samples taken across the dike. The dike is apparently not exposed at the surface, though other and larger pegmatite dikes are close at hand.

This dike is especially interesting from its close relationship to the gold-bearing quartz vein, which is probably 75 feet away. The vein is from 2 inches to 2 feet in thickness and in places is squeezed into lenticular masses like the pegmatite in the Gertie mine. (See fig. 8.) This squeezing suggests that the origin of the vein was similar to that of the pegmatite, and that it was not formed through gradual building up by percolating waters, but was squeezed through the rocks in

a pasty mass. Relationship to the pegmatite is further suggested by the occurrence of black tourmaline in the vein. The tourmaline is in needles up to 2 inches long by one-sixteenth inch thick, confined to the outer 2 or 3 inches of the vein. Some muscovite occurs, but apparently only along the cracks in the quartz. Two granite dikes from 2 to 4 inches thick lie beneath and more or less parallel to the vein, but follow a zigzag course from nearly a contact to several feet away.

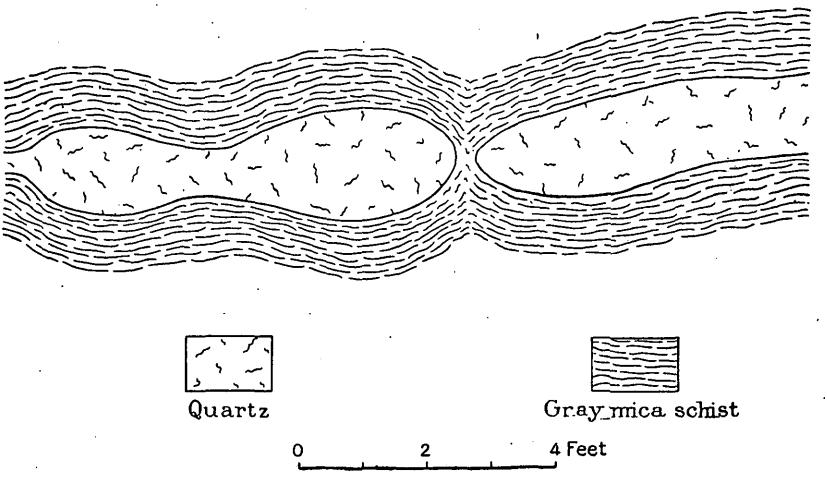

FIGURE 8.—Diagrammatic sketch of quartz vein in Forest City mine, 1½ miles east of Oreville, S. Dak.

TIN QUEEN CLAIM.

On the Tin Queen claim, owned by Frank Hebert and lying east of the Forest City claim, are two large outcrops of pegmatite of rather coarse structure. The dikes appear to be lenses and to reach 50 feet in width. In the western dike is a shoot about 4 feet in diameter carrying a considerable sprinkling of cassiterite, ore which in quantity would undoubtedly be worth mining. The shoot contains a large amount of muscovite mica with quartz and very little or no feldspar; the parts of the dike carrying feldspar and less mica contain less tin. The cassiterite when crushed gives a purplish powder like some of the Carolina cassiterite and the mineral obtained at Tinton. Light-red garnets reach over an inch in diameter in the dike, but are crushed so that they can be extracted only in small fragments.

The other dike contains little visible cassiterite, but carries amblygonite in masses reaching several feet in diameter. Two carloads of amblygonite are said to have been shipped several years ago. The dike also carries lithiophilite, a blue-green apatite, vivianite, possibly another iron phosphate, dufrenite, and ilmenite.

FIRST FIND CLAIM.

About 2 miles east of Oreville is the First Find claim, on which a pegmatite dike carrying cassiterite and columbite crops out boldly along the road, where it forms the southwest side of a small hill and is exposed for a width of 100 feet, though this is probably much more than the width of the dike, owing to the low dip. It is said that the dike can be followed for three-quarters of a mile to the northwest.

A small open cut has been made in the dike and some ore taken out. The cassiterite, so far as could be seen, is confined to a shoot a few feet wide and of uncertain extent and direction.

ANNIE NO. 1 CLAIM.

The Annie No. 1 claim, held by H. G., F. W., and William Mills, lies on the west side of Slaughterhouse Gulch near its junction with Allen Gulch, about half a mile west of the Hill City railroad station. In Slaughterhouse Gulch an open cut has been made which exposes a pegmatite dike carrying cassiterite and a quartz vein 4 to 6 feet wide carrying wolframite with some graphite on surfaces along which there has been movement. The pegmatite is somewhat wider than the quartz, and the latter is probably a segregation from the dike. The strike is N. 20° W., with a steep easterly dip.

In the pegmatite cassiterite occurs in irregular fragments and tabular aggregations, the latter reaching a breadth of several inches by one-eighth or one-quarter inch thick, and appearing to be thus flattened out as a result of crushing, as the cassiterite is greatly broken. Owing to their flattened condition the cassiterite masses resemble small veins. The portion of the dike in which the cassiterite occurs is almost wholly mica, most of the particles of which are oriented parallel to the flattening of the cassiterite. A little graphite occurs along slipping planes, and there is some black tourmaline. Besides quartz, feldspar, and muscovite, no other minerals were noted in the pegmatite proper.

In the quartz vein there is only a little cassiterite, but it carries some very black wolframite, though not, so far as exposed, in commercial quantity. Small particles of bismuth, in places altered to a carbonate, also occur through the quartz. There is here and there some muscovite. In places the foliæ of muscovite are coated brightly with graphite, so that when split apart they appear to be entirely composed of that substance, but rubbing uncovers the mica scales. Fifty feet east of this vein another quartz vein 8 to 10 feet wide has been exposed which runs N. 10° E. and dips 35° W. At the surface it shows many pittings partly filled with iron oxide, apparently indicating that the cavities were at one time filled with wolframite.

At the other end of the claim, about 1,000 feet N. 25° W., is a small exposure of greatly crushed, finely micaceous pegmatite, which shows

cassiterite in thin seams similar to those at the south end. Near its center it holds a lenticular quartz mass about 1 foot wide by 2 feet long. The pegmatite is practically pinched off by faulting at the bottom of an 11-foot prospect hole.

No connection can be traced between the outcrops at the opposite ends of the claim, and they are probably disconnected lenticular masses.

TIN BOOM NO. 1 CLAIM.

The Tin Boom No. 1 claim, on the opposite side of Allen Gulch, is also held by the Messrs. Mills. It includes several dikes of cassiterite-bearing pegmatite.

Near the south end of the claim is a dike carrying glassy quartz in lenticular masses several inches thick, surrounded by fine-grained muscovite. The dike seems to be a transition stage between the pegmatite dikes and the quartz veins of the region and reaches a thickness of several feet. Cassiterite, in scattered particles and in veinlets similar to those on the Annie No. 1 claim, occurs in the mica, and the quartz contains pieces three-quarters of an inch or more thick and 3 inches wide by 10 inches long.

A second dike on the property, farther up Allen Gulch, has the normal structure of the pegmatite of the region; that is, it is a brittle mass of granular feldspar, muscovite, and quartz. It dips 63° N. 87° E., and a 35-foot shaft shows it to be 1 foot to 2 feet wide. At the shaft the dike carries cassiterite in irregular pieces reaching an inch in thickness.

A couple of hundred feet farther up the gulch what seems to be the same dike widens to 8 feet and shows a large percentage of white albite but very little cassiterite.

TIN BOOM NO. 2 CLAIM.

The Tin Boom No. 2 claim, also held by the Messrs. Mills, adjoins the Tin Boom No. 1 on the east. On the north end of the Tin Boom No. 2 is a 4-inch quartz vein, striking N. 10° W. and dipping steeply west, which carries some cassiterite in masses 2 or 3 inches broad by 1½ inches thick, generally accompanied by some muscovite. The cassiterite is lighter colored than that occurring in the pegmatite and is found along the vein for perhaps a hundred feet.

A short pegmatite dike a few inches wide crosses the vein at almost right angles and carries considerable cassiterite.

MOHAWK CLAIM.

The Mohawk claim, which still belongs to the Harney Peak Tin Mining, Milling and Manufacturing Company, adjoins the Tin Boom No. 2 and lies between it and Hill City. It has been considered one

of the best claims belonging to the company, and considerable work was done on it, including a tunnel, now badly caved, and a shaft somewhat less than 100 feet deep.

The tin occurs in a shoot in a pegmatite, which has been somewhat squeezed, and the description of the cassiterite found on the Tin Boom No. 1 would apply here, but the prospects are better in the Mohawk.

OTHER CLAIMS.

Other claims in the southern hills were visited, but showed either little tin or no features especially different from those of the deposits already described. Probably hundreds of dikes and veins carrying some tin were unvisited owing to lack of time. Among those seen which showed some special features, but are not described, were the Etta claim (which will be described under "Tantalum"), about 1½ miles by road south of Keystone; the Peerless claim, one-half mile nearer Keystone, where cassiterite is found in connection with amblygonite, lithiophilite, columbite, etc.; the Black Metal claims, described under "Tungsten," a mile north of Hill City; the Ottumwa claims, 4 miles east of Hill City, where cassiterite occurs in quartz veins with small amounts of wolframite, tourmaline, feldspar, and mica, and in a thin dike of quartzose pegmatite; and the Ingersoll claim, 8 miles east of Hill City, where a coarsely crystalline dike, 10 to 15 feet thick, carrying scattered fragments of cassiterite, is made up of albite, muscovite, and quartz, with pink, blue, green, and black tourmaline, lepidolite, lithiophilite, purpurite, and columbite.

TINTON AREA.

GENERAL OUTLINE.

The Tinton area is reached from the Spearfish branch of the Burlington Railroad at Iron Creek, whence a stage runs 8 miles west to Tinton, on Nigger Hill, close to the Wyoming line. Except for a mile at the beginning, the road is good for a mountainous country. Tinton, a collection of fourteen or fifteen houses, most of which belong to the Tinton Company, is situated on the flat top of Nigger Hill.

Spearfish Canyon, through which the railroad runs, is cut in Carboniferous (Pahasapa) limestone at the mouth of Iron Creek, up which the wagon road follows. In going from that point to Tinton the traveler crosses areas of Cambrian shales and sandstones and many dikes of various intrusives. Tinton is near the middle of an area of monzonite and syenite porphyries, which are considered by Darton and Smith [a] to be remnants of a laccolith. In this laccolith are areas

[a] Darton, N. H., and Smith, W. S. T., Sundance folio (No. 127), Geol. Atlas U. S., U. S. Geol. Survey, 1905, pp. 4, 8, 11, and 12.

of schist, pegmatite dikes (Algonkian), and other intrusives much older than the laccolith, which is of Tertiary age. Darton and Smith conclude, therefore, that the pegmatites and other old rocks are floating in the porphyries and that ore deposits in the pegmatites can not be expected to last to great depth, owing to the fact that the dikes themselves are cut off at no great depth by the porphyries. To the present writer it seems an equally tenable hypothesis that the pegmatites, at least in those parts which are connected with considerable areas of schist, as at Tinton, may be masses that are now islands in the surrounding flood of porphyries and hold their original place with regard to the lower rocks.

Movement has broken the individual particles of the pegmatites all over the area. The cracks formed, which are generally minute, are filled with quartz or feldspar, with lesser amounts of mica. Like the other minerals, the cassiterite particles are seamed with quartz and feldspar. There appears to be more of a tendency for the cassiterite to take its crystal form in the Tinton region than in the localities observed in the southern hills, but good crystals can not be obtained on account of the crushing.

Some stream tin has been mined and shipped from Bear Gulch and other stream beds in the vicinity of Nigger Hill. Exploitation has been attempted for a number of years by the Tinton Company, and a mill has been erected about half a mile northwest of the workings, where a better supply of water is available. At the time visited (September, 1908) the mill was being overhauled and remodeled. A small amount of tin concentrates had been produced up to 1904, but none since then.

ROUGH AND READY CLAIM.

The principal claim of the Tinton Company is the Rough and Ready, located a few hundred feet southwest of the company's buildings, on a large pegmatite dike. The dimensions of the dike are uncertain, but it can be clearly followed from a point a short distance below the top of the hill on the west side for about 1,000 feet to the northeast, toward the company's buildings. The width of the dike can not be so easily told and probably varies considerably from point to point. At its widest it may be between 200 and 300 feet, with arms running north and south. The pegmatite is cut by many small dikes of hornblendic and diabasic rocks ranging from a few inches to several feet in thickness. Some of the hornblendic dikes are so crushed as to be schistose and seem from the greater crushing and alteration to be the older.

Two large open cuts have been made, one 100 by 200 feet and the other 50 by 100 feet. The former is probably 40 feet deep at most

and the latter 30 feet. An adit, which has been run under the cuts, is 500 feet long and is in pegmatite all the way. It is said to have a depth of 85 feet at the end. The rock from the open cuts can be fed into the adit through chutes. Two drifts have been run. One, bearing nearly north, runs for 40 feet through gray mica schist, then strikes tin-bearing pegmatite, which it follows for 75 feet; a branch turning to the northeast runs for 100 feet through schist. The drift on the south runs through pegmatite for its whole length, probably 150 feet. The pegmatite is of the same general composition as the tin-bearing dikes of the southern Black Hills, but differs considerably in texture and composition from point to point. It shows in places a crushed phase in which grayish quartz occurs in plates as much as 4 inches long by three-eighths of an inch thick. At these places part of the feldspar is finely granular, but other portions are crystallized in individuals several inches thick. The cassiterite, although the individual particles are somewhat aligned with the quartz, was apparently crystallized after most of the crushing took place, as it shows less effect of the movements that fissured the other minerals. The appearance of the rock, owing to the different degree to which the various minerals are affected, suggests that the movement may have occurred when the crystallization of the mass was only partly complete.

In places there are bands or shoots of the pegmatite which are very micaceous, the individual plates or leaves of muscovite reaching a width of 2 inches. Slipping planes occur here and there and are coated with sericite, or in a few places with graphite and manganese oxide. The accessory minerals in the dike, besides cassiterite, are black tourmaline, pyrite, columbite, and, sparingly, a pretty blue-green mica in massive form.

The cassiterite occurs in shoots, the proportions of which are not easily ascertained, but which apparently have a flat lenticular or tabular form and are up to 5 or 6 feet thick, possibly more. Between these shoots the pegmatite undoubtedly carries some cassiterite, but probably in very small amount. Where the cassiterite occurs in the coarse mica shoots already mentioned it is in large pieces which reach 1 or 2 inches in longest dimension. In such shoots there is considerable quartz, but little feldspar. Cassiterite also occurs in shoots of feldspar with little quartz and mica, where it is generally in grains about the size of pop corn, or smaller. In fine mixtures of quartz, feldspar, and mica some of the cassiterite is in fine particles, aptly called "pepper tin." As in parts of the tin area of the Carolinas, the cassiterite on crushing gives a purplish powder and it is thus distinguished from tourmaline on this claim.

No original figures concerning the tin content of the rock can be given. Some parts are rich enough so that no doubt could be enter-

tained as to the possibility of profitable exploitation, should these parts prove sufficiently large. Other parts are too lean to work, and the rock of this kind is probably in excess. Whether the mass as a whole can be worked at a profit, or whether the shoots alone can be worked, are problems which can be settled only by extensive sampling or a mill run. The company considers that they have been settled satisfactorily by its experiments and F. R. Carpenter,[a] after sampling the mine and rechecking his work, concludes that the pegmatite as a whole will run 0.75 per cent of metallic tin. He quotes Count de Rilly, Dunraven Young, and Doctor Carmichael as in practical agreement with him, the lowest estimate being 0.69 per cent.

OTHER CLAIMS.

Cassiterite is to be seen on many other claims in the vicinity, in every case in pegmatite dikes. None is known to have been found in any other rock, or in tin-bearing quartz veins similar to those near Hill City.

On the Tinton claim, about one-half mile northeast of the Rough and Ready claim, some rich ore is said to have been taken from a shallow incline. The cassiterite occurs with quartz, feldspar, and muscovite and has been in large crystals, but is now all more or less crushed. One remarkable lath-shaped crystal collected was 2⅝ inches long by three-sixteenths of an inch wide and one-sixteenth of an inch thick. About 1 inch of the crystal fell out in breaking away the specimen, but the impression is clear.

On the Iron claim there is some excellent tin ore in rather fine grained micaceous pegmatite, but its extent is unknown.

On a number of other claims in the vicinity tin ore was seen, but none were beyond the early prospecting stage.

SUMMARY, COMPARISONS, AND CONCLUSIONS.

The tin deposits of the Black Hills occur in pegmatites and in quartz. They are nowhere equally disseminated but occur in shoots.

The tin-bearing dikes, with a few notable exceptions, such as that on the Rough and Ready claim at Tinton and the Etta dike, are narrow, the widest other than these being about 25 feet in thickness, but most of them running from 1 to 7 or 8 feet. The quartz veins are ordinarily narrower than the dikes and probably represent the final segregation but one (the last being water) from granitic magmas.

The shoots of profitable tin-bearing rock are ordinarily of small cross section and of uncertain length (depth), and their occurrence in narrow dikes necessarily means that in general, except possibly at Tinton, they can be worked only on a small scale at each place

[a] Tin in the Black Hills, South Dakota: Min. World, vol. 25, 1906, pp. 600–601.

and not, as is so often advertised, that "all that is needed to make them pay is to work them as low-grade propositions on a big scale." Possibly a solution of the problem of profitable exploitation would be the establishment of a central milling plant at Hill City which would take tin, tungsten, and, if the demand justified, tantalum ores, on a custom basis. This would give the men owning claims a chance to realize on the comparatively small amounts of good ore, running from 2 to 100 tons or more, which they would get out during a season, and the quantity of such ore that would thus be offered for sale would probably be sufficient to keep a 5 or 10 stamp mill busy, or a mill of other design of like capacity. An electromagnetic separating plant would be necessary to separate the tungsten and tantalum ores from the cassiterite. There is, of course, a possibility that much larger mines than are indicated here may be developed, but nothing was seen during this hasty reconnaissance to show such a likelihood, and local report did not refer to unseen properties as pointing to it.

The tin deposits of North and South Carolina, from which a small output has been made, are also in pegmatite dikes, and show a remarkable geologic similitude to the Black Hills occurrences, although they are not nearly so extensive. The age of the South Dakota dikes has been fixed by several investigators as pre-Cambrian; that of the dikes of the Carolinas as possibly late Paleozoic.[a] The pegmatite dikes of the two regions have been similarly forced into schists and have been given a lenticular form, and this form is exaggerated in the Carolinas. The appearance of many of the hand specimens from the two regions is similar, though, especially in the less stanniferous localities, there is in places extreme variation from the commoner types.

So far as known there is no place in the world which produces any considerable amount of tin ore directly from pegmatite dikes, though placers formed from them have been worked to a greater or less extent in France and South Africa. It is said that many of the veins from which the placer tin in the Malay Peninsula has been disintegrated are pegmatitic in character, but few or none of them are rich enough to pay for working.

Tin veins in granite, from which most of the world's lode tin is obtained, are, however, closely allied to pegmatites in that they have crystallized from emanations that were among the very last given off by granitic magmas. The likeness between the deposits of the two types is close, so that no reason is apparent why the deposits in pegmatites should not be as large and last as well as the better-known veins in granite.

[a] Keith, Arthur, personal communication.

Tourmaline occurs in fair abundance in the dikes, reaching 1½ to 2 inches in diameter at Tinton. Columbite, tantalite, and wolframite are common accessories, though the last is known with the cassiterite of the region, except as a rarity, only in quartz veins. In those dikes which carry only a little cassiterite the list of accessory minerals is large. From the Etta mine the following minerals are enumerated by O'Harra:[a]

Minerals from Etta mine.

Albite.	Griphite.	Petalite.
Almandite.	Grossularite.	Quartz.
Andalusite.	Heterosite.	Rutile.
Apatite.	Ilmenite.	Scheelite.
Arsenopyrite.	Lepidolite.	Scorodite.
Autunite.	Leucopyrite.	Sphene.
Barite.	Liebnerite.	Spinel.
Beryl.	Löllingite.	Spodumene.
Biotite.	Melanite.	Stannite.
Bismuth.	Microcline.	Tantalite.
Columbite.	Molybdenite.	Tourmaline.
Corundum.	Monazite.	Triphyllite.
Cupro-cassiterite.	Muscovite.	Triplite.
Epidote.	Olivenite.	Wolframite.
Galena.[b]	Orthoclase.	Zircon.
Graphite.		

Chalcocite, apparently original, was collected by the writer from this dike in September, 1908.

The absence from these dikes of some minerals that generally accompany cassiterite is very noticeable. No topaz or axinite are known, and no fluorspar was seen by the writer. There is very little chalcopyrite or pyrite in the dikes.

TUNGSTEN.

GENERAL OUTLINE.

Tungsten ore is not known to have been produced commercially in the Black Hills except at Lead, though near Hill City a considerable number of tungsten-bearing veins and dikes have been discovered and a large amount of prospecting has been done. In this region wolframite is the tungsten ore of economic importance. Scheelite occurs sparingly, in some places as an original mineral and in others as an alteration product of wolframite. At Lead wolframite occurs in the form of impregnation deposits in a sandy dolomite. In the vicinity of Hill City the mineral is found in pegmatite dikes and in quartz veins which are probably a later product of the same igneous phenomena that caused the dikes. Wolframite is not known to be

[a] O'Harra, C. C., Mineral resources of South Dakota: Bull. South Dakota Geol. Survey No. 3, 1902, p. 64.

[b] It seems questionable whether galena, if found in the Etta dike, could have been an original mineral.—F. L. H.

present in any considerable quantity in the pegmatites which carry cassiterite, and in fact it is known in only a couple of places in the dikes in quantity sufficiently large to encourage prospecting. In the quartz veins, however, wolframite and light-gray cassiterite are intimately associated.

DEPOSITS NEAR HILL CITY.

BLACK METAL CLAIMS.

On the Black Metal Mining Company's group of claims, a mile north of Hill City, there are a number of wolframite and cassiterite bearing quartz veins on which considerable development work has been done.

About 400 feet from the south end of the group, on the center line of Black Metal claim No. 3, which lies on the west side of China Gulch, is a quartz vein 6 to 8 inches wide striking N. 23° W., dipping steeply to the east, but almost vertical, and about 30 feet long. It cuts a gray fine-grained quartzose mica schist which strikes N. 75° W., with a dip of 35° N. 15° E. The walls are loose and show the effects of some slipping. The wolframite is of a bright, shining black color in irregular masses as much as an inch in thickness and several inches in length. So far as developed at the time, it was probably not rich enough to pay for mining. There is a small amount of muscovite mica, apparently following cracks in and thus later than the quartz. Thin seams of pyrites also follow cracks in the quartz. The wolframite decays, leaving in places a little scheelite, but generally only iron oxide. A similar vein, striking N. 88° W., with a steep dip to the north, though almost vertical, lies 42 feet farther south. This vein has been followed on the surface for 60 feet. It is faulted about 3 feet at the shaft. From the bottom of the shaft, which is 47 feet deep, the quartz showed pyrites along cracks and some that was possibly original.

Wolframite extends into the quartz from the sides of the vein in blades up to one-eighth of an inch thick and 2 inches long, which must have been formed either before or contemporaneously with the quartz. Like the other vein, this one is only a prospect, but it is one which encourages further work.

Farther north, on the west side of China Gulch, on Black Metal claim No. 5, is a quartz vein 9 to 12 inches thick, which is exposed in two prospect holes. The vein strikes N. 50°–55° E., dips 45° N. 35°–40° W., and has been followed for about 125 feet. It carries considerable black tourmaline in crystals an inch or more in length by one-sixteenth to one-eighth of an inch in thickness. Some wolframite is found mixed with light-colored cassiterite in masses up to 2 pounds in weight. The color of the cassiterite is in places hidden by stains of

iron oxide. During the tin excitement this ground was held as a tin claim.

On Black Metal claim No. 6, near the north end of the group, is a quartz vein 6 to 8 inches thick, striking N. 5° W. and standing nearly vertical. A vertical shaft about 4 feet wide has been sunk, with the vein in the middle at the top. At a depth of 65 feet the vein is in the east wall of the shaft. The vein is generally free, but is in places "frozen" to the walls. The country rock, as in the other claims of the group, is quartzose mica schist, in places graphitic and here and there, near the vein, impregnated with small needles of black tourmaline.

The vein carries wolframite intimately intergrown with light-gray cassiterite, some of which is almost colorless. These minerals form tabular masses reaching 1½ inches in thickness and probably 8 to 10 inches in breadth. They occur near the middle of the vein, and C. G. Todd, in charge for the Black Metal Mining Company, stated that none had been seen on the sides of the vein. A granitic dike a few inches in width is said to lie along the vein in places, and at such points the vein is richest.

A small shaft house has been erected and drifts have been carried on the vein for about 30 feet each way at a depth of 65 feet. The vein is said to be widening a little toward the north. The shaft was full of water at the time of the writer's visit, so that it could not be descended. What seems to be the same vein is seen several hundred feet farther north, but it shows neither wolframite nor cassiterite at that point.

Southwest of this vein, on the same claim, is a quartz vein 4 to 8 inches thick, with a strike of N. 55° E. and a variable dip. It carries some wolframite, slender needles of black tourmaline, and some muscovite. In places thin branch veins enter the schist, which is here graphitic, and at some points bunches of wolframite occupy the whole width of the vein, so that the wolframite is said to be in the "slate," the name by which the schists are generally known in the locality. The vein is traced for only a short distance.

On Black Metal claim No. 7 a thin quartz vein carries wolframite, small pieces of green and white scheelite, brown cassiterite, pyrites, and a little mica. On Black Metal claim No. 8 is an irregular quartz vein that carries some wolframite and small particles of scheelite, original in the vein. Part of the scheelite is of a delicate green color. There is some cassiterite, which, where free from iron-oxide stains, is light gray in color, and some pyrites.

On Black Metal claim No. 1 a very small amount of brown cassiterite and green scheelite was found in dumps from prospect holes on quartz veins which carried albite, muscovite, and pyrite. On both claims 1 and 2 of this group are pegmatite dikes typical of the region,

which carry a little blackish-brown cassiterite. In places quartz from all the dikes of the group shows white lines of minute air bubbles in a glassy groundmass, such as is common at many places in quartz connected with pegmatites.

GOOD LUCK CLAIM.

On the Good Luck claim of the American Tungsten Company, 3½ miles east of Hill City, a tungsten-bearing quartz vein 2 feet wide has been worked to some extent. The vein strikes N. 30° W. and dips southwest, underlying 15 feet in a depth of 40 feet. On the 40-foot level a drift follows the vein for 83 feet and reaches the surface on a hillside below the shaft house. The quartz shows white lines of minute cavities approximately parallel to the walls, and the wolframite occurs in roughly tabular aggregates that are also parallel to the walls. These aggregates reach a weight of probably 8 or 10 pounds. The wolframite is mostly brilliant black, but here and there a piece has the purplish rosiny appearance of hübnerite. Single cleavage blades reach perhaps 8 inches in length. The wolframite weathers into iron oxides, which fill some of the spaces left. In places the original structure of the wolframite may be seen in the iron-oxide skeleton loosely filling the cavity. A little scheelite appears to be formed by the alteration of the wolframite, but it may be original. A careful outlook was kept for tungstite formed by the breaking down of the wolframite, but none was found.

A very little scheelite, which is unquestionably original, of a light-green color, also occurs in the dike. Muscovite occurs along cracks in the quartz and in places penetrates the quartz to a depth of an inch, so that it was evidently a part of the dike, while the quartz was unsolidified and is an original mineral of the vein. The mica is in places mixed with graphite, probably collected from graphitic schists as the vein matter was forced through them. Graphite is not an uncommon mineral in the pegmatites of the Black Hills.

A shaft house, with hoist and engine, and a concentrating plant have been put up on the property. Other claims are held by the company, but were not visited owing to lack of time.

VIDA MAY CLAIM.

Four miles east of Hill City, and about a mile south of the Hill City and Keystone road, W. R. Pettit and John Nash have a claim known as the Vida May. The vein on which it is located is visible for less than 100 feet along the surface and is irregular in thickness, strike, and dip. The dip is 30° and more southward.

The dike occupies a fissure along an overthrust fault of unknown throw. At some points it reaches 10 inches in thickness and at

others it pinches out. In the thicker part wolframite occurs in chunks, some of which are several inches thick. In places the dike pinches to half an inch and is almost wholly made up of wolframite. Some muscovite is present through the vein and shows a tendency to form in lines that give the vein a somewhat banded appearance.

One of the most remarkable features of the vein is a layer of impure graphite on each side from half an inch to 2½ inches thick. Muscovite occurs in this layer also and shows thin lines of minute flakes parallel to the vein. No structure of the graphite can be definitely made out. The graphite is undoubtedly segregated from the graphitic schists through the agency of the vein-forming materials. Smaller amounts of graphite have been noted at a number of places as included in the pegmatite dikes, but it seems significant that along quartz veins, the magmatic segregation which was probably most watery at the time of its intrusion, the most graphite should have been deposited. The same phenomenon was noted in Slaughterhouse Gulch. It is strongly suggested by these occurrences that the graphite is brought into solution by the hot waters accompanying the intrusion.

HENRY PETTIT AND OTHERS' CLAIM.

On the north side of Palmer Gulch, about 3½ miles southeast of Hill City, Henry Pettit and others have a claim located on a rather typical coarse pegmatite dike. The dike, which strikes N. 60° E. and dips northwest, occupies the brow of a hill. It is 30 feet or more thick at most, but thins toward the southwest and pinches out a few hundred feet from the middle of the claim. Three similar dikes lie within 300 feet down the hill to the southeast, and a fourth within 50 feet northwest of the southwest end of the dike. From the opposite side of the gulch the dikes look like stone walls, rising one above the other, holding up a terraced hillside.

In places the dike on which the claim is located is very coarse, and is cut transversely by smaller dikes as much as 2 feet in thickness. Some of the smaller dikes, 6 to 8 inches thick, carry wolframite in small amount, occupying cracks and crevices, and one dike contains a thin vein of solid wolframite one-eighth to one-fourth of an inch thick. In places this vein splits and each branch is as thick as the single vein. In one place a dike about 2 feet thick has decayed, leaving a trench several feet deep. Along the trench is a vein of iron oxides 2 to 3 inches thick, which probably is formed from the decomposition of either wolframite or pyrite. No tungsten can be detected in the oxides, but this seems to be the usual condition under such circumstances in this region. When wolframite decays the tungsten seems to be either left as scheelite or completely removed from the residual mass. Some pieces of the vein appear to bear a

resemblance to crystallized wolframite, so that it seems quite possible that prospecting may show a vein of solid wolframite. The iron oxides carry some white chalcedony.

Quartz veins reaching 8 inches in thickness cut the dike and carry some wolframite.

WOLFRAM CLAIMS.

Three miles east of Oreville, on the west flank of Harney Peak, A. J. Reuchel, J. J. Sharp, and C. H. Cummings have four claims located on coarse pegmatitic dikes. At the upper end of the claims a dike in which wolframite has been found stands 30 to 40 feet above the surface, with a strike of N. 5° W. It is apparently vertical and 20 to 30 feet thick. On the south end of this prominent outcrop some wolframite occurs in irregular bunches an inch and more in thickness through a shoot not over 2 feet wide. At this place the pegmatite is composed of coarse feldspar and quartz with smaller bunches of muscovite. The claim which appeared to be the best of the four at the time visited is located below (northwest of) this place, at the junction of the dike just described with a second striking N. 40° W. At the junction the dikes are only a few feet wide, but they gradually widen as they separate and 100 feet away the second dike is as wide as the first.

The exposures were not good, but in the first dike a few feet from the junction wolframite occurred as thin plates, 1½ inches wide by one-sixteenth of an inch thick, interleaved with muscovite mica, and in coarser pieces in feldspar and in quartz, as well as in mixtures of the two. The crystallization is very imperfect and evidently was contemporaneous with the formation of the other minerals.

No tourmaline, cassiterite, lithia minerals, or other accessory minerals that are common to the dikes of the region were noticed in close connection with the wolframite, but a short distance away black tourmaline is found in the dikes.

PINE CREEK.

A specimen of wolframite given to the writer from the head of Pine Creek, 8 miles southeast of Hill City, weighs about a pound and shows rough crystal outlines. It contains a small amount of colorless scheelite and some biotite. This is the only biotite noted with any of the minerals treated in this paper.

DEPOSITS NEAR LEAD.

The deposits near Lead have been excellently described by J. D. Irving,[a] and beyond stating that so far the deposits have proved

[a] Some recently exploited deposits of wolframite in the Black Hills of South Dakota: Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 683-695.

small and that most of the ore in sight has been removed the present writer can add little to his description. The total amount of tungsten ore produced by the mines has been small, but may have reached 100 tons. Concerning the geology Irving states:[a]

The metamorphic rocks of this area comprise a series of schists, phyllites, quartzites, amphibolites, and other varieties of crystalline rocks, everywhere tilted to a high angle, showing an advanced stage of metamorphism, and inclosing numerous intruded dikes of eruptive rock, chiefly rhyolite and phonolite. Unconformably upon the eroded surface of these upturned schists lie the nearly horizontal strata of the Cambrian, having at the base a conglomerate which varies from practically 0 to 22 feet in thickness, and above this (in certain portions of the Lead City area) layers of quartzite and loosely compacted sand. These beds are in some places highly auriferous. They constitute the so-called "fossil placers" so well described by Devereux,[b] and were in former years an important source of revenue in the hills. Indeed, at two of the mines mentioned in this paper, the Durango and the Harrison, wolframite has been extracted through the shafts and tunnels once used in exploiting these auriferous gravels. In the Yellow Creek area the basal conglomerate is thin and nonauriferous and passes by gradual transitions into a hard, dense quartzite, the two together constituting a bed which varies from 10 to 25 feet in thickness. Resting upon this quartzite (or, where that is poorly developed, directly upon the auriferous conglomerates) lie the ore-bearing beds, composed of a rather loose, shaly material, very heavily charged with iron oxides and the carbonates of lime and magnesia, and, in some places, so decomposed as to be a mere soft, earthy gouge, often stained with black oxide of manganese. If traced, however, to localities where decomposition is not so far advanced, it is found to be a dense, reddish-brown rock, showing many glistening facets of lime-magnesia carbonates, and sometimes exhibiting a well-marked stratified structure, due to the interposition of thin and often discontinuous layers of argillaceous shale. Microscopic and chemical examinations have shown this rock to be a crystalline dolomite. In other districts, where it is deeply buried and entirely unaltered, it is grayish blue and contains considerable glauconite. This ore-bearing rock is known among miners as "sand rock." The transition between it and the underlying quartzite is sometimes sharp; but in the two districts where the wolframite has been found it is gradual; the sand grains increasing in abundance as we go downward until the dolomite appears merely as a cement and finally disappears altogether. For this reason, and also because silicification has always occurred together with the deposition of the wolframite, the calcareous nature of the ore-bearing rocks has often been overlooked, and the deposits have been spoken of as "mineralized quartzite." This misconception should be avoided, because the process of mineralization has been one of replacement, and the original material replaced was in large part lime-magnesia carbonate, whether present as a cement or forming the body of the rock.

Above the dolomitic beds generally occur layers of shale, which become much more argillaceous and often contain considerable glauconite as one passes vertically upward. Above these shales, both in the vicinity of Lead City and Yellow Creek, are found remnants of a rhyolite sheet, showing in many cases a well-developed columnar structure.

Wolframite has been found at several points on the hills west of the Homestake mine at Lead, among them at the Hidden Fortune, the Harrison mine, and other properties, which are located on the ridge running northwestward and approximately in the same direc-

[a] Op. cit., pp. 686-687.

[b] The occurrence of gold in the Potsdam formation, Black Hills, Dakota: Trans., X, 465, et seq.

tion as the strike of the schists and the open cuts of the Homestake mine. About 2½ miles S. 25° E., on a flat-topped hill west of Yellow Creek, gold-bearing wolframite deposits have been found in the Little Pittsburg, Wasp No. 2, and Two Strike mines. All these deposits occur in the flat-lying Cambrian rocks. None of the deposits could be studied in detail by the present writer owing to caving of the workings or other reasons. Irving's description of the occurrence is here quoted:[a]

The wolframite occurs in flat, horizontal but rather irregular masses, from nearly 0 to 2 feet thick. They frequently cover considerable areas, of which perhaps the largest so far discovered may be 20 to 30 square feet; but they are so extremely irregular that it is difficult to form an exact estimate of their lateral extent. These wolframite bodies are intimately associated with the flat masses or "shoots" of refractory siliceous ore, so extensively developed in the Black Hills of late years, which consist of an extremely hard, brittle rock, composed chiefly of secondary silica and carrying, when unoxidized, pyrite, fluorite, barite, and occasionally gypsum. Many cavities occur, lined with druses of minute quartz crystals, with clusters of purple or green fluorite or tabular crystals of barite. Oxidized portions are heavily stained with oxide of iron, and contain much infiltrated calcite, while the cavities often show drusy linings of jarosite. In the areas where the wolframite is found, the siliceous ore is always oxidized (no traces of original sulphides being discernible) and contains more barite than that from the other and more typical localities (the barite frequently forming as much as 50 per cent of the rock) and is usually of coarser texture. In form these bodies of siliceous ore are flat, channel-shaped masses, having in the districts under discussion a thickness of from 1 or 2 to 15 feet and ranging in length from 2 feet to as much (in rare instances) as 500 feet, while the width is from 5 or 6 to 50 feet or more.[b] The ore is usually banded, the banding being continuous with the bedding planes of the adjoining strata, and the shoots occur along lines of fracture termed "verticals," on either side of which the dolomite has been replaced from a fraction of an inch up to 12 feet in distance. Careful investigation of the ore bodies of this type shows that they are replacements of the dolomitic beds by silica, pyrite, and other accessory minerals. The mineralizing waters seem to have gained access to the soluble beds through the fractures and to have been confined to them by overlying impervious beds.

The ore is a mass of fine-grained wolframite in which the particles are in some specimens not over 0.01 inch across. In other specimens they are said to reach a width of one-fourth of an inch. Fresh pieces are bright black, showing the shining cleavage faces of the wolframite particles. When rubbed against other rocks the pieces have a dull brown and totally different appearance. Cavities are lined with minute crystals of wolframite. Some vugs also show white, yellow, or green scheelite. The latter two are noted by Irving,[c] but have not been seen by the present writer. Scheelite also occurs in small amount interstitially. Stibnite is stated by Irving to occur similarly.

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a Op. cit., pp. 688-689.

b These dimensions refer only to the siliceous ore bodies found in the Lead City and Yellow Creek areas—the wolframite districts. The "shoots" in the Ruby Basin district are often of much greater size.

c Op. cit., p. 690.

Irving concludes that the wolframite occupies its present position through metasomatic replacement of the limy and magnesian portions of the sandy dolomite—that is, as the lime and magnesia carbonates were dissolved wolframite was deposited in their place—that the same solutions that brought in the gold ores brought in the wolframite, and that the wolframite and gold belong to the same ore body.[a] This seems in accord with all the facts.

As to the origin of the ore, Irving believes that ascending solutions have dissolved the wolframite from older deposits below and transferred them to their present position. These older deposits he considers to be probably similar to those of the southern hills—that is, to be connected with pegmatitic or granitic rocks, or with quartz veins closely related to such rocks.[b]

To the present writer it seems more likely that the ores of the two areas are more closely related, genetically, than this hypothesis allows. It has been shown that in the southern hills wolframite occurs with ordinary pegmatites and with the later phases of such dikes that are seen in quartz veins. In the Lead region there are many rhyolite dikes, closely related in composition to the pegmatite dikes farther south. It is probable that either from them or from other intrusions closely related to a granitic magma watery portions separated, holding a more tenuous solution of quartz than that which made the quartz veins of the Hill City and Keystone region, so that veins were not formed, but instead the soluble carbonates were removed and replaced by the quartz, wolframite, scheelite, pyrite, gold, and other minerals held in solution. Irving predicted[c] that the deposits would probably not be of great commercial importance, and this prediction has proved true. The total output, though unknown, has not been large, but, as stated, possibly 100 tons. Little ore is left in sight, and there is no promise of production beyond small lots of a few tons now and then. Some ore is said to remain in the Hidden Treasure and Little Pittsburg claims.

TANTALUM.

GENERAL OUTLINE.

The mixture of tantalates and columbates ordinarily known as columbite when containing a preponderance of columbium or as tantalite when containing a larger percentage of tantalum has been found at a large number of places in the Black Hills and its distribution corresponds approximately with that of tin. Most of the minerals of this description found in South Dakota are properly classed as columbite, for most of them carry an excess of columbium. The occurrence of columbite in the Black Hills was first noted in print

[a] Op. cit., p. 694. [b] Op. cit., pp. 694–695. [c] Op. cit., p. 695.

by W. P. Blake[a] in 1884, when he described a mass weighing a ton which he found on the Ingersoll claim.

As already stated, there was practically no demand for the material except for curiosities and mineral collections or experimental work, mostly chemical, until the invention and exploitation of the tantalum incandescent lamp in 1904. A temporary rise in price was caused by this demand, but it was supplied by a comparatively small output which came largely from Western Australia, where tantalum ores, especially manganotantalite, are found carrying 80 per cent or more of tantalum oxide (Ta_2O_5). The South Dakota minerals generally run much lower in tantalum oxide than the Western Australia ores, and naturally users prefer the richest ores to be obtained, other things being equal.

The analysis of columbite is very difficult, the separation of the tantalic and columbic compounds requiring discernment, skill, and patience beyond the ordinary, and when titanium is present it adds very largely to the difficulty. As such analyses are not often demanded of chemists, most of them have little practice in the separations, and it thus happens that there are not many who are capable of making satisfactory determinations. As ordinarily performed, the separation depends on the difference in solubility of the double fluorides of potassium and the metals, the tantalum salt crystallizing from the more dilute solution. An approximation of the amount of tantalum oxide present can sometimes be made by taking the specific gravity of the mineral, though specimens from different localities show considerable variation in this respect.

Like cassiterite, columbite (in which are included minerals containing much tantalum) is present in the pegmatite dikes of the Black Hills, and, so far as is known, only in them. This mineral was not seen in the quartz veins, which contain both cassiterite and wolframite. It is apparently a mineral that crystallizes before that stage of magmatic segregation in which the quartz veins originate is reached. The Western Australia columbium and tantalum minerals are also in pegmatite dikes or in placers derived from them.

Like cassiterite, columbite occurs in South Dakota in larger pieces in coarsely crystalline dikes than it does in dikes whose minerals are of small dimensions. In this region it forms, however, individual masses very much larger than those of cassiterite.

DETAILED DESCRIPTION OF DEPOSITS.

ETTA MINE.

The Etta mine, already referred to under "Tin," lies 1½ miles south of Keystone. A large mass, roughly circular in outline, of very coarse pegmatite is intruded into the schists and through its

[a] Am. Jour. Sci., 3d ser., vol. 41, 1884, pp. 340-341.

resistance to erosion now forms the summit of a round hill about 300 feet above the valleys which lie on two sides of its base. The dike is about 150 by 200 feet in horizontal measurement. The minerals reach gigantic size, and the crystals of spodumene are probably unequaled by any other known occurrence, single crystals reaching 35 feet in length with a cross section of approximately 3 by 6 feet. No terminal planes were seen, but the prisms forming the body of the crystals are remarkably good. The spodumene is mined for the lithia contained in it. The material is considerably decomposed and resembles wood, so that the miners refer to the crystals as "logs." Some of the spodumene crystals form stars which radiate from masses 3 to 5 feet across, predominantly composed of honey-yellow muscovite and feldspar. In some places the feldspar is albite; in others microcline. The albite is in thin plates, and the microcline also shows partially crystal forms from one-half inch to several inches wide. The mica is in plates from one-eighth to three-fourths of an inch across. Through these masses are mixed other minerals in greater or less profusion—white beryl; small spodumene crystals; a dark metallic mineral in small crystals, the largest masses of which are little more than half an inch across; cassiterite, also in small particles; quartz; secondary opal; and probably other feldspars and other minerals. Similar masses occur in other portions of the dike, but the component minerals differ in proportional quantity from point to point.

Cassiterite is said to have been found in the dike in masses weighing a number of pounds each, and, on account of similarity in color, columbite has often been mistaken for it.

In parts of the dike feldspar occurs in larger masses than in the portions described, and here columbite occurs in larger crystals and masses. One mass is reported to have weighed 600 pounds. The crystals are embedded in the feldspar (mostly microcline where in large masses, with some albite), but the columbite is also associated with quartz, albite, muscovite, and beryl, in the last of which it may be wholly immersed.

All the crystals seen are tabular and run from a small fraction of an inch to several inches in width; they are somewhat longer than wide and comparatively thin. The proportions between the dimensions vary considerably. The crystals grow into one another and inclose other minerals. Internally many of the crystals show peculiar shining pencil-shaped surfaces, which may be due to this intergrowth.

A small amount of columbite has been mined in connection with spodumene mining and many hundred pounds of it has found its way into private and public collections of minerals, but the whole makes a comparatively small tonnage. The dike contains some ilmenite, leucopyrite (iron arsenide), and a few other heavy minerals

which could not be separated mechanically from the columbite but might easily be parted electromagnetically.

W. P. Headden made a series of analyses of columbite specimens from the Etta mine, the results of which were published in 1891.[a] His determinations were made entirely on comparatively large crystals. The specific gravity and the columbium oxide and tantalum oxide content, as determined by Headden, are given below; his analyses also covered tin, iron, manganese, and calcium oxides, but do not mention titanium. Analyses by Headden of material from other portions of the Black Hills are also given in the original article.

Parts of analyses of columbites from the Etta mine.

	Specific gravity.	Cb_2O_5.	Ta_2O_5.		Specific gravity.	Cb_2O_5.	Ta_2O_5.
1	5.890	54.09	18.20	6a	6.612	35.11	47.11
2	6.181	47.05	34.04	6b		35.17	47.08
3	6.245	46.59	35.14	7a		31.80	52.14
4	6.376	40.37	41.14	7b	6.707	31.31	52.49
5	6.515	39.94	42.96	8	6.750	29.78	53.28

It will be noticed at once that there is a wide range in the tantalum content of columbite from the same dike, so that in the sale of columbite a great difference in the content of different lots might and probably would occur, and to obtain the average content of any lot would require the most careful sampling. No analysis of the fine-grained metallic mineral is known to have been published hitherto, and as it was supposed to be columbite in smaller crystals, in order to get some means of comparison with the larger crystals an analysis of material collected by the writer was undertaken by R. C. Wells, of the United States Geological Survey. The material was obtained by crushing parts of hand specimens collected near the center of the dike from the west side of the open cut made in mining for spodumene. In the specimens the largest mass of the mineral (an aggregate of small crystals) did not exceed one-half inch in diameter and most of the particles were less than one-eighth of an inch thick. Portions of two specimens, collected several feet apart, were crushed and panned down until apparently free from light-colored minerals. The specific gravity is 5.26.

Doctor Wells has found that the mineral contains a considerable amount of titanium, some iron, and probably both columbium and tantalum. The separation of these elements has proved so difficult that the analysis could not be completed in time for publication in this paper. The large amount of titanium suggested the possible presence of rutile, but a microscopic examination of the mineral failed to discover it.

[a] Headden, W. P., Columbite and tantalite from the Black Hills of South Dakota: Am. Jour. Sci., 3d ser., vol. 41, 1891, p. 95.

Part of the material containing the mineral has been digested with hydrofluoric, sulphuric, and hydrochloric acids in an endeavor to discover crystal forms, but small movements in the dike have so shattered the mineral that no great success has yet been obtained.

OTHER OCCURRENCES.

As would be expected, tantalum minerals are found in the gravels of streams receiving the waste from dikes carrying such minerals. In Grizzly Bear Creek, flowing on the west side of the Etta pegmatite, between it and the Sarah claim, the mineral was found in working the gravels for gold and tin. In placer tin Headden found tantalite carrying a higher percentage of tantalum than any analyzed from the Etta mine.

Headden also mentions a mass of columbite exposed in the Sarah claim, one-quarter of a mile northwest of the Etta mine, which showed a section 8 by 14 inches. It was broken, and how much had been taken from it or how much was left could not be told. No other pieces were to be seen.

At the Peerless mine, one-half mile north of the Etta, large pieces of columbite are occasionally found. What is supposed to be the same mineral also occurs, in small particles not over one-sixteenth of an inch in diameter, distributed through a sugary yellow rock, made up almost wholly of muscovite mica and forming part of a large, coarsely crystallized pegmatite dike. The total amount of columbite in sight is not great. The dike is being mined for amblygonite, a mass of which 20 feet across has been exposed to a depth of 20 feet and for a length of 40 feet without reaching its limits. Several tons of lithiophilite have been collected in the course of mining and stacked up. On the west side of the dike there are poorly crystallized black tourmalines 2 to 3 inches in diameter. Muscovite occurs in plates several inches across, but they are feathery and worth little commercially. A little cassiterite is found in the dike.

The 2,000-pound mass of columbite found by W. P. Blake on the Ingersoll claim has been mentioned. Besides this, other large masses have been found. George Madill and his partner report having found a 500-pound mass in a claim being prospected for mica, on the south fork of Grizzly Bear Gulch, 2½ miles southwest of the Etta. A small specimen sent in shows the columbite in thin blades, with mica, feldspar, and quartz. Small amounts of columbite have been found in the stream gravels near Nigger Hill (Tinton) and a little is present in the dikes of the region.

Bock Brothers, of Hill City, have shipped some columbite mined near the head of Laughing Water Creek north of Custer, and small amounts of columbite have been reported from a number of claims in the vicinity.

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NOTE ON A WOLFRAMITE DEPOSIT IN THE WHETSTONE MOUNTAINS, ARIZONA.

By FRANK L. HESS.

About 12 miles south and a little east of Benson, Cochise County, Ariz., an attempt has been made to mine wolframite from deposits which are, so far as known to the writer, unlike anything heretofore described in the literature of ore deposits. Benson is at the west end of the El Paso and Southwestern System, on the main line of the Southern Pacific Railroad, and is the point from which the Southern Pacific's Sonora branch departs. The Whetstone Mountains, in which the deposits are situated, are one of the many short ranges of the region and lie directly south of the town.

The country has an elevation of 3,576 feet at Benson (Southern Pacific station). It is exceedingly dry and supports a poor growth of mesquite. The yucca gives a grateful touch of green to the landscape, and along the base of the mountains there are a few live oaks in the watercourses. The mountains are rugged and rocky. In the broad San Pedro Valley, with the Whetstone Mountains on the west and the Dragoon Mountains on the east, are irrigated patches of alfalfa, with tall bordering cottonwoods which are peculiarly beautiful in contrast with the bare surroundings. Part of the water for irrigation is obtained from small artesian wells said to be 300 to 400 feet deep.

The tungsten deposits lie on the eastern slope of the Whetstone Mountains between McGrew Spring and French Joe Canyon, half a mile from either place, at both of which water may be obtained. The locality is reached by a very fair road, and aneroid readings give it an elevation of 1,130 feet above Benson, or approximately 4,800 feet above sea level. The property was formerly worked by the Euclid Mining Company, but nothing has been done for a couple of years except to ship a few tons of ore (the entire output) which had been mined some time before.

The deposit is at the base of a steep rise, in granite which is intrusive in a series of metamorphic rocks, including siliceous mica schist and limestone. The wolframite occurs near the contact of the granite and schist and in a tongue of granite 60 or 70 feet long and perhaps half as wide which runs out into the schist. The granite is very light colored and, except in segregations to be described, contains no dark constituents.

Half a dozen prospect holes, the deepest of which is down about 25 feet, have been sunk along a line running N. 55° E. (magnetic) within a distance of 200 yards. These holes either cut or are close to a white quartz vein which gradually dwindles at both ends, but in the middle attains a thickness of 2 feet. The vein has a steep dip to the northwest. At the time visited the holes all contained more or less water.

A little wolframite is found in the quartz vein accompanied by small amounts of mica, pyrite, bornite, and probably chalcopyrite. A more noteworthy quantity of wolframite occurs in segregations in the granite. The mineral is designated wolframite without a chemical analysis, as it is too black and opaque to be hübnerite, and fusion with soda gives the green color characteristic of manganese. Though this color is given by very small amounts of manganese, such as might be contained in ferberite (iron tungstate), the crystals are stumpy and the crystal terminations do not have the beautiful chisel shape of the ferberite of Boulder County. Some of the crystal faces are curved. Owing to their being wholly embedded in quartz, it has been impossible to make measurements of faces. The crystals are comparatively small and do not reach over one-half inch in length or three-sixteenths of an inch in thickness. The wolframite does not appear at many places in the vein. It occurs also in segregations in the granite similar to hornblendic and biotitic segregations in many other granites. The richer exposed deposits have been mined out, but there could not have been any very large ones, as the excavations are all small. The deposits still to be seen are lenticular in shape and are not over 2 feet long by a few inches broad. The breadth of the lenses could not be measured. In these segregations the wolframite varies considerably in the percentage it forms of the mass. In places there are small bunches of which much the larger part is wolframite, but it is said that as mined and hand picked the ore averaged 10 per cent WO_3.

The particles of wolframite in the granite are tabular and reach one-fourth inch in length. They are thin, the thickness probably averaging about one-sixth to one-fourth of the length and the breadth reaching two-thirds of the length. No parallel arrangement is noticeable. No scheelite is visible to the unaided eye, but in thin section the microscope shows a narrow band of a mineral which is probably scheelite bordering a portion of the wolframite. This band is so narrow that it is difficult to determine the matter decisively.

The segregations that have been worked have been close to the quartz vein mentioned, but there are other prospect holes 100 or more feet away, and one small lens of wolframite-bearing granite occurs 200 feet from the vein, up a small gulch. It is said that there is another occurrence on top of the hill above the workings, but the writer did not know of this until after his visit. Efforts were made for several years to work the deposits, and an air concentration plant was put up, but the quantity of ore did not prove to be large enough to pay for working.

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