Geology of Lost River Mine Area, Alaska

GEOLOGICAL SURVEY BULLETIN 1129

With a section on ore reserves prepared in cooperation with the U.S. Bureau of Mines

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By C. L. SAINSBURY

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By C. L. Sainsbury

ABSTRACT

The Lost River tin mine is in the York Mountains, in the western part of the Seward Peninsula, Alaska. It was operated intermittently from 1904 through 1955. The present report is based largely on mine data compiled by geologists of the U.S. Geological Survey between 1951 and 1955, supplemented by data gathered by other workers from 1903 to 1951. Only the tin and tungsten resources of the mine are considered in this report. Beryllium resources of the mine area are being investigated currently, and will be the subject of separate reports.

The bulk of the bedrock of Lost River valley consists of the Port Clarence limestone, of Paleozoic age. Near the mine the limestone is of Early Ordovician age, and is marmarized and partly replaced by silicate minerals, and cut by numerous veinlets containing silicates, ore minerals, and fluorite; a granite pluton that does not crop out has been penetrated by exploratory openings. Many basalt porphyry and rhyolite porphyry dikes intrude the limestone in the mine area. All the ore milled to date has come from an altered rhyolite porphyry dike known as the Cassiterite dike. The main ore minerals are cassiterite and wolframite, which are associated with sulfides and minor amounts of other ore minerals in the intrusive rocks and the limestone. Both the granite and the dikes are greisenized and cut by veinlets. Introduction of ore minerals probably began when the intrusive rocks were greisenized and the limestone altered to marble and tactite, while deposition of tin and tungsten minerals, along with base-metal sulfides, continued in veinlets. Subsequently, the greisen and limestone were extensively kaolinized, so that in places the greisen was converted almost entirely to clay minerals, and the early iron sulfides were almost completely removed. Petrographic evidence suggests that kaolinite formed in part by a reaction between topaz and quartz, which could have progressed, where limestone was near, according to the following equation:

$$\begin{array}{l} \text{topaz} + \text{quartz} + \text{water} + \text{limestone} \longrightarrow \text{kaolinite} + \text{fluorite} + \text{carbonic acid} \\ (Al,F)_2SiO_4 + SiO_2 + H_2O + CaCO_3 \longrightarrow Al_2Si_2O_5(OH)_4 + CaF_2 + H_2CO_3 \end{array}$$

The alteration of the limestone to clay and clay-carbonate rock shows extensive migration of ions during kaolinization.

The main reserves of tin and tungsten ore are in the Cassiterite dike. The reserves classed as measured and indicated ore, and containing more than 1 percent tin (or combined tin and WO_3), amount to 305,000 tons. Chances are good that additional exploration will find additional tin and tungsten ore, and possibly beryllium ore.

INTRODUCTION

The Lost River tin mine is in the York Mountains, in the western part of the Seward Peninsula, Alaska, about 90 miles northwest of Nome (fig. 1). The York Mountains are moderately rugged and generally rise to altitudes of 2,000–2,500 feet; their highest point is Brooks Mountain, with an altitude of 2,898 feet. A broad wave-cut terrace, 1 to 4 miles wide and 400–600 feet high, forms the southern edge of the mountains, along part of the coast of the Bering Sea. Lost River drains part of the York Mountains and flows southward from the mountains into the Bering Sea.

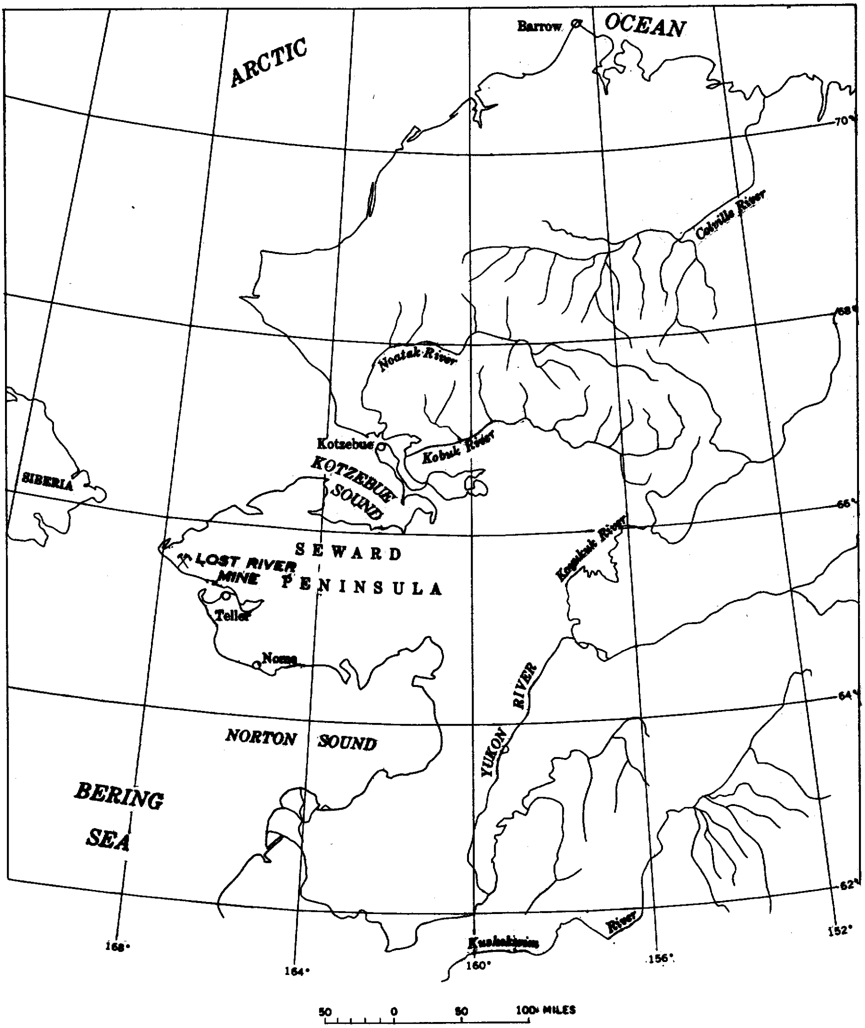

FIGURE 1.—Index map of a part of northwestern Alaska, showing location of Lost River mine.

The Lost River mine lies on Cassiterite Creek, which enters Lost River about 6 miles upstream from the river's mouth. The mine is difficult to reach by land routes; employees of the mine, as well as fresh food and emergency supplies, were brought from Nome by light aircraft. During ice-free months, heavy supplies can be lightered from oceangoing ships at the mouth of Lost River or brought by boat from Teller about 25 miles to the southeast. During the winter, supplies may be brought by tractor train along the beach or even across the ice of the Bering Sea when the ice is sufficiently thick. Supplies were hauled from the mouth of Lost River to the mine by truck.

The climate in the Lost River area is arctic—wind, fog, and rain are common in the summer; the winters are severe, with moderate snowfall and strong north winds from the York Mountains. Although the mine has been operated through some winters, winter operations were hampered by the weather and the scarcity of mill water in late winter and early spring. The area is treeless and has very little vegetation of any kind even in low areas; the barren mountain slopes are generally covered with frost-riven rubble. (See fig. 2.)

The Lost River mine was operated intermittently from 1904 through late 1955; it had produced, according to U.S. Bureau of

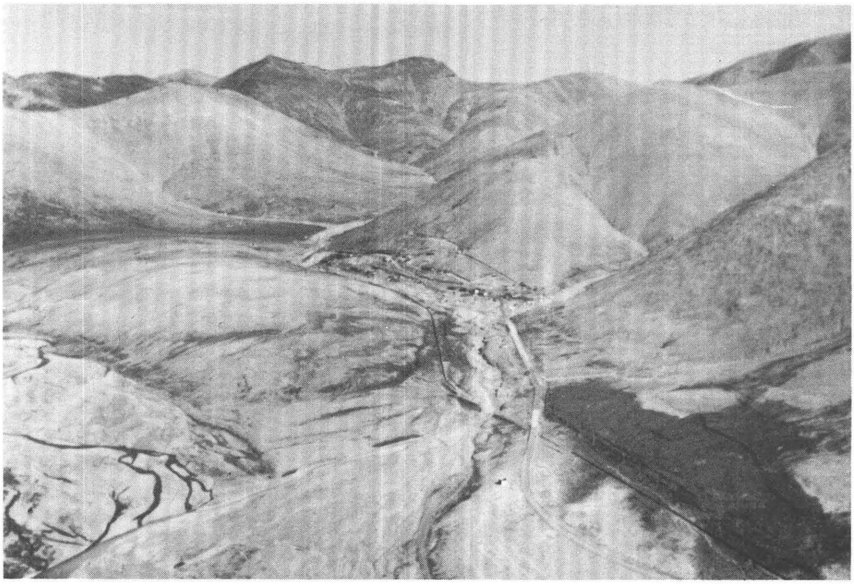

FIGURE 2.—Air view of Lost River valley, Alaska. View up Cassiterite Creek from its confluence with Lost River on left. First valley on right below camp is Camp Creek. Pipeline and road lead to airfield and beach. Note tendency toward rounded and subdued topography caused by heavy mantle of limestone fragments riven by intense frost action.

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Mines records, a total of about 350 short tons of tin metal from lodes and about 93.4 short tons of tin metal from placers. The most active period of production was from 1951 through 1955, when it was operated by the U.S. Tin Corporation, largely with Government funds from the Defense Production Administration advanced against production. During this period the lower levels of the mine also were explored under an exploration contract with the Defense Minerals Exploration Administration. Late in 1955, operations ceased; the mine was later taken over by the U.S. Government for nonpayment on the loan advanced by the Defense Production Administration, and later sold at public auction. Present owners are Mr. Lenhart Grothe and Mr. Thomas Pearson, of Red Devil, Alaska.

The U.S. Geological Survey has investigated the tin deposits of the Seward Peninsula at intervals since 1900 (Brooks, 1900, 1903; Collier, 1903; Knopf, 1908; Steidtmann and Cathcart, 1922). Most of the studies were more in the nature of brief investigations of the progress of mining and of prospecting activity than complete geologic investigations. No systematic geologic maps of the area have been published.

In 1918, F. C. Fearing, a private engineer, prepared a detailed report on the mine; this report furnished valuable assay data to the writer.

Many workers of the Geological Survey have contributed unpublished data used in this report, especially J. B. Mertie, Jr., R. R. Coats, J. R. Houston, G. D. Eberlein, A. E. Weissenborn, and P. L. Killeen. Mertie and Coats prepared the surface geologic map of the mine area during their investigations, which began in 1940, and their unpublished reports were consulted freely by the writer, as were those of other workers. The writer has attempted to give credit to all those whose ideas are used in this report, but takes the responsibility for the conclusions expressed herein.

In 1942, the U.S. Bureau of Mines began an exploration program at the mine that included trenching and diamond drilling. The report by the Bureau of Mines on this program (Heide, 1946) has also furnished valuable assay data. During the drilling program, Coats, Killeen, and C. A. Kirschner of the Geological Survey logged the drill cores, mapped the geology, and assisted in the geologic interpretation of the new data.

The U.S. Geological Survey collected data from the Lost River mine at intervals during the period 1951 through 1955 while the mine was operating under Defense Production Administration and Defense Minerals Exploration Administration contracts. The writer was responsible for collection of data from the mine at intervals from 1952 until 1956, and J. R. Houston was at the mine continuously between June and early September 1953. The laboratory studies connected with the work at the mine from 1952 to 1955 were done by the writer in 1956, and the task of interpreting and integrating all the data collected since 1943 fell to him, although some of the geologic maps that accompany this report were compiled in whole or in part from Houston's field maps. In 1960, the writer started a project to evaluate the beryllium potential of the Lost River area; the project included preparation of 1:62,500-scale maps. Preliminary reports discussing the beryllium potential have been published (Sainsbury, 1961; 1962a, b).

ACKNOWLEDGMENTS

The writer received wholehearted cooperation from the resident management at the mine, notably from general superintendents Paul Sorenson, Everett Hoagland, and Howard Murray, and from mine foreman Jack Ferguson, who made base maps and assay data available and had special samples assayed, at times when the normal assay load was heavy.

The U.S. Bureau of Mines in Juneau, Alaska, made available assay data from samples of the U.S. Tin Corporation that were assayed in Juneau. The results of spectrographic and mineralogic studies made by the Bureau on these samples also were given to the writer.

SCOPE OF REPORT

This report is largely a discussion of the tin and tungsten potential of the Lost River mine area; it is written to make available to the public geologic data gathered during the last period of operation of the mine, particularly information that was assembled under the D.M.E.A. contract, and to integrate this information with data gathered previously. It cannot provide a final answer to the many problems that are connected with such a complex mine. The lower levels of the mine are flooded, and the openings in the extensively kaolinized rocks below the permafrost zone will cave and close quickly. Interest continues in the lode tin deposits of the Seward Peninsula, and it is assumed that the geologic data from the Lost River mine area will apply to other lode deposits of similar geologic setting on the Seward Peninsula.

AREAL GEOLOGY

Although the Lost River area is but a small part of a larger region in the Seward Peninsula that contains lode and placer tin, only the areal geology of a part of Lost River valley and vicinity (pl. 1) is considered in this report. The areal discussion is based partly on work done by U.S. Geological Survey geologists other than the writer, particularly J. B. Mertie, Jr., R. R. Coats, P. L. Killeen,

A. Knopf, E. H. Steidtmann, and S. H. Cathcart, although geologic mapping presently (1962) in progress by the writer will provide additional information that may require modification of ideas expressed herein.

BEDDED ROCKS

The Port Clarence limestone, of Early Ordovician age, forms the bulk of the bedrock of Lost River valley. In the vicinity of Lost River mine, the Port Clarence contains gray cherty limestone in addition to argillaceous and dolomitic limestone.

Near the Lost River mine, the limestone is marmarized and partly replaced by silicate minerals, and is intensely interlaced with veinlets containing silicates, ore minerals, and fluorite. The marmarization and veining of the limestone are related to an underlying granite mass not exposed at the surface but intersected by mine workings and diamond-drill holes. Similarly marmarized limestone containing silicate and ore minerals is near the contacts of other granite stocks in the area. Silicate minerals and tactites in marmarized limestones have formed along channels in the limestone and are not everywhere close to granite contacts.

INTRUSIVE ROCKS

Igneous rocks in the form of bosses and dikes intrude the Port Clarence limestone within the area shown on the geologic map (pl. 1). In composition these rocks range from basalt to granite; the mafic rocks occur only in dikes and in one very small boss. Their composition is in part determined by chemical reaction between magma and ingested limestone and dolomite.

DIKES

Many basaltic and rhyolitic dikes, which strike mostly northeast to east, are concentrated in a zone a few miles wide in which the Lost River mine area lies. The eastward continuation of the belt lies between granite masses exposed on Tin Creek and on Brooks Mountain. The dikes probably followed faults, but their age relation to the granite bosses is obscure, although some are known to cut the granite.

Rhyolitic dikes.—The silicic dike rocks in general are light-colored porphyritic rocks composed mainly of quartz, orthoclase, and albite. In hand specimens, the unaltered rhyolitic rocks range in color from grayish white to pale green. The degree of granularity of the rocks varies, for some are almost entirely crystalline and others are best described as rhyolite porphyry with a greenish, almost glassy groundmass. The rhyolitic dikes range in thickness from less than a foot to as much as 55 feet in local "swells." The principal rhyolitic dikes in the Lost River area are: the Cassiterite dike, the Ida Bell dike, the Hidden dike, the Rust dike, and the Greenstone lode. Other rhyolitic dikes and dike-cemented breccia zones are known, but they are smaller bodies that cannot be traced with accuracy. Only the Ida Bell and the Cassiterite dikes are of economic importance with respect to tin and tungsten in the immediate mine area.

The Cassiterite dike can be traced about 8,000 feet, from the west side of the valley of the North Fork of Tin Creek to the valley of Lost River. In its western part, near Lost River mine, the dike strikes N. 85° E. and dips steeply south, but the strike of the eastern part is S. 60° E. The major changes in direction may occur at faults. The Cassiterite dike varies in thickness from a few feet to as much as 20 feet, and probably averages about 12 feet.

The Ida Bell dike has been traced from the east side of Lost River valley eastward to the upper valley of Cassiterite Creek, a distance of at least 10,000 feet. Where exposed in Bureau of Mines trenches near the mine it averages about 35 feet in thickness. The dike strikes about N. 70°–75° E. and dips vertically. It cuts the Cassiterite dike on the low ridge west of Lost River mine.

Basaltic dikes.—The basaltic dikes are dark gray-to-black fine-grained porphyritic rocks. Some are amygdaloidal, and some include a variety of xenoliths and clearly are composite rocks that include admixed rhyolite dike rocks. Some of the altered basaltic dikes exposed underground at Lost River have a relict diabasic texture and some show clear evidence that they are the result of desilication of more silicic rocks through digestion of limestone.

The most nearly continuous basaltic dikes are the Dolcoath and the Bonton. These dikes have a trend slightly north of east, similar to the trend of the silicic dikes. The Dolcoath dike has been traced for approximately 3 miles; it has been altered and metallized with ore minerals over much of its eastern part. The Bonton dike strikes about N. 70° E., but, unlike the Dolcoath, it is not known to contain ore minerals. A small mafic boss crops out south of the western part of the Bonton dike.

GRANITE

Two bosses of granite crop out in the Lost River area. The larger is exposed on the southeast slope of Brooks Mountain where the outcrop, elongated in a northerly direction, measures about 9,000 by 3,000 feet. The granite is coarsely porphyritic, and contains phenocrysts of orthoclase as much as 1.5 inches in length, which constitute about three-quarters of the volume of the rock. The matrix consists of orthoclase, plagioclase, quartz, and minor biotite.

Few rhyolitic dikes cut the granite of Brooks Mountain, although one dacite dike does. The granite has a chilled marginal facies and is fresh, except for slight tourmalinization within a few feet of the contact and for tabular alteration zones along some fractures in the granite.

Another body of granite crops out in the valley of Tin Creek, about 3.7 miles southeastward from Brooks Mountain. It measures about 3,500 by 1,500 feet in plan and is elongate in a northeasterly direction. The granite is fine grained and equigranular and is composed of quartz, orthoclase, sodic plagioclase, and biotite; its average grain size is 0.1 inch. A chilled border facies was recognized locally, and the granite is altered near the northeast border, where it contains pyrite and small quartz veinlets containing cassiterite, and along dikes which intrude the granite. Part of the northwest contact of the granite is controlled by faulting. Several dikes with chilled borders intrude the granite and tactite in limestone near the granite contact.

Granite also underlies the Lost River mine and is exposed in the underground workings. The granite body, which appears to be a cupola of a larger mass, measures about 400 feet in width at the lowest mine level. The granite is intensely altered and is converted to greisen in large part. The least altered part is a fine-grained holocrystalline rock containing quartz, orthoclase, oligoclase, and small amounts of biotite, fluorite, apatite, and opaque minerals. No dikes are known to cut the granite, but it intrudes and has altered some mafic dikes. Texturally, the granite at Lost River mine resembles that of the Tin Creek boss, but is distinctly different from that of Brooks Mountain.

AGE RELATIONS OF THE IGNEOUS ROCKS

Although some dikes are younger than the granite, some probably are older, and it seems doubtful that there is a simple regional sequence according to rock type. Rhyolitic and dacitic dikes cut the granite in the valley of Tin Creek, and a dacite dike cuts the granite in Brooks Mountain. Crosscutting rhyolite dikes, such as the Cassiterite and Ida Bell dikes, suggest more than one period of intrusion. In the Lost River mine an altered rhyolite dike cuts a metasomatized basalt dike, and a second basalt dike has been intruded by granite. The mineralization in the Dolcoath, Cassiterite, and Ida Bell dikes is so similar to that in the granite in the Lost River mine that there is little doubt that all were mineralized simultaneously after the granite had solidified. If these dikes are not older than the granite, they certainly cannot be much younger. The suggested age relations are, from oldest to youngest: granite of Brooks Mountain, basaltic dikes, most of the rhyolitic dikes, granite of Cassiterite and Tin Creeks, and late rhyolitic and dacitic dikes.

Economically, the important fact is that some dikes, both basaltic and rhyolitic, have been mineralized and some apparently have not.

GEOLOGIC STRUCTURE

FOLDING IN THE LIMESTONE

The structure of the Port Clarence limestone in the vicinity of Lost River mine is imperfectly known. The monotonous lithology of the limestone and the intense frost action make geologic mapping difficult and uncertain. Throughout the Lost River drainage basin the limestone generally dips northward from 15° to 40°. Flatter and steeper dips are rare. In some places, good exposures of bedrock in creek beds or on ridge tops show complex folding in the limestone, and this folding is caused in part by thrust faulting.

The limestone exposed underground at Lost River mine strikes eastward and dips northward; some minor folds are impressed upon the regional structure.

REGIONAL FAULTING

Thrust faults as well as three systems of high-angle faults have been recognized in the Lost River area. The high-angle faults probably in large part antedated and guided injection of the dikes. The predominant strikes of the earlier systems are N. 65°–85° E. and N. 55°–75° W. The third system of faults, striking somewhat west of north, in part postdates the intrusion of the dikes, for several of these faults displace the major eastward-trending dikes, possibly as much as 4,000 feet. On the other hand, a postulated fault of this system that may follow Cassiterite Creek does not displace the Cassiterite nor the Ida Bell dike. The magnitude of displacement on all the faults cannot be determined accurately because of the heavy talus, but displacements in the faults of the N. 65°–85° E. system are as much as several hundred feet. Mertie and Coats (written communication, 1941) stated that the older faults are younger than the granitic intrusions exposed on Tin Creek and on Brooks Mountain, that dikes were injected along these older faults, and that the northward-trending faults ruptured the dikes. The northward-trending faults shown cutting the Cassiterite dike (pl. 2) are taken from a field map by Mertie and Coats, but because underground openings did not reveal these faults, they are shown as dashed lines which do not indicate offset on the Cassiterite dike.

The writer believes that no definite conclusions can be drawn from the available information regarding the ages of the faults in relation to all the known granite plutons. Underground mapping at the Lost River mine indicates that the granite postdates most of the dikes and possibly many of the faults. Some of the faults trending almost north were intruded by dikes and metallized with tin, tungsten, and sulfide minerals; this fact suggests that some of them also predate the granite at Lost River mine. Underground mapping shows that, although the eastward-trending Cassiterite dike probably was injected along a normal fault, postmineralization movement has occurred on the fault.

The faults are important economically because they are believed to have been the main channelways for ore-forming solutions. Repeated movement on faults intruded by dikes shattered both the dikes and wallrocks, and provided favorable channels for mineralizing solutions.

GENERAL OCCURRENCE OF TIN-TUNGSTEN MINERALS IN THE LOST RIVER AREA

Tin and tungsten minerals are widely distributed in the Lost River area. Though individual occurrences differ markedly, the tin-bearing minerals at major prospects are associated with boron- or fluorine-bearing minerals. The constant association of tin with boron and fluorine regardless of the kind of country rock points to granitic rocks as a common source for all the deposits.

Most of the tin deposits around the granite masses on Brooks Mountain and on Tin Creek are in limestone near the contact rather than in the granite itself. On Brooks Mountain, hulsite (tin-bearing iron and magnesium borate) and paigeite (a tin-bearing iron borate) are intergrown with base-metal sulfides in a gangue consisting of mixtures of the following minerals: fluorite, axinite, tourmaline, calcite, idocrase, diopside, and phlogopite. Most of the deposits are along distinct fissures or veins in the limestone, though a very little cassiterite and a little zeunerite, a secondary uranium mineral, were found in marginal parts of the granite. On Tin Creek, cassiterite and stannite are in the margins of the granite associated with quartz, topaz, pyrite, galena, arsenopyrite, and several silicates, and are along veins that cut the granite.

At the Lost River mine, cassiterite and wolframite are the chief ore minerals. Other metallic minerals in the tin-tungsten ores include stannite, arsenopyrite, pyrite, galena, chalcopyrite, ferroan sphalerite, molybdenite, stibnite, and bismuthinite, and the ores contain traces of cadmium, indium, beryllium, and other rare elements (table 1). Quartz, fluorite, topaz, zinnwaldite mica, clay minerals, and the usual calcium-magnesium-iron silicates are the chief nonmetallic gangue minerals. Of these, fluorite is the most abundant.

LOST RIVER MINE

Although the Lost River mine has been extensively explored by means of pits, trenches, and diamond-drill holes, the main workings are along the Cassiterite dike and in an unexposed granite mass. These two igneous bodies have been the most extensively developed because they contain most of the known tin-tungsten ore in the Lost River mine area.

The spatial relations of the geologic features to the mine workings, pits, trenches, and diamond-drill holes are shown on plate 2, a surface geologic map made in 1940 by Mertie and Coats, with later additions by Coats and Killeen and Sainsbury. The map has been modified slightly in the light of later information gained by the writer in 1961–62.

MINE WORKINGS

The main workings of the Lost River mine are along the Cassiterite dike and in or near a granite cupola at the 365 level (pl. 3). The workings on the Cassiterite dike include the main or No. 3 adit which is about 1,250 feet long and is at an altitude of 306 feet above sea level, and the Nos. 2, 1, and 0 adits that are shorter and are at altitudes of 401, 502, and 609 feet, respectively. In late 1951 or early 1952 the U.S. Tin Corporation drove a new and larger adit on the same level as the No. 3, in the footwall of the dike, to serve as a haulage way. The two adits are connected by short crosscuts.

The No. 2 adit originally was about 140 feet long, but in 1953–54 stopes from the No. 3 adit broke into it and much of the adit caved into the stopes. The No. 1 adit is about 420 feet long and is driven along the dike. The adit is caved badly at the portal. The No. 0 adit is less than 40 feet long and was caved near the portal at the time of this study.

Between the No. 3 and the No. 2 adits, the dike has been explored by two sublevels, at distances of 26 and 55 feet above the No. 3 adit, and by a series of raises and stopes. All the stopes are in the Cassiterite dike above the No. 3 adit. (See pl. 10.)

The No. 1 shaft, an old inclined shaft, was sunk for a vertical distance of about 424 feet along the footwall of the dike and two levels, here named the 294 and 398 levels, were driven from it. The 294 level was driven southwestward for about 250 feet, to cut the Cassiterite dike about 80 feet from the shaft. The 398 level intersected the dike about 10 feet south of the shaft station; the level also was driven 68 feet northward into the limestone on the footwall of the dike.

In 1951–52, the No. 2 shaft was sunk vertically for 385 feet from the No. 3 adit level, from a point about 40 feet north of the collar of the No. 1 shaft. From this shaft the 100, 195, and 365 levels were driven. The 100 level connects the No. 2 and No. 1 shafts, the latter being caved above and below this level at the time of the examination. The 195 level intersects the Cassiterite dike to the south, from which point drifts were driven 450 feet eastward and 150 feet westward. (See pl.3.)

On the 365 level, the dike is explored by the 50 drift east, and the granite cupola by the 32 crosscut south and by its branching crosscuts. (See pl. 7.) In October 1955, the 32 crosscut south and the 195 crosscut west were caved at the granite contacts. At other points, the drifts and crosscuts on this level were being heavily squeezed by rock pressure and since then may have become inaccessible. All workings below the 195 level adit were flooded when mining operations ceased.

Other workings at the Lost River mine, which were not connected to the main workings, consist of: the Randt adit, on the Cassiterite dike west of the present main workings; the Ida Bell adit, on the Ida Bell dike; underground workings on the Greenstone lode; the Devereaux adit; and numerous unnamed exploratory trenches and pits. Most of these workings are caved or inaccessible now. The locations of most are shown on plate 2.

GEOLOGY

MARMARIZED LIMESTONE

At the Lost River mine, the Port Clarence limestone is erratically altered to marble throughout an area measuring roughly 3,000 by

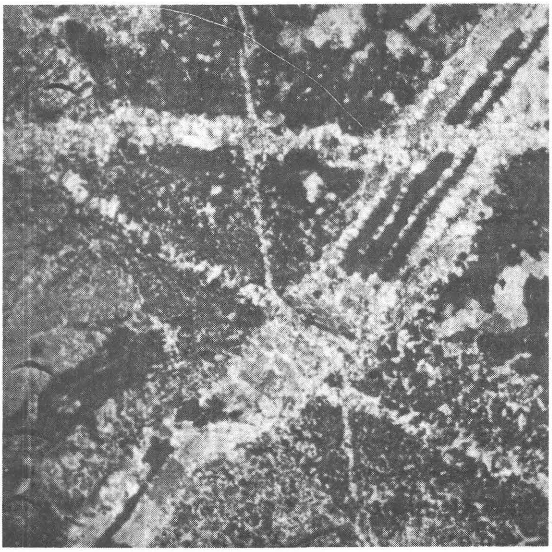

FIGURE 3.—Photomicrograph showing the complexity of veining of marmarized limestone, main adit. Black areas are fluorite, light veinlets mostly pink mica, gray areas in veinlets mostly tourmaline. Crossed nicols. About × 8.

2,000 feet. At places the marble has been converted to tactite that contains a highly varied suite of ore and gangue minerals in different amounts. Both tactite and marble are cut by innumerable veinlets in which the gangue minerals include fluorite, carbonates, zinnwaldite, hornblende, pyroxene, idocrase, topaz, plagioclase feldspar, garnet, sericite, kaolinite, tourmaline, quartz, and probably many others (fig. 3). The ore minerals include arsenopyrite, pyrite, pyrrhotite, ferroan sphalerite, stannite, cassiterite, scheelite, wolframite, chalcopyrite, hematite, galena, bismuthinite, ilmenite, magnetite, stibnite, rutile, phenacite, beryl, chrysoberyl, and probably others. Late alteration products in the veins consist of clay minerals, limonite, gypsum, manganese compounds, malachite, and a secondary yellow arsenic mineral. No one vein contains all the ore and gangue minerals named, and the mineralogy of individual veinlets differ from place to place.

In concentrates panned from the larger veins, the writer found arsenopyrite, pyrite, cassiterite, wolframite, chalcopyrite, bismuthinite, magnetite, and ferroan sphalerite to be the most abundant ore minerals. Much of the cassiterite in these veins is in the form of minute clear to milky white crystals resembling zircons.

In places, marmarization of the limestone is related to the heat from small veinlets rather than to heat from the granite, for highly marmarized limestone, as at the shaft station on No. 3 adit, is directly above limestone not nearly as recrystallized.

MINOR DIKES

Several small discontinuous and complex dikes which cut the marmarized limestone were explored to some extent. The Intermediate dike is a highly altered, light-colored dike shown by drill holes and underground workings to trend parallel to the Cassiterite dike (pl. 2). The length and exact attitude of the dike are unknown; present data indicate that it contains only low-grade ore.

The Greenstone lode (pl. 2), which crops out at the surface a few hundred feet south of the portal of the main adit, consists of a sill-like dark dike cut by a similar light-colored dike. The detailed relations of the various rocks have been obscured by intense alteration which converted part of the limestone wallrock to tactite and introduced much fluorine with small amounts of tin and tungsten into all three rocks. The Greenstone lode was explored before 1918 by a short drift and crosscut; in 1942 and 1943 it was trenched and drilled by the Bureau of Mines.

Another tabular intrusive, the Tungsten lode, was found at the mine in 1953 during grading for camp buildings. This lode (fig. 4) is an altered rhyolitic dike which contains tin and tungsten minerals.

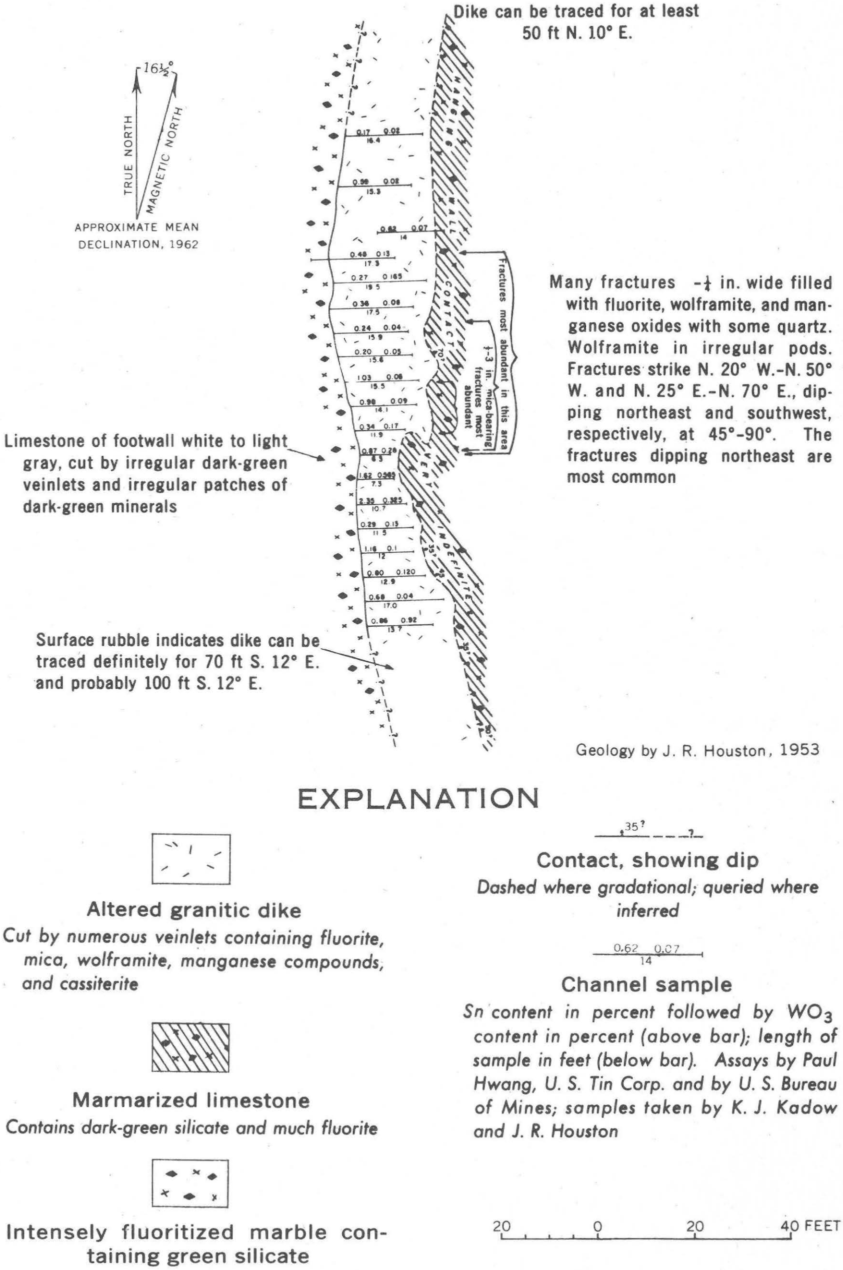

FIGURE 4.—Geologic sketch map of surface Tungsten lode, Lost River mine, Alaska.

Samples for 100 feet along the dike have a weighted average of 0.54 percent tin and 0.14 percent WO_3 across an average width of 14.1 feet. Initially the dike appeared to be promising because of the apparent richness of wolframite which occurred in pods and crystals as much as several inches in diameter. One drift on the lower level of the mine was driven westward partly in an attempt to find the down-dip extension of the lode, but without success.

A rhyolite porphyry dike, the Ida Bell, strikes about N. 70°–75° E., dips vertically, and averages about 35 feet in thickness. It cuts the Cassiterite dike about 1,800 feet west of the portal of the main level of the mine. Near the intersection with the Cassiterite dike it is altered and metallized to the surface. The Ida Bell dike has been tested by surface trenches, an adit and winze long since caved, and several diamond-drill holes. All this work was done prior to 1944.

CASSITERITE DIKE

LITHOLOGY

The main workings of the Lost River mine lie along the Cassiterite dike, which has furnished all the ore milled through 1955 and which contains all the measured and indicated ore reserves of the mine. Coats (written communication, 1943) described unaltered rock from similar rhyolite porphyry dikes in the area thus:

> The rhyolite porphyry, where fresh, is pale green or gray, with a considerable range in the proportion of the millimeter-sized phenocrysts of quartz, orthoclase, and albite, listed in decreasing order of abundance. Two of the named dikes, the Cassiterite and Ida Bell, can be traced into areas where they have undergone relatively little alteration by thermal fluids. In such areas, specimens of the Cassiterite dike contain sixty or seventy percent of phenocrysts, those of the Ida Bell contain from ten to twenty percent.

None of the Cassiterite dike exposed in the mine resembles the unaltered dike rock described by Coats. The hardest facies is a gray porphyritic-appearing rock that is composed mainly of quartz and topaz and is classed as greisen. In places the greisen contains several percent sulfide minerals, cassiterite, and wolframite; selected specimens assay as much as 2.7 percent tin.

Another distinctive facies of the dike is a soft kaolinized rock, commonly gray green or faintly purplish, with a pseudoporphyritic texture caused by white kaolinite patches as much as 1 cm across (fig. 5). Locally, as at the east end of the No. 1 adit (pl. 4), the dike is altered to white or tan clay containing cassiterite and limonite. In other places, as in the west drift of the 195 level, the dike consists almost entirely of pinkish mica in large and small flakes (fig. 6). Where possible, these variations are shown on the geologic maps, although the distinctions are somewhat arbitrary because all varieties intergrade.

ATTITUDE AND CONTACT RELATIONS

The Cassiterite dike thickens and thins along strike and dip, such variations often coinciding with abrupt changes in strike or dip.

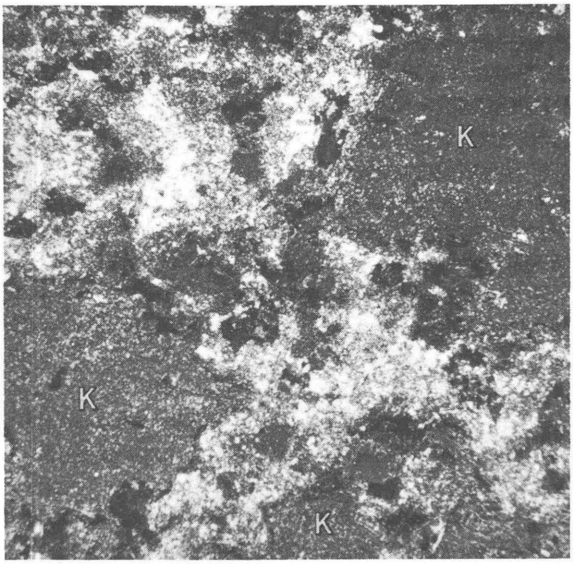

FIGURE 5.—Photomicrograph of kaolinized facies of Cassiterite dike. Kaolinite (K) forms rounded patches in part pseudomorphous after quartz. Dark areas are fluorite, light areas are mica. Crossed nicols. About × 8.

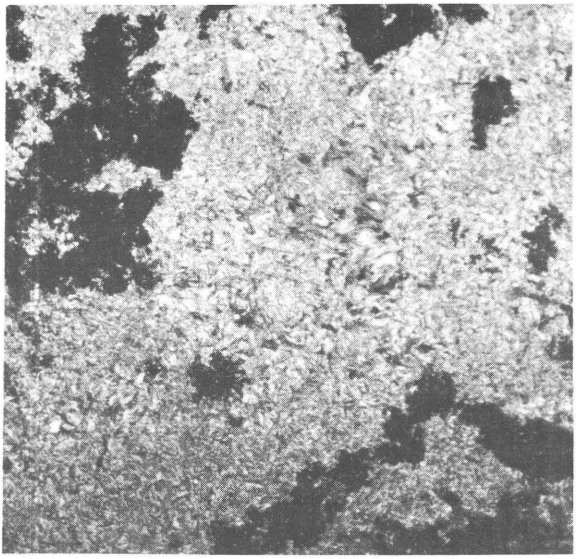

FIGURE 6.—Photomicrograph of fluorite-mica facies of altered Cassiterite dike. Dark areas are fluorite. Crossed nicols. About × 8.

Rolls of the dike to a flatter dip often plunge to the east at low angles. The tendency of the dike to widen where it steepens supports the theory that it was injected along a normal fault (section 6, pl. 5).

Within the mine, the dike ranges in thickness from 3 to more than 20 feet, although the average thickness is about 11 or 12 feet. At places, the thickness of the dike is controlled by postdike faulting (pl. 4).

The dike sends few offshoots into the wall, although it branches locally and includes small horses of limestone. The horses are not numerous, and pose no dilution problem in mining.

The contact between the dike and the limestone varies in sharpness. At some places the contact is sharp, but at some places as much as several feet of clay gouge or altered limestone lie along one or both walls. The clay may represent kaolinized dike rock, limestone, or altered limestone, all somewhat sheared by the postmineral faulting along the dike. A zone of hard altered limestone in whole or in part consisting of tactite or fluorite, tourmaline and chrysoberyl may be on one or both walls. Locally fluorite is the dominant mineral in the altered limestone, and its distribution has been shown on the geologic maps where possible in an attempt to relate tin values to fluoritization. In the stoped areas of the mine a selvage of fluorite or fluorite-tourmaline rock usually lies along one or both dike walls, but in some areas of good ore, contacts are sharp between dike rock and unaltered limestone. Some of the fluoritized limestone along the dike exhibits a well-defined layering parallel to the dike walls and locally contains considerable beryllium. The fluorite is both triboluminescent and thermoluminescent, and when struck by the pick, emits a greenish light that aids in its identification underground.

GRANITE

LITHOLOGY

The granite has been explored by six diamond-drill holes from the surface and by drifts and diamond-drill holes on the 365 level. The least-altered part is exposed in the 195 crosscut west and consists of a light-colored fine-grained faintly porphyritic granite cut by a few veinlets ¼- to ½-inch thick that lie along joints. In thin section the granite is seen to consist volumetrically of about 45 percent quartz, 30 percent orthoclase, 20 percent oligoclase, about 3 percent biotite, and minor fluorite, apatite, and opaque minerals (fig. 7). Myrmekitic and graphic intergrowths of quartz and oligoclase are common. The average grain size is about 0.1 inch. The quartz forms a few patches larger than the average grain size and gives to the rock its faint porphyritic texture. Chemical analyses of this fresh granite are given in table 5.

Some of the granite has been converted to a hard sulfide- and cassiterite-bearing greisen similar to that formed in the Cassiterite dike (fig. 8). Much of the granite is extensively kaolinized, and in

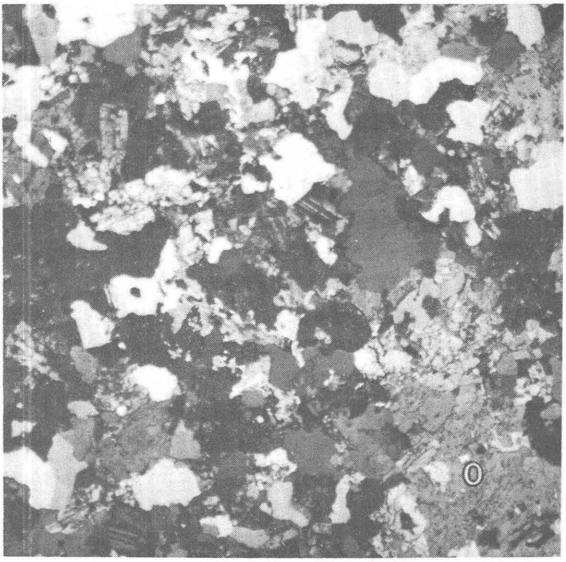

FIGURE 7.—Photomicrograph of freshest granite, 195 crosscut west, 365 level. Note twinned plagioclase feldspar and large anhedral patches of orthoclase (O). About × 8.

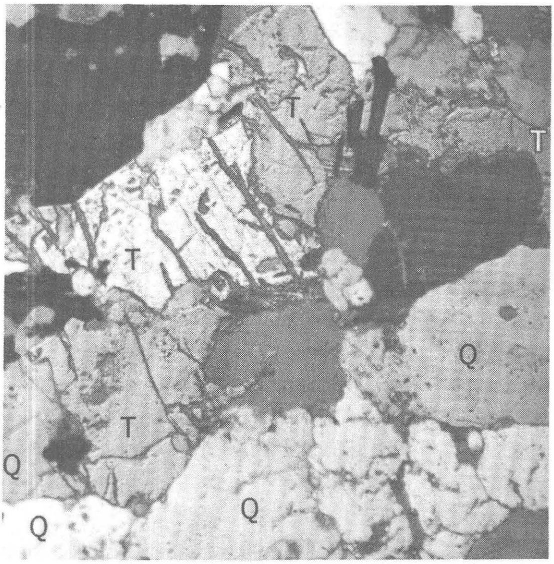

FIGURE 8.—Photomicrograph of quartz-topaz greisen containing sulfide minerals, 365 level. Grains with pitted surface and high relief are topaz (T), grains of lower relief that contain abundant inclusions are quartz (Q). Black areas are sulfide minerals. Note thin kaolinite veinlets along cleavages in topaz. Partly crossed nicols. About × 8.

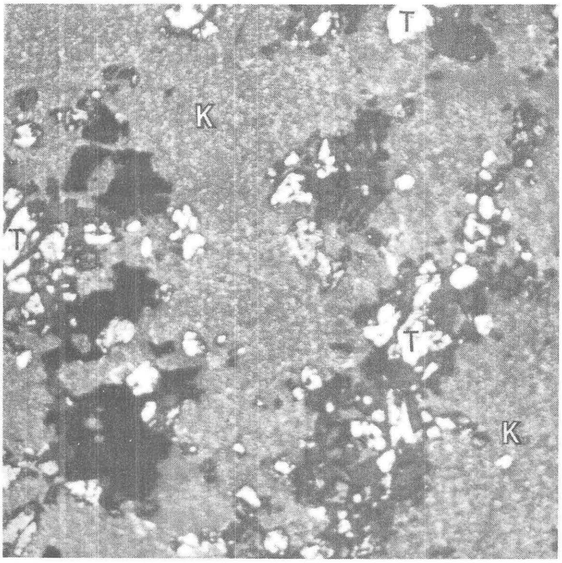

FIGURE 9.—Photomicrograph of intensely kaolinized granite, 365 level, with fluorite (dark) and scattered relict topaz (T) in a matrix of kaolinite (K). Crossed nicols. About × 8.

places it has been altered entirely to kaolinite in which small amounts of cassiterite and base-metal sulfides remain (fig. 9).

CONFIGURATION AND CONTACT RELATIONS

The information on configuration of the granite is very limited, but the granite apparently forms a cupola with the highest part beneath the general area above the Calcite drift (pl. 7). In general the cupola trends N. 20°–30° E., approximately under the area of marmarized limestone on the surface. What detailed information is available indicates that the contact is very irregular and even "overhanging," as in the 190 raise. The relatively steep dips and the swing in strike of the contact where exposed on the 365 level suggest a trough plunging irregularly eastward and may partly explain the high degree of kaolinization of the limestone in this area.

The granite contact as exposed in drifts and raises appears to be an intrusive contact along which there has been only minor dislocation subsequent to the kaolinization. In the Calcite drift and in the 195 crosscut, the granite lies against altered basalt and contains basalt fragments. Thin sections show that the basalt contains altered feldspar laths which give to the rock an unmistakable relict basaltic or diabasic texture. Locally, the basalt contains euhedral plagioclase crystals altered to sericite. Minor faulting involving displacement of less than 2 feet has occurred along the contact in the 195 crosscut west.

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RELATION OF DIKES TO GRANITE

The geologic relations of the Cassiterite and Ida Bell dikes to the granite are not known, and might not be determined positively even with a good deal more exploration. As shown by plate 7, granite crosses the projection of the Cassiterite dike, and nothing resembling rhyolite was found cutting the granite. There are three possible explanations of this relation: (a) The dike is older than the granite; (b) the dike is younger, but was so thoroughly recrystallized during greisenization and alteration as to be indistinguishable from altered granite; or (c) the dike is an offshoot of the granite. The failure to recognize rhyolitic dike material in the granite anywhere in the mine or in drill cores of granite, the known intrusion of basaltic dikes by granite, and the extensive alteration of the Cassiterite dike that is indistinguishable from that in the granite are regarded as evidence that the Cassiterite dike is older than or at least as old as the granite. Because the ore minerals were introduced into both granite and dikes subsequent to their emplacement, the question of the detailed geologic relations between granite and dikes is not important economically and needs no further discussion here. Dikes and granite were metallized by ore-forming solutions moving along later fractures, and it is these fractures that are important.

DISTRIBUTION OF THE ORE MINERALS

Ores of tin and tungsten occur at Lost River mine in three varieties of rock: altered dikes, veins in marmarized limestone or in tactite developed from limestone, and granite. The metallization of all three environments, however, was probably parts of a single process.

In the rhyolite dikes and in the granite, the earliest ore minerals were introduced during greisenization. Much of the granite, and probably most of the Cassiterite dike, was converted to a hard gray greisen (topaz-quartz rock) in which cassiterite is disseminated as small grains. In places, however, the greisen is cut by veinlets containing tin and tungsten minerals along with base-metal sulfide minerals (fig. 10).

Owing to the different chemical environment, very little greisen was formed in limestone, for the introduction of silica formed tactite containing various silicate minerals. Fluorine was deposited in tactite as fluorite rather than as topaz.

Marmarization of the limestone, formation of tactite and greisen, and veining and metallization of the limestone probably were in large part contemporaneous. The development of veins probably continued after the formation of masses of tactite near the granite and after the greisenization of the granite and the rhyolite dikes, for all are cut by younger veinlets.

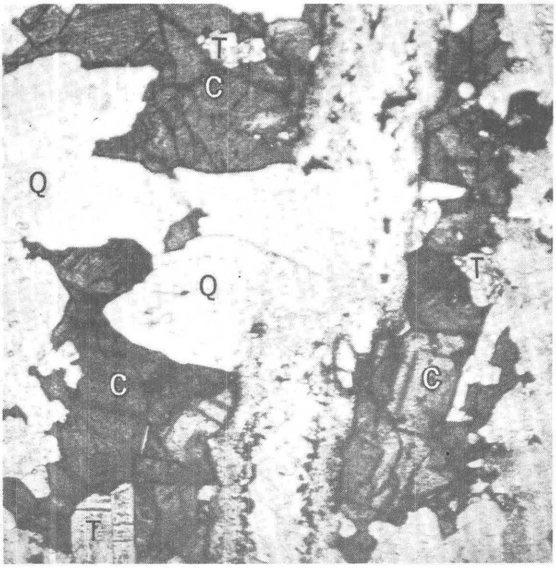

FIGURE 10.—Photomicrograph of large zoned cassiterite crystals (C) in greisen cut by later veinlet of topaz, fluorite, and tourmaline. Note that topaz crystals (T) and quartz (Q) are in part surrounded by cassiterite. Specimen from Cassiterite dike. Ordinary light. About × 8.

LIMESTONE

In much of the marmarized limestone and tactite, ore minerals are either sparsely disseminated or mixed with gangue in small veinlets, and the rock is not ore. In some places, however, the marmarized limestone and tactite contain a high percentage of tin, especially near the dike walls.

The tactite and fluoritized limestone along the walls of the Cassiterite dike locally contain as much or more tin than the adjacent dike (see D, pl. 8), and in any future operation, the altered wallrock should be assayed to determine where it is of ore grade.

The evidence is inconclusive as to whether the tin content of the limestone is higher near the granite contact. The limestone near the granite in the 32 crosscut south contains tin and tungsten ranging in combined amounts from less than 0.1 percent to as much as 0.7 percent. Though the tin content in this crosscut increases near the granite contact, information from drill holes indicates that this is not true everywhere. The altered limestone above the granite contains 0.1–0.3 percent tin, about the same amount as much of the limestone near the contact.

A few veins have been found in the limestone underground. Exploration on the 365 level disclosed one vein 8–33 inches thick. This vein, the Calcite vein, contains wolframite and cassiterite in a gangue of carbonate minerals. It strikes about N. 78° E. and dips 40°–60° NW.; it has been explored for a distance of about 125 feet. Much of the wolframite occurs as rich pods, especially in the western part. The richer part of the vein, which is about 40 feet long, assays about 1.3 percent tin and about 1.0 percent WO_3. The Calcite vein feathers out on its western end about 70 feet from the granite, and a smaller vein that may be en echelon with it is exposed in the 125 crosscut. Diamond-drill hole D.M.E.A. 3 failed to cut the vein at its projected intersection with the granite.

Another vuggy crustiform calcite vein about 12 inches thick is exposed in the 294 level from the inclined shaft. It strikes almost perpendicular to the Calcite vein, but it cannot be identified on the 365 level. None of the veins known appear large enough to yield substantial tonnages of ore.

CASSITERITE DIKE

The Cassiterite dike is altered and metallized throughout the explored distance of about 2,200 feet eastward from its intersection with the Ida Bell dike (pl. 2); it contains 0.1–2.5 percent tin except in small areas where it is notably richer. The ore minerals occur as grains disseminated in the dike, and in veinlets that in general strike and dip subparallel to the dike. (See especially pl. 5, and inset C, pl. 7.) Specimens of the hard gray greisen, free of veins, contain as much as 2.7 percent tin, and samples taken in the east end of the No. 1 adit, where the dike now consists of massive clay in which no veinlets are discernible, contain fully as much tin as samples taken where veinlets are visible. Although the higher assays can be correlated with an abundance of veinlets, the absence of visible veinlets in the kaolinized dike is not prima facie evidence that none ever existed there, for the intense kaolinization has in large part obliterated older veins.

Within the dike, tin and tungsten are distributed somewhat differently. (See pl. 10 for detail.) The tungsten content of the dike is relatively high between the intersection of the Cassiterite and Ida Bell dikes and the inclined shaft; the WO_3 content in any one block of ore may be as high as 0.9 percent, but the tin content averages less than 0.5 percent, although small areas may be considerably richer. East of the shaft the tungsten content is progressively lower and in most of the main tin ore shoot is negligible.

The economic implications of the differences in distribution of the tin and tungsten minerals are important. During the period 1952–55 no tungsten concentrates were produced, mostly because the ore milled probably contained less than 0.1 percent WO_3, and the mill was not capable of producing a tungsten concentrate from ore of this tenor. However, tungsten probably could be recovered from ore that contains 0.4–1.0 percent tungsten, provided the mill were modified to attempt recovery.

Assay data of the U.S. Tin Corporation indicate that tin is evenly distributed within the dike from the hanging wall to the footwall. The tungsten content near the hanging wall is materially greater than near the footwall. The reason for this disparity is not known.

Ore shoots.—The distribution of tin and tungsten in the Cassiterite dike is shown by assay on plate 10. The tin ore of economic grade begins near the old raise from the No. 3 adit and continues to a point near the 545 east raise. The west margin of the ore is intersected near the east end of the 195 level; this fact indicates that it rakes to the east at an angle of about 30°. Within this raking body are two ore shoots. The main ore shoot contains 1.5–2.5 percent tin, and its general shape is that of a "horn of plenty" that has a plunge length of at least 700 feet and a width as measured along the No. 3 adit of about 360 feet. This shoot apparently narrows at depth, although additional drifting to the east on the 195 level is necessary to determine whether lean ore at the extreme east end of the level represents a local impoverishment or is the end of the ore shoot. The grade of ore in the east drift of the 195 level was determined by long-hole drills and may be subject to slight errors.

A smaller ore shoot, shown on plate 10 as a possible ore shoot, contains over 3.0 percent tin where penetrated by the No. 3 adit. Between the two ore shoots, the ore contains 1.0–1.5 percent tin, but east of the smaller shoot the tenor of the ore drops off rapidly to less than 1 percent. The decrease in tin content corresponds roughly with a change in the strike and dip of the dike.

The geologic factors that govern the position of the ore shoots cannot be stated certainly. The main ore shoot does not correspond with any specific strike or dip of the dike; it does not correspond with the intersection of the limestone beds with the dike; and it cannot be correlated with the degree of fracturing of the dike. It does show a rough parallelism with the upper surface of the underlying granite, which suggests a temperature zonation near the granite or a center of activity similar to those in Cornwall that have been classed as "emanative centers" by Dines (1956, p. 8). Within the shoot, as well as elsewhere in the mine, are small areas of rich ore that can be correlated with discrete veinlets or zones of veinlets in the dike (pls. 4, 5, and 8). Many of the veinlets are traceable for as much as 50 feet, and selected small samples contained as much as 8 percent tin. Locally, cassiterite forms solid bands in these veinlets as much as an inch thick, and some zones of veinlets are quite rich.

For example, a channel sample across 4 feet of the zone of veinlets exposed in the upper part of the 365 east raise assayed 3.45 percent tin. Most of the larger veins in the dike are parallel or subparallel to the dike walls, whereas in the adjacent limestone many veinlets trend at large angles to the dike.

GRANITE AREA

The granite and adjoining limestone have been explored by a raise, by drifts, and by diamond-drill holes in sufficient detail to establish the amount and the distribution of the metal values (pls. 9 and 10). The tin content of the granite can be correlated in a broad way with the degree of greisenization and with the relative abundance of the small veinlets.

Studies in the 32 crosscut south and in the Calcite drift, which extends into the granite, indicate that the granite was first greisenized and mineralized and then kaolinized. The greisen where unaltered is a hard gray sulfide-rich rock containing small granular patches of disseminated cassiterite. The cassiterite is abundant enough to be identifiable in all thin sections of the greisen.

Only two assays of the granite in the 195 crosscut west are available, and these are at the contact with the limestone. In this crosscut, part of the granite is altered to kaolin, but the least altered rock is a fine-grained granite containing abundant orthoclase feldspar. The absence of cassiterite in thin sections of this rock suggests strongly that this part of the granite contains very little tin compared to the mass as a whole; this hypothesis is borne out by assays from drill cores.

Comparison of assay maps with geologic maps shows that the higher assays from granite are of parts that contain relatively abundant veinlets. In the 32 crosscut south, the average assay for a 50-foot section that includes altered limestone and some greisenized granite is about 0.5 percent tin; this section is particularly rich in small cassiterite-sulfide veinlets. A section including 11 feet of limestone and 47 feet of greisenized granite contains 0.38 percent tin, and is veined. The same situation occurs in the Calcite drift, where the highest assays were obtained from a 95-foot section that lies well inside the granite. The geologic map shows that these high assays correspond almost exactly with a persistent veinlet that trends along the drift. A selected specimen from this vein assayed 6 percent tin.

The weighted average of all channel or muck samples taken in the Calcite drift, including long-hole samples, is about 0.30 percent tin; of those in the 32 crosscut south 0.32 percent tin; and of those from the 190 raise about 0.25 percent tin. The average tenor of samples from D.M.E.A. drill-hole cores, in sections within the granite, ranges from 0.05 to 0.13 percent tin. The average WO_3 content of the granite probably is not more than 0.03 percent, and it seems probable that the border "shell" contains more than the interior.

Throughout the entire granite area, base-metal sulfide minerals are closely associated with cassiterite, and locally galena and ferroan sphalerite constitute as much as several percent of the rock. Ferroan sphalerite is especially abundant in small veins in the walls of the 32 crosscut south, and assays along the south wall, over a distance of 50 feet, average about 1.0 percent zinc. In the Calcite drift, galena is very abundantly disseminated in the kaolinized granite, where in places it may constitute several percent of the rock. Polished sections of this ore show that most of the galena is associated with fluorite, which occurs in the cubic cleavage of the galena.

Other sulfide minerals identified in the granite are arsenopyrite, pyrite, pyrrhotite, chalcopyrite, molybdenite, stannite, bismuthinite, and stibnite, listed in approximate order of decreasing abundance. Polished sections of ore (figs. 11 and 12) show also an unidentified brass-yellow mineral that is strongly anisotropic in reflected light. The mineral gives a good microchemical test for copper.

In order to test for rarer elements in the ores, samples of various concentrates were analyzed spectroscopically, with the results shown in table 1. Of particular interest is the high indium content of the concentrates and the fact that beryllium was detected in all samples. Beryllium-bearing minerals have been reported from tactites associated with granite intrusives at Iron Mountain, N. Mex., and other places; Mertie and Coats found beryllium in several minerals from Lost River, particularly in idocrase (Coats, written communication, 1957), and work in progress by the writer has shown that potentially economic beryllium deposits occur near the mine. Borovich and Gotman (1939) showed that cassiterite from cassiterite-sulfide mineral deposits is consistently high in indium. Selected specimens of the brilliant-black ferroan sphalerite contain as much as 1.0 percent cadmium, 0.1–0.5 percent indium and tin, and 11.7 percent iron. Niobium occurs in the range 0.001–0.01, being highest in those samples high in cassiterite. No tantalum was detected in any of the samples.

ORE GENESIS

The genesis of the ores at Lost River was discussed briefly by Knopf (1908b, p. 60–61) and by Steidtmann and Cathcart (1922, p. 122–124).

The mode of occurrence of the ores at Lost River is so similar to that of other cassiterite-sulfide deposits the world over that there can be little doubt that the tin ores are genetically related either to the granite in which they occur in part, or to a deep granite mass. The

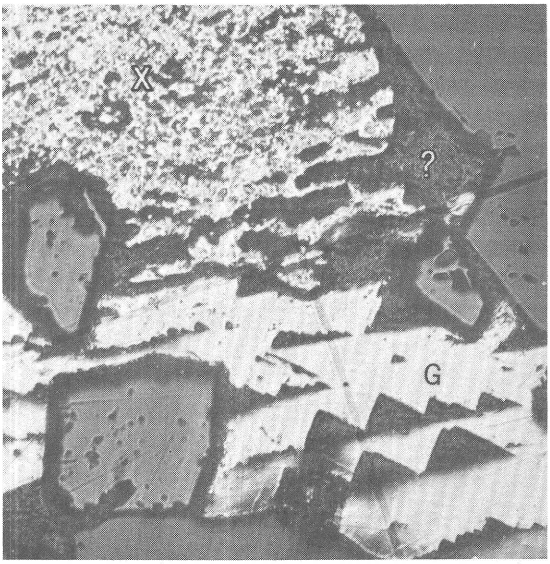

FIGURE 11.—Photomicrograph of polished section of galena-rich granite from the Calcite drift, 365 level, showing galena (G) with cubic cleavage, and unidentified brass-yellow mineral with strong anisotropism (X). Gray areas in unknown mineral are soft sooty-black stannite(?). About × 100.

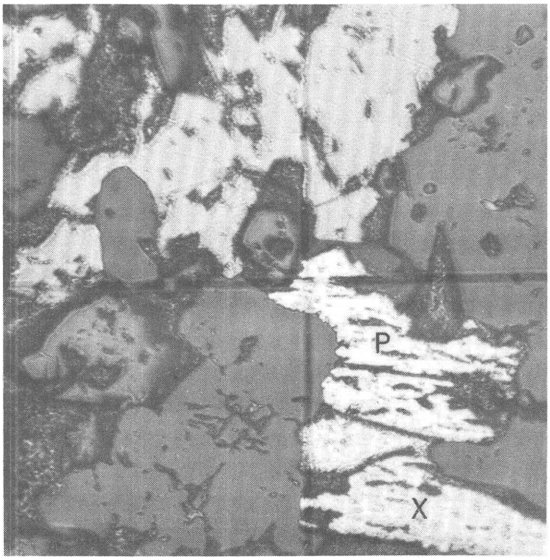

FIGURE 12.—Photomicrograph of polished section of greisen, 32 crosscut south, 365 level, showing pyrite (P) with shredded texture inherited from mica it replaced, and unidentified brass-yellow mineral (X). About × 15.

TABLE 1.—*Semiquantitative spectrographic analysis of ore and concentrates, Lost River mine, Alaska*

[Analyst: Joseph Haffty]

Content range (percent)	Field sample					
	55-ASn-72	55-ASn-73	55-ASn-74	55-ASn-75	55-ASn-76	55-ASn-77
>10	Pb	Sn	Sn	Fe	Sn	Sn
5–10					Al	
1–5	As, Al, Ca, Fe, Mg, Si, Sn	Al, Fe, Si, W	As, Fe, W	As	As, Fe, Si, W	Al, Fe, Mg, Si
0.5–1				Al, Sn, W	Ca	W
0.1–0.5	Cu, Ti, W, Zn	As, Bi, Ca, Mg	Al, Cd, Cu, Pb, Si	Cu, Si, Zn	Mg	
0.05–0.01	B, Bi	Cu, Mn, Pb, Zn	Bi, Mg, Mn	Mg	Bi, Cu, Mn, Zn	
0.01–0.05	Ag, Co, In, Mn	B, In	In, Zn	B, Bi, Ce, Mn, Pb	B, In, Pb, Ti	As, Cu, In, Pb, Zn
0.005–0.01	Ga, V	Ga, Nb, Ti	B, Ga, Ti	In	Ga, Nb, Sr, V	B, Ga, Mn, Ti
0.001–0.005	Ba, Be, Cd, Cr, Mo, Ni, Nb, Sc, Sr, Y, Zr	Ag, Ba, Be, Mo, Ni, Sc, Sr, V, Zr	Ag, Ba, Mo, Nb, Ni, Sc, Sr, V, Zr	Ag, Ba, Mo, Nb, Ni, Sr, Ti, V, Zr	Ba, Be, Cr, Mo, Ni, Sc, Zr	Ba, Mo, Nb, Ni, Sc, V, Zr
0.0005–0.001		Cr	Cr	Be, Cr	Ag	Cr
0.0001–0.0005			Be			Be
0.00005–0.00001						
0.00001–0.00005						Ag

55-ASn-72. 5-foot sample from granite contact, calcite drift.
73. Concentrate from feeder to concentrate box in mill.
74. Concentrate from laboratory-size pebble mill.
75. Sulfides from flotation of mill concentrates.
76. Mill concentrates after flotation.
77. Concentrate from rich cassiterite veinlet in 156 E. raise.

introduction of the earliest ore minerals probably began with the greisenization of the intrusive rocks and the conversion of limestone to marble and tactite; deposition of tin and tungsten minerals in veinlets, along with base-metal sulfides, continued and subsequently the greisen and limestone were extensively kaolinized. No attempt has been made to establish a detailed paragenetic sequence among the myriad ore and gangue minerals at the mine; only a general sequence of the main ore and gangue minerals is suggested.

Tin and other elements in ferroan sphalerite and wolframite indicate that tin was being deposited during the period of sulfide deposition. A selected specimen of brilliant black ferroan sphalerite from the 195 crosscut west, which was spectrographically analyzed, contained iron in the range 5–10 percent, cadmium and manganese in the range 0.5–1.0 percent, indium and tin in the range 0.1–0.5 percent, and smaller amounts of copper, aluminum, calcium, silicon, gallium, nickel, magnesium, barium, lead, vanadium, silver, and titanium. A chemical analysis of a second fragment showed 11.7 percent iron. A selected specimen of wolframite from the Calcite vein contained tin in the range 1.0–5.0 percent.

The evidence presented indicates that tin, tungsten, and sulfide ore minerals were introduced during one cycle of ore deposition in

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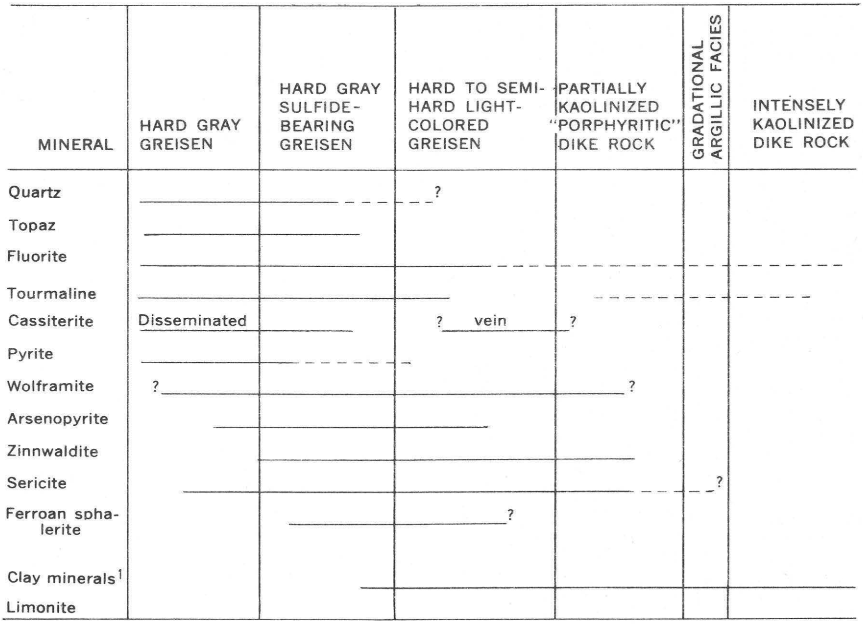
TABLE 2.—*Generalized paragenetic sequence of the major ore and gangue minerals at Lost River mine plotted against related rock types formed by progressive alteration accompanying metallization and postmineral kaolinization*



[1] Chiefly kaolinite and dickite, but also with subordinate montmorillonite and mixed-layered chlorite-montmorillonite, as determined by x-ray studies

which cassiterite in part overlapped the sulfide minerals. The general sequence of the main ore and gangue minerals is shown in table 2, plotted against the rock types that formed successively in the change of greisen to kaolin.

According to the Kullerud (1953) method, a sphalerite containing 11.7 percent iron must have been deposited at a minimum temperature of 600° C., if iron were present in excess. This temperature is within the range reported by Coes (1956) for the synthesis of topaz, a mineral associated with the ferroan sphalerite at Lost River, and is well above the stability ranges of the argillic minerals formed by the postmineral alteration discussed in greater detail on pages 31–48.

The key to the genesis of the ores at Lost River mine is found in the relation of ores to the various rock types produced during the introduction of the ore and gangue minerals. The original rock of the Cassiterite, Ida Bell, and the other light-colored dikes probably was rhyolite porphyry containing abundant orthoclase feldspar, oligoclase feldspar, and quartz, as was noted by Coats (written communication, 1943). The granite of the cupola was similar in composition, but was somewhat coarser in grain. No unaltered dike

FIGURE 13.—Photomicrograph of pyrite in unaltered greisen, 32 crosscut south, 365 level, showing relict texture preserved from replaced mica. Mineral with high relief is topaz. Ordinary light. About ×15.

rock is found within the mine openings, but unaltered or slightly altered granite of the cupola is exposed by the 195 crosscut west and in drill cores from holes that penetrate granite north of the Calcite drift.

The hard gray sulfide-bearing greisen, seen in the Cassiterite dike and in the cupola, particularly in the 32 crosscut south, consists of quartz, topaz, ore minerals, mica, fluorite, calcite, apatite, and clay minerals. The absence of feldspar is diagnostic, and the ubiquitous ore minerals in samples of hard gray rock, whether from the cupola or the Cassiterite dike, show conclusively that some ore minerals were introduced during greisenization. Many of the sulfide minerals replaced mica, although in a few specimens examined replacement began in crushed portions of rock. Some of the sulfide mineral grains retain a shredded texture inherited from the mica they replaced (figs. 13 and 14). Partly replaced mica is very common.

Distinct sulfide veinlets of microscopic size are decidedly uncommon in the Cassiterite dike and in the granite, as compared to disseminated sulfide minerals. In all sulfide-bearing greisen, cassiterite occurs enclosed in quartz, between grains of quartz, or between quartz and topaz. Cassiterite tends to be more common in crushed portions of the rock. Cassiterite and sulfide minerals are generally associated in all thin sections examined under the microscope, and this intimate association is borne out by assays. The age relations among the sulfide minerals in any one slide generally are determinable, but the relative age of the cassiterite cannot be established accurately. The intimate association of cassiterite and sulfide minerals suggests that all were introduced during one continuous cycle of metallization. A few cassiterite-bearing veinlets definitely are later than the early cassiterite-bearing greisen that contains disseminated sulfide minerals, for they cut the greisen. They probably belong to the same general period of ore deposition, however.

Available evidence definitely indicates that some wolframite was introduced later than the cassiterite, for although wolframite is but sparsely distributed in the greisenized granite, it is very common in the crustiform Calcite vein which cuts tactites and kaolinized limestone, and it was found as very large crystals in an arsenopyrite vein within the greisenized granite cut by the Calcite drift. Elsewhere in the mine, wolframite is common in veinlets containing sulfide or carbonate minerals. As pointed out previously, the distribution of tungsten-rich ore in the Cassiterite dike does not coincide with that of the tin-rich ore, again suggesting an age disparity.

The sulfide minerals are disseminated also in the contact tactite, often as large patches between the silicate minerals. In some specimens pyrite appears to have replaced calcite in the tactite.

The general paragenetic sequence of sulfide minerals is arsenopyrite, pyrrhotite (very sparse), pyrite (early stage); then galena, ferroan sphalerite, and chalcopyrite, all at least in part contemporaneous;

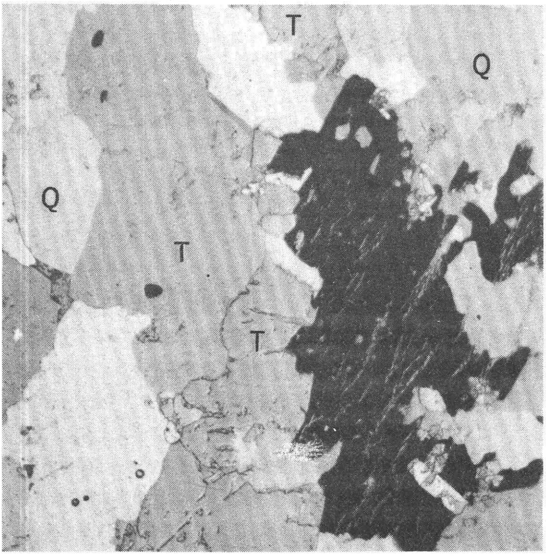


FIGURE 14.—Photomicrograph of pyrite in greisen, Calcite drift, 365 level. Note complete absence of kaolinization and shred texture of pyrite. T, topaz; Q, quartz. Partly crossed nicols. About × 15.

then late pyrite, followed by stannite(?), and a soft silvery sulfide replacing early pyrite. Stibnite was found as minute needles coating pyrite in a vug. In specimens from the dike, a little chalcocite has replaced chalcopyrite. The two generations of pyrite are quite easily distinguished, for the early generation always replaced micaceous minerals and retains a shredded texture inherited from the mica (figs. 12 and 13). The later generation of pyrite occurs as euhedral crystals unrelated to other ore minerals, and in small veinlets cutting other sulfide minerals.

Cassiterite in minute colorless crystals resembling zircon was detected in concentrates of many of the small tin-bearing veins, but most of the cassiterite is deeply colored in shades of brown, red brown, and yellow brown. Samples of mill tailings also were found to contain a fairly large amount of the minute crystals of colorless cassiterite. Small amounts of these crystals were hand picked and viewed spectroscopically without detection of lines other than those due to tin.

The significance of the two types of cassiterite is not known. However, as it was the custom in the mill to cut the concentrate from the tables at the upper edge of the dark cassiterite concentrate, it is possible that part of the colorless cassiterite was lost; this loss would explain the high percentage of tin in the tailings.

POSTMINERAL ALTERATION

RHYOLITE PORPHYRY AND GRANITE

Widespread and intense argillic alteration followed the greisenization and the introduction of the ore minerals. This alteration was so complete in places that the greisen was converted almost entirely to clay minerals, and the early iron sulfides were almost completely removed. The alteration obliterated earlier veins, textures, and many minerals, and greatly complicates recognition of earlier events. It was not until the mine was developed to its present stage that exposures were sufficient to show the true relation between the alteration and the earlier greisenization and introduction of ore minerals, although Coats (written communication, 1943) recognized the sequence of greisenization, ore mineralization and dickite-chloritic alteration in the dike. Clay alteration was mapped in detail by the writer and by Houston, and samples collected by them were studied in the laboratory. However, the samples collected and identified were but a small part of what would be required for a comprehensive discussion of the various phases of the alteration. Many problems concerning the alteration remain unanswered, but the major relations are clearly indicated by the work done to date (Sainsbury, 1960).

The clay minerals were separated and identified by John C. Hathaway and Carol J. Parker of the U.S. Geological Survey; a few addi-

TABLE 3.—*Clay and other minerals present in altered rocks, in parts in 10, Lost River mine, Alaska*

Analysts: J. C. Hathaway, unless otherwise indicated; *, C. L. Sainsbury. Mixed layered chlorite-montmorillonite alternates in regular chlorite and montmorillonite layers in 1:1 ratio. Where the particular kaolinite group species could not be determined, the estimate appears between "kaolinite" and "dickite" as "Kaolinitic minerals." Where it could be inferred from the X-ray data, the type of mica is indicated as: a, probably zinnwaldite; b, probably 2-layer monoclinic muscovite; c, probably trioctahedral (zinnwaldite?).

Sample location (pls. 6, 7)	Parent rock	Lab. No.	Field sample	Fraction or composition	Montmorillonite	Mixed layered chlorite-montmorillonite	Kaolinite	Kaolinitic minerals	Dickite	Mica	Other
1	Dike, No. 1 adit	142520	55-ASn-5	Clay	3		4				Unidentified.
				Silt			6				
2	Dike, 195 level	142523	55-ASn-35	Clay		5			4		
				Silt		Tr.			9		
3	Dike, 195 level, west drift	142524	55-ASn-38	Clay		5		3		Tr.	
				Silt		1	4			4, a	Fluorite, 1.
4	do	142528	55-ASn-47	Clay		3	5			Tr.	
				Silt			1			5, a	Fluorite, 3.
5	Dike, 195 level, east	(*)	58-ASn-102	Clay				Dominant			
6	Dike, 365 level	142546	55-ASn-71	Clay		2	4				Chlorite, 3.
				Silt			8			Tr.	Chlorite, tr., dolomite, tr.
7	do	(*)	58-ASn-100	Clay		Some			Dominant		
8	Dike, 195 level	142525	55-ASn-39	Clay		6	2			Tr.	
				Silt		1	1			6, a	Fluorite, 1.
9	Granite, DDH DMEA 5	(*)	58-ASn-114			Tr.	Some			Dominant	
10	Granite, 365 level, Calcite drift	142526	55-ASn-41	Clay		5	1			3b	
				Silt		Tr.	1			8b	
11	Granite, South heading, Calcite drift	(*)	58-ASn-103			Some	Dominant			Some	
12	Granite, DDH DMEA 7	(*)	58-ASn-107			Dominant	Some			Tr.	
13	Granite, 365 level, Cal. drift.	142527	55-ASn-42	Clay		4		5			
				Silt		Tr.	4			5, b	
14	Granite, south heading, Calcite drift.	(*)	58-ASn-104			Minor	Dominant				
15	Granite, 365 level 32 crosscut south.	142536	55-ASn-56	Clay		4	5			Tr.	
				Silt		Tr.	8			1	
16	do	142537	55-ASn-57	Clay		3	5				
				Silt		Tr.	8				
17	Greisenized granite, 365 level, 32 crosscut south.	142538	55-ASn-58	Clay		Tr.	5			Tr.	Quartz, 1; fluorite, 2; galena, tr.
				Silt			3			Tr.	Quartz, 3; fluorite, 3; galena, tr.
18	do	142539	55-ASn-59	Clay		Tr.	8				Quartz, tr; fluorite, tr; galena, tr.
				Silt			6				Quartz, 1; fluorite, 1; galena, 1.

19	do	142540	55-ASn-62	Clay		3	3			Tr	Fluorite, 3.
				Silt		Tr	1		3	2, c	Fluorite, 3; quartz tr.
20	do	142541	55-ASn-63	Clay		5		4			
				Silt		Tr			8	1	Quartz, tr.
21	Granite, 365 level, 32 crosscut south.	142542	55-ASn-64	Clay		4		4		Tr	
				Silt		Tr			8	Tr	
22	Greisenized granite, 365 level, 32 crosscut south.	142543	55-ASn-65	Clay		2			4		Chlorite, 3.
				Silt					8	Tr	Chlorite, tr; dolomite, tr.
23	do	142544	55-ASn-66	Clay	6			3		Tr	
				Silt	2			3		4, c	Quartz, 1.
24	do	142545	55-ASn-69	Clay	5			4		Tr	
				Silt	1			4		4, c	Quartz, 1.
25	Granite, DDH DMEA 3	(*)	58-ASn-105			Some	Some			Dominant	
26	Limestone, 365 level	142521	55-ASn-21	Clay		3		6			Dolomite, tr.
				Silt		1			7	Tr	Dolomite, 2.
27	Limestone or tactite, 365 level, 32 crosscut south.	142522	55-ASn-22	Clay		4			5		Cassiterite, tr.
				Silt		1			7		Fluorite, 1; cassiterite, tr.
28	do	142529	55-ASn-49	Clay		4	2		2		Calcite, 1; dolomite, tr.
				Silt		Tr		3		Tr	Calcite, 4; dolomite, 1; talc, tr.
29	Limestone, DDH DMEA 8.	(*)	58-ASn-112			Dominant	Some			Tr	
30	do	(*)	58-ASn-106			Some		Dominant			
31	Limestone or tactite, 365 level, 32 crosscut south.	142530	55-ASn-50	Clay		3	3				Calcite, 4; dolomite, tr.
				Silt			2			Tr	Calcite, 6; dolomite, tr.
32	do	142531	55-ASn-51	Clay		4	4				Calcite, 2.
				Silt		Tr	1			Tr	Calcite, 5; talc, 2.
33	do	142532	55-ASn-52	Clay		3			5	Tr	Dolomite, tr.
				Silt		Tr			7	Tr	Dolomite, 2.
34	do	142533	55-ASn-53	Clay		2			6		Fluorite, tr.
				Silt					8		Fluorite, 2.
35	do	142534	55-ASn-54	Clay		2			7		
				Silt		Tr			9		
36	do	142535	55-ASn-55	Clay		1			8		Cassiterite, tr.
				Silt		Tr			9		
37	Veinlet in limestone, 195 level.	(*)	55-ASn-30			Dominant		Some			
38	do	(*)	55-ASn-40		Dominant				Some		

tional samples were separated and identified by the writer (table 3). Locations of all samples are shown on plates 6, 7 by a reference number. Hathaway and Parker's report is included here in full; brief notations were added by the writer under the column heading "Parent rock" in table 3:

These samples are altered materials from a wide zone of intensely altered limestone, a granite cupola, and granite dikes, all of which contain some cassiterite and wolframite, and many contain abundant sulfides of Fe, Zn, Pb, Sn, Mo.

PROCEDURE

A portion of each sample was disaggregated by gentle crushing and wet-sieved to remove particles larger than 62 microns in diameter. The material passing the sieve was dispersed in distilled water with sodium tetraphosphate added as a dispersing agent. The silt (2–62 microns) and clay (less than 2 microns) fractions were separated by repeated centrifuging. Excess water was removed using porcelain filter candles, and a portion of the concentrated clay suspension was Ca^{++} saturated by passing the portion through a Ca ion exchange resin column. Oriented aggregates were prepared from this material and the remaining clay allowed to dry at room temperature.

X-ray diffractometer patterns were made for each sample as follows:

Clay fraction

1. Oriented aggregate, untreated
2. Oriented aggregate, ethylene glycol treated
3. Oriented aggregate, heated to 400° C
4. Oriented aggregate, heated to 500° C
5. Randomly oriented powder, untreated.

Silt fraction

6. Randomly oriented powder, untreated.

Additional patterns were made for 13 of the samples after treatment of the clay with hot 6N HCl for one hour.

The minerals present in each sample are tabulated * * * with quantitative estimates given as parts in ten. Inasmuch as these estimates are derived from the intensity of the diffracted lines, and as many factors in addition to quantity of a mineral affect diffraction intensity, these estimates are not intended to give more than a very general indication of the relative amounts of the various minerals present.

The rocks differ mainly in the degree of alteration to clay. The bleached white-to-gray "quartz-porphyry" differs only from the hard gray dike rock in containing more micaceous minerals, abundant sericite and clay minerals, and some fluorite. Pyrite is partly altered to limonite. Progressive alteration produced a rock with relict porphyritic texture which was initially mapped by all geologists, including the author, as "kaolinized feldspar porphyry," but many thin sections of the rock fail to disclose any feldspar minerals. The white clay patches were formed initially by the kaolinization of large euhedral topaz crystals, followed by similar complete replacement of the quartz somewhat later; in most places a few remnants of quartz and topaz remain (fig. 15). Pyrite and pyrrhotite were partially converted to limonite or were entirely removed, but cassiterite was unaffected. With continued alteration, the remaining quartz and topaz were kaolinized or were converted to a mixture of sericite and clay minerals, particularly where the granite was incompletely greisenized and contained feldspar. This alteration produced a soft rock of porphyritic texture, with white clay patches surrounded by a matrix of clay, sericite, fluorite, and minor topaz. The only sulfide minerals that survived in much of this rock were arsenopyrite, generally in the veinlets, and some ferroan sphalerite. Continued alteration converted the remaining clay minerals, which in different samples comprise mixed-layered chlorite-montmorillonite and dickite with some sericite and zinnwaldite, to a soft white clay consisting almost entirely of kaolinite. In this white clay the only dark minerals recognizable in hand specimen are cassiterite and limonite.

The granite was kaolinized in a manner similar to the rhyolite, though with differences in details. Kaolinization is complete in some parts near the contact, and in zones as much as half an inch wide along fractures. Most of the granite is only partly altered to clay, and in the fresher parts, as along the 195 crosscut west, the clay alteration is limited to joints and thin veinlets. In the least altered granite the feldspar is only partly sericitized.

The clay alteration is later than and independent of the introduction of tin and tungsten minerals. Assay data on Houston's map of the

FIGURE 15.—Photomicrograph of kaolinized greisen containing topaz relicts (T) in fine-grained kaolinite (K). Crossed nicols. About × 8.

A-2-E stope (pl. 5) and on the maps of the 365 level (pls. 7, 9) show clearly that, although high assays of tin and tungsten may be obtained from clay areas, equally high assays are obtained from the least kaolinized granite or dike rock. This absence of correlation between clay alteration and tin and tungsten mineral content shows conclusively that argillization followed metallization and was impressed upon rocks previously metallized. Geologic maps and assay data of the No. 1 adit also show complete independence of ore values and argillization, for the dike east of the 365 E. raise is altered almost completely to clay but contains no more tin than greisen in the western part of the adit.

LIMESTONE AND TACTITE

Postmineral alteration of limestone, marble, and tactite to clay was most intense along the Cassiterite dike and locally near the contact of the granite. Some clay alteration followed preexisting veinlets to form clay zones as much as a foot thick and a particular set of veinlets containing clay and carbonate minerals with few ore minerals was formed, but these veins are small and discontinuous.

On the 365 level, the limestone between the Calcite vein and the granite contact in the 32 crosscut south is converted to clay-carbonate rock, and a zone as much as 20 feet thick on each wall of the Cassiterite dike consists almost entirely of clay minerals derived from limestone. Stratified clay seams crossing the bedding, slump features, and disoriented and kaolinized limestone fragments encased in clay indicate that some solution stoping accompanied the kaolinization.

Similar clay alteration is exposed on the east drift of the 195 level. On the eastern end of the No. 3 adit and in the hanging-wall part of the 545 E. raise, the alteration is less intense, but the limestone is soft and contains large vugs and patches of carbonate as much as several feet long, generally purple or gray white. The tin and tungsten content of the kaolinized limestone is low.

FACTORS AFFECTING MINERALOGY OF CLAYS

The mineralogy of the clay seems to have been controlled in large part by the bulk composition of the rock just before clay alteration, but the mineralogy of the clay is more uniform than might be expected when the chemical composition of the original rocks is considered. The mineral assemblages in the argillized rocks show the greatest variation in the amount and type of mica. The periphery of the granite mass, where altered, seems to favor a high percentage of mica, generally muscovite, whereas zinnwaldite is most common in the Cassiterite dike in and above the 195 level. It is unlikely that variations in physical factors such as temperature and pressure could have caused simultaneously and at almost the same place the formation of kaolinite from granite or rhyolite and chlorite-montmorillonite from limestone, dolomite, and tactite. Presumably the chlorite-montmorillonite clay, which contains relatively large amounts of calcium, iron and magnesium, formed from rocks that contained a ready source of calcium, iron, and magnesium ions, or formed in solution that contained such ions.

The percentage distribution of the clay minerals relative to the rocks in which they occur is summarized in table 4. The most notable features brought out by the table are:

1. No single rock type altered consistently to any particular type of clay. For example, the mixed-layered chlorite-montmorillonite formed from limestone, from dike rock that contained a high percentage of zinnwaldite mica, from greisenized granite or dike rock, and probably from tactite. The same is true to some degree for kaolinite and dickite.
2. Montmorillonite is relatively rare; it occurs in only 4 of 38 samples. Where it does occur, it was derived from granite or acid dike rock which, however, may have been greisenized previously.
3. The bulk of the clay in all rocks is kaolinite, or dickite, the silt fraction commonly containing about 45 percent more kaolinite than the clay fraction. Almost all the chlorite-montmorillonite and montmorillonite occurs in the clay-size fraction; this indicates that the kaolinite is well crystallized.
4. No montmorillonite is found in clays derived from limestone. In one of two sampled veinlets which cut marmarized limestone, calcium-montmorillonite and dickite were the principal clay minerals. Dickite is most common in samples from the Cassiterite dike or from areas in and near the granite that contain numerous veinlets (pl. 7).

The tremendous complexity of the distribution of the clay alteration on the lowest level of the mine, as shown in plate 7, illustrates

TABLE 4.—*Distribution of clay minerals in rocks in which they occur, Lost River mine, Alaska*

[Distribution expressed in percentage of relative amounts shown in table 3. Mica and other minerals not calculated]

Clay mineral	All samples		Granite, rhyolite, greisen		Limestone (in part tactite)		Total, clay size plus silt size		
	Clay size	Silt size	Clay size	Silt size	Clay size	Silt size	All types of rock	Granite, rhyolite, greisen	Limestone and tactite
Montmorillonite	7	2.0	12.0	3	0	0.0	4.6	7.0	0.0
Chlorite-montmorillonite	37	3.5	37.0	2	35	4.0	22.0	22.0	22.0
Kaolinite group	56	95.0	53.5	95	63	96.5	73.7	70.1	77.5
Kaolinite	25	35.0	30.5	52	12	5.5	29.0	39.0	9.0
Dickite	20	54.0	6.0	36	43	85.5	10.7	12.6	7.0
Kaolinite or dickite, undifferentiated	11	6.0	17.0	7	8	5.5	34.0	18.5	61.5

the impossibility of attempting to show a zonal distribution of clays outward from any single vein or center of alteration. Diamond-drill holes into the granite below the 365 level demonstrated that within the granite this complexity is three-dimensional (table 8). In a small way, this complexity reflects conditions similar to those shown on a regional scale in the Cornwall district of England (see especially Ussher, Barrow, and MacAlister, 1909, p. 105–118).

GENESIS OF THE CLAY

The general similarity of the clays that formed from diverse rock types, at places widely scattered horizontally and vertically within the mine, indicates that the argillic alteration was almost contemporaneous throughout the altered area. For the following reasons the writer believes that the alteration is hypogene and post-mineral:

1. Supergene oxidation at Lost River is slight even at the surface. Primary sulfide minerals comprising pyrite, pyrrhotite, chalcopyrite, arsenopyrite, galena, and ferroan sphalerite are found in the dike at the upper levels of the mine and in veinlets on the surface of the ground. The York Mountains were glaciated, and since deglaciation the ground probably has been frozen to a depth of several hundred feet. Permafrost persists yet in the upper levels of the mine. In such permafrost areas frost action is the main agent of erosion.
2. The igneous rocks in the Lost River area show no appreciable chemical weathering, even at the surface. The principal dikes can be traced from the mine into areas where they are completely fresh.
3. In the Lost River area, kaolinized rock is spatially associated with areas containing fluorite, topaz, and ore minerals. In such areas, primary sulfide minerals are found at the surface.
4. The lower workings of the mine are at least 200 feet below the normal water table. The Lost River area has been uplifted periodically during the Pleistocene and Recent epochs (Steidtmann and Cathcart, 1922). It is highly unlikely that surface weathering would have penetrated below the water table.
5. The volume of clay increases near the granite.
6. In much of the clay, rounded fragments of slightly altered greisen can be found. This relation is easily explained if it is assumed that kaolinization followed greisenization, but it is difficult to understand how patches of greisen could form at isolated places within essentially homogeneous clay.
7. Many parts of the dike that consist almost entirely of solid clay contain disseminated cassiterite in economic amounts. This relation is easily explained if it is assumed that kaolinization was impressed upon a rock that already contained disseminated

cassiterite, but it is very difficult to explain how disseminated grains of cassiterite could have formed in solid clay. Such masses of homogeneous kaolin containing disseminated cassiterite almost certainly represent altered greisen in which no potassium feldspar remained to produce mica during argillization.

8. At many places in the Cassiterite dike, discrete veinlets can be seen that transect rock in all stages of hardness from unaltered greisen to intensely kaolinized rock. (See fig. 21.) It is difficult to conceive of a mechanism that would form a single vein or fracture that crossed without change such diverse rock types, but the veins are easily explained if kaolinization was impressed upon a rock previously greisenized and veined prior to argillic alteration.
9. Near the granite, veins are quite common that have a center "rib" of hard fluorite with clay as much as several inches thick on the walls. The center rib is traversed with fractures filled with kaolinite. It is difficult to visualize formation of a core of fluorite in a clay vein, but it is easy to visualize kaolinization that followed a previously existing vein to give such a relation. In several such veinlets, small fractures filled with clay leave the vein and cut banded dark rock consisting of dark silicates, tourmaline, fluorite, and pyrrhotite. The clay obviously is later than such rock. The associated sulfide minerals are fresh.

Thin sections and specimens of much of the highly kaolinized dike rock normally contain residuals of topaz in association with minor fluorite and ore minerals, and where greisen is but slightly kaolinized it is seen in thin section that kaolin even in the early stages replaces both quartz and topaz (fig. 16). As kaolin increases, topaz and quartz decrease, and the thin sections indicate that in such rock the kaolin is the product of a reaction between quartz and topaz. Greisen consisting of quartz and topaz could react according to the following equation:

topaz + quartz + water + limestone → kaolinite + fluorite + carbonic acid

$$(Al,F)_2SiO_4 + SiO_2 + H_2O + CaCO_3 \rightarrow Al_2Si_2O_5(OH)_4 + CaF_2 + H_2CO_3$$

The reaction could proceed merely by the addition of water containing calcium carbonate to a mixture of quartz and topaz. In those parts of the dike that were incompletely greisenized, the potassium feldspar remaining furnished sufficient potassium to form sericite and (or) zinnwaldite in appreciable amounts. However, in places the zinnwaldite of the typical zinnwaldite-fluorite-cassiterite veinlets has been kaolinized, which indicates that other factors, such as temperature, also were important in kaolinization.

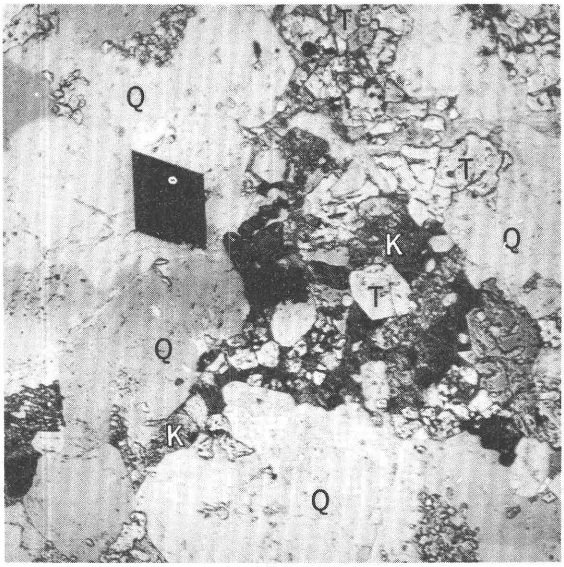


FIGURE 16.—Photomicrograph of the early stage of kaolinization in greisen containing sulfide minerals. Mineral with high relief is topaz (T), with lower relief is quartz (Q). Note fuzzy patches of kaolinite (K) begin to form in fine-grained aggregate of quartz and topaz between large quartz grains. Black areas are sulfides. Note euhedral pyrite or arsenopyrite. Partly crossed nicols. About × 8.

CHEMICAL CHANGES DURING ALTERATION

Thirteen samples of rock that represent fresh granite, greisenized rhyolite and granite, and kaolinized granite and rhyolite, were analyzed chemically. These analyses are reported in table 5. Included in the table is the average of the analyses of the three samples of freshest granite from the 195 crosscut west. Owing to the extreme diversity of minerals present in small amounts in the greisen and the kaolinized greisen, the percentages of which were not determined, the analyses give only an approximate composition expressed in terms of the usual oxides and the most common unusual constituents, which are fluorine and sulfur. Although these complications introduce errors into the analyses, the percentages of the reported constituents are accurate enough to show the general chemical changes involved in producing greisen from granite and kaolinized rock from greisen or partly greisenized granite.

TABLE 5.—*Chemical composition of granite, greisen, and kaolinized granite or greisen, Lost River mine, Alaska*

[Analysts: P. L. D. Elmore, K. E. White, and S. D. Botts; F determined by Lillie Jenkins; all of U.S. Geological Survey]

Laboratory analysis	147066	147067	147068	Average of three analyses of freshest granite, (147066–68)
Field sample	54-ASn-121	54-ASn-122	54-ASn-123	
Reference (fig. 17)				1.
Description and location	Granite from face 195 crosscut west, 365 level.	Granite from center of 195 crosscut west, 365 level.	Granite from caved SE. drift from 195 crosscut west, 365 level.	
Sp gr	2.58	2.58	2.587	2.582
SiO_2	75.40	76.10	75.70	75.73
Al_2O_3	13.80	13.40	13.70	13.63
Fe_2O_3 [1]	.31	.20	.20	.24
FeO	.23	.72	.73	.56
MgO	.23	.19	.16	.19
CaO	.70	.60	.58	.63
Na_2O	3.60	3.30	3.50	3.47
K_2O	4.80	4.60	4.70	4.70
TiO_2	.02	.02	.02	.02
P_2O_5	.00	.00	.00	.00
MnO	.17	.10	.06	.11
H_2O	1.30	1.20	1.00	1.17
CO_2	.06	.07	.08	.07
FeS_2 [2]				
F	.65	.39	.61	.55
Total	101.27	100.89	101.04	101.07
Less $O=F_2$	.27	.16	.26	.23
Corrected total	101.00	100.73	100.78	100.84

Laboratory analysis	147069	147075	147071	147076
Field sample	55-ASn-11	55-ASn-309	55-ASn-60	55-ASn-310
Reference (fig. 17)	4	2	3	5
Description and location.	Greisenized rhyolite from No. 1 adit.	Fresh, partly greisenized granite(?) from DDH 5, 323–328.2 ft, 365 level.	Greisenized granite from 32 crosscut south 365 level.	Greisenized granite from DDH 5, 131.4–135 ft, 365 level.
Sp gr	2.975	2.75	2.92	3.10
SiO_2	65.50	75.00	66.50	59.80
Al_2O_3	18.30	14.00	15.50	16.50
Fe_2O_3 [1]	.00	.50	.00	.00
FeO	2.10	2.10	2.60	4.60
MgO	.18	.40	1.70	.12
CaO	3.40	.39	.28	.30
Na_2O	.05	1.10	.30	.04
K_2O	.69	3.00	.06	.06
TiO_2	.00	.02	.02	.06
P_2O_5	.01	.02	.02	.02
MnO	.16	.46	.12	.11
H_2O	1.40	1.60	2.30	.61
CO_2	.08	.12	.09	1.20
FeS_2 [2]	3.10		6.90	11.30
F	7.92	2.14	3.28	5.26
Total	102.89	100.85	99.67	99.98
Less $O=F_2$	3.30	.90	1.40	2.20
Corrected total	99.59	99.95	98.27	97.78
Unattacked by $HF+H_2SO_4$ [3]	23	5	18	28

See footnotes at end of table.

TABLE 5.—*Chemical composition of granite, greisen, and kaolinized granite or greisen, Lost River mine, Alaska*—Continued

Laboratory analysis	147070	147074	147077	147078
Field sample	55-ASn-66	55-ASn-308	55-ASn-311	55-ASn-312
Reference (fig. 17)	8	10	7	9
Description and location	Partly kaolinized, partly greisenized granite from 32 crosscut south, 365 level.	Kaolinized granite from DDH 4, 105.5–110.6 ft, 365 level.	Kaolinized granite from DDH 1, 150–155 ft, 365 level.	Kaolinized granite from DDH 2, 164–173 ft, 365 level.
Sp gr	2.92	2.17	2.40	2.40
SiO_2	70.60	50.90	71.90	71.00
Al_2O_3	15.80	19.70	14.20	12.80
Fe_2O_3 [1]	.50	1.10	.30	.30
FeO	1.10	.85	1.70	2.60
MgO	1.50	9.30	1.00	2.10
CaO	.74	1.20	.82	.98
Na_2O	.06	.38	.43	.37
K_2O	1.70	.76	4.6	1.10
TiO_2	.01	.02	.02	.02
P_2O_5	.00	.00	.01	.01
MnO	1.40	.16	.49	.34
H_2O	4.20	14.10	3.50	7.20
CO_2	.90	.16	.31	.26
FeS_2	------	------	------	------
F [2]	2.44	1.10	1.94	1.12
Total	100.95	99.73	101.22	100.20
Less $O=F_2$	1.00	.46	.82	.47
Corrected total	99.95	99.27	100.40	99.73
Unattacked by $HF+H_2SO_4$ [3]	------------------	------------------	3	------------------

Laboratory analysis	147073	147072
Field sample	55-ASn-307	55-ASn-313
Reference (fig. 17)	--------------------------	--------------------------
Description and location	Kaolinized granite from DDH 7, 218–223 ft, 365 level.	Kaolinized greisenized rhyolite from 195 level.
Sp gr	2.60	Not determined.
SiO_2	70.80	34.00
Al_2O_3	15.30	31.70
Fe_2O_3 [1]	1.00	.80
FeO	1.60	1.80
MgO	.38	5.70
CaO	.62	10.40
Na_2O	2.30	.04
K_2O	5.90	1.70
TiO_2	.02	.00
P_2O_5	.01	.01
MnO	.24	.36
H_2O	1.60	7.00
CO_2	.08	.06
FeS_2 [2]	------	------
F	1.37	11.70
Total	101.22	105.27
Less $O-F_2$	.58	4.90
Corrected total	100.64	100.37
Unattacked by $HF+H_2SO_4$ [3]	2	20

[1] Obtained by calculation based on the determination of total iron and FeO. May include iron of pyrite except in samples 147069, 147071, and 147076.
[2] Total sulfur calculated to FeS_2.
[3] Residue after treatment of a part of the sample with hot $HF+H_2SO_4$ and subsequent elimination of HF. Optical examination showed the residue to be topaz.

Figure 17 shows the relations of the rocks analyzed by means of a triangular diagram with corners represented by fresh granite, fresh greisen, and complete kaolinization.

The chemical changes involved during greisenization and kaolinization are summarized in figures 18 to 20. Chemical changes are shown in grams per 100 cc of rock, obtained by multiplying the weight percentages shown in table 5 by the specific gravity of the rock.

Workers who earlier studied the tin deposits of Cornwall gave excellent descriptions of the associated clay deposits. A very fine discussion by Ussher, Barrow, and MacAlister (1909) of the origin of the clay in the Saint Austell granite of Cornwall is applicable almost en toto to the kaolinized granite and dike rocks of Lost River, the difference being only in the size of the granite areas involved. The writers concluded that the formation of the clay and the "Cornish stone," which is partly kaolinized granite, is intimately connected with the formation of the tin lodes but that much of the clay contains very little tin, whereas other clay pits expose greisen containing appreciable cassiterite. The exact time relation between the kaolinization and the introduction of the ore minerals was not discussed, but certain paragraphs hinted that kaolinization was considered to be late, although still part of the pneumatolytic action of the granites (Ussher, Barrow, and MacAlister, 1909, p. 106, 115). Later workers

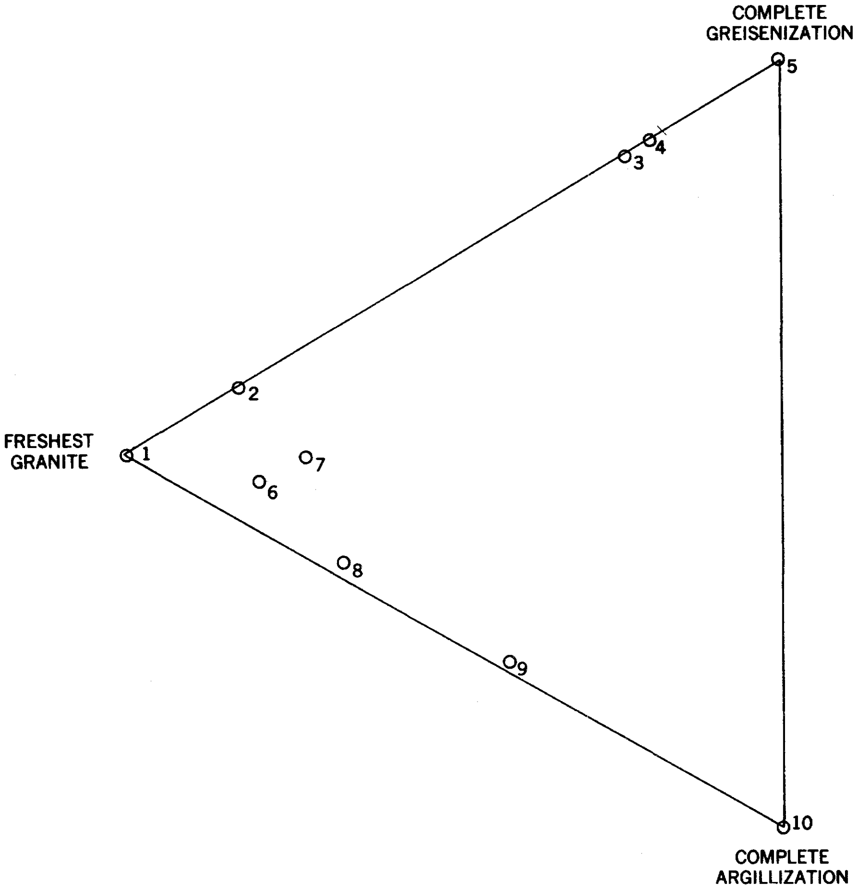


FIGURE 17.—Diagram showing relations of analyzed rocks. For reference numbers, see table 5.

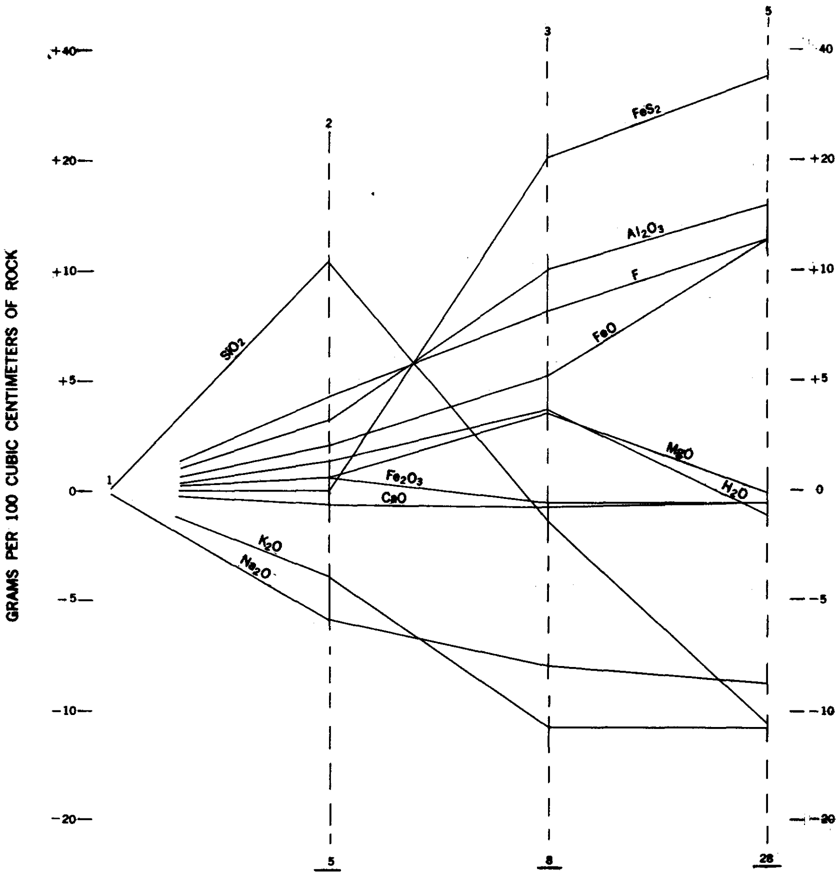


FIGURE 18.—Chemical changes during greisenization. Numbers above lines are sample reference numbers, those below lines represent approximate amount of topaz in rock.

concluded the kaolinization is related to late-stage activity at the very end of the mineralization (Hosking, 1951, p. 34).

The notable scarcity of carbonate in the clay formed from granite and rhyolite and the common occurrence of carbonate in the clay formed from limestone suggest that the fluids that produced the kaolinization were deficient in CO_2 until they entered an area where CO_2 was available in the wall rock. The scarcity of quartz veins observed underground at Lost River mine also is notable, although quartz-cassiterite veinlets are common at the surface in the mine area. If the postulated equation (p. 39) for the formation of kaolinite from greisen is valid, large amounts of carbonic acid would form during the kaolinization, thereby contributing to the maintenance of an acid environment. The reaction would produce fluorite and may explain the late pale-green fluorite that coats vugs of carbonate in the kao-

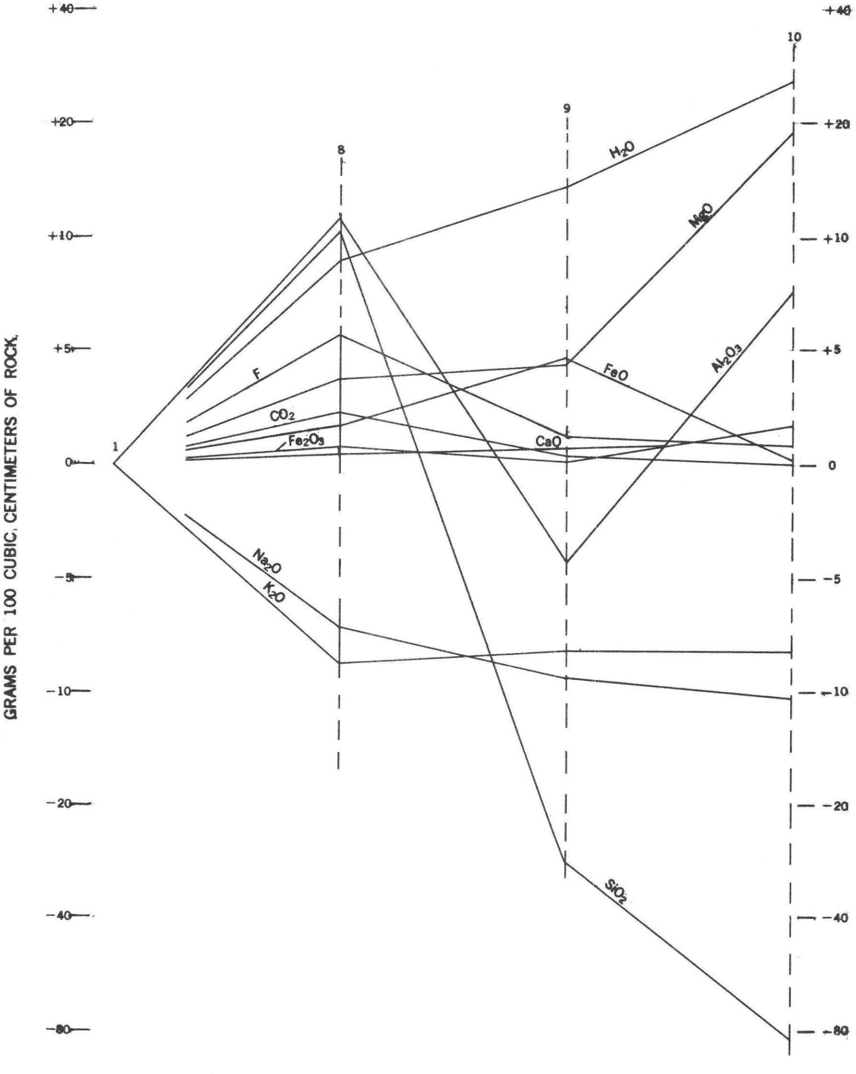


FIGURE 19.—Chemical changes in argillization of ungreisenized granite.

linized limestone and tactite near the granite on the 365 level. Fluorine without doubt was one of the most mobile of the introduced elements, probably from the earliest metasomatism until final kaolinization, for even hairline veinlets in the marmarized limestone are bordered by a zone several inches wide in which fluorite is disseminated, and at places fluorite replaced thin limestone beds for many feet from the veinlets. The scarcity of cassiterite in crystals of megascopic size in much of this fluoritized limestone suggests either that tin did not closely accompany fluorine, or that the introduction of

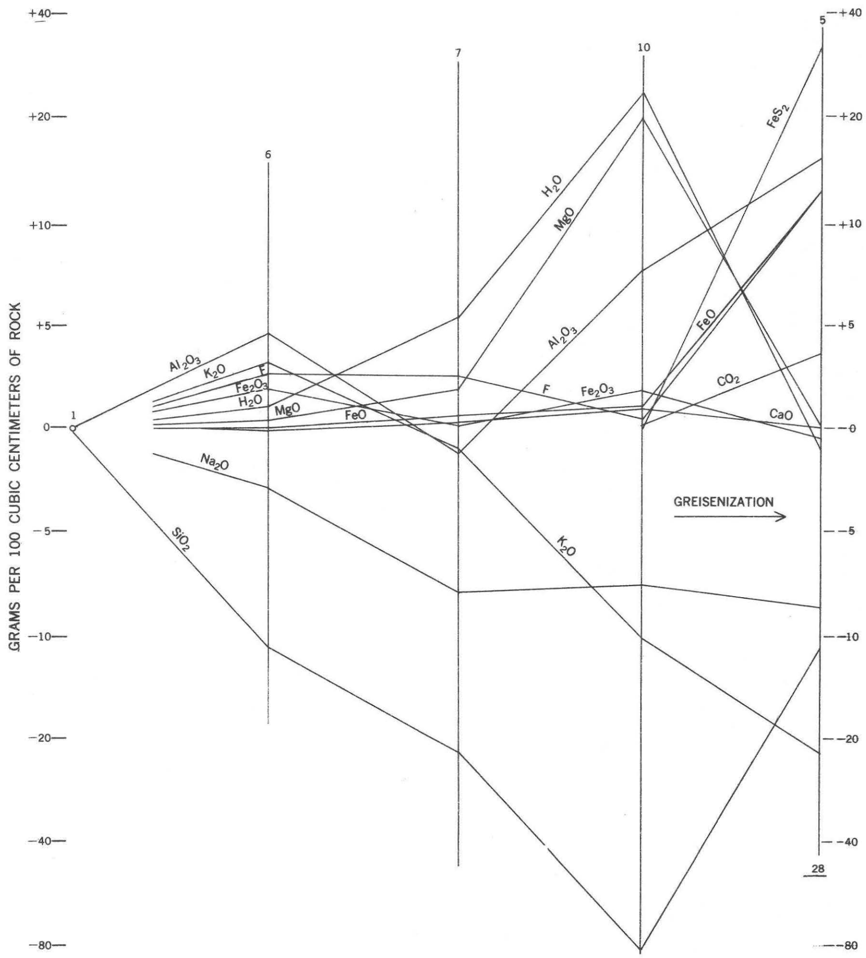


FIGURE 20.—Chemical changes in argillization of partly greisenized granite.

fluorine in part preceded or followed the introduction of tin in these veinlets.

The writer considers the kaolinization at Lost River to be later than the greisen which contains cassiterite and base-metal sulfide minerals, hence, later than the introduction of most of the metallic ores. If this time relation is valid, it offers a logical explanation for the incongruence of the metallized and kaolinized areas of the granite and the rhyolite dikes. Much of the clay derived from greisen will contain cassiterite in commercially valuable amounts, as in the east heading of the No. 1 adit (pls. 4 and 10), but clay derived directly from intrusive rock will contain very little cassiterite, as in many parts of the granite body. The kaolinization followed the formation of some of the veinlets that contain cassiterite, wolframite, and sulfide minerals,

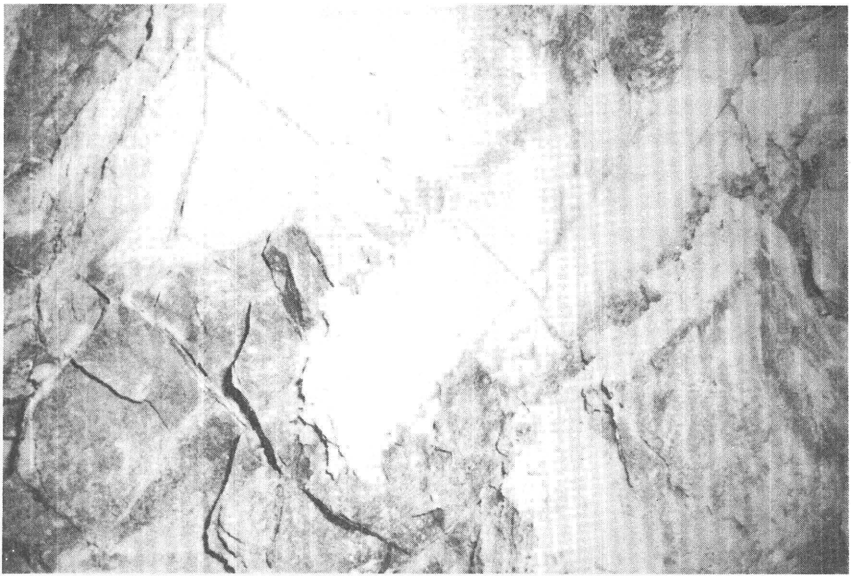


FIGURE 21.—Photograph showing irregular patch of solid white kaolinite in Cassiterite dike near 545 east raise, main adit. Note small veinlets with sharp outline in lower left of photograph. Veins of similar orientation and size but with very diffuse outline are preserved in the solid kaolinite.

for at several places (fig. 21) the sharp outlines of the veinlets are destroyed by the kaolinization, and the mica in some of the veinlets is kaolinized.

ECONOMIC ASPECTS OF CLAY ALTERATION

The kaolinization has important economic aspects, for even moderate kaolinization makes artificial support of openings necessary (Coats, written communication, 1943). Openings in badly kaolinized rock are costly to maintain, especially in the granite, for unless they are lagged solidly the clay swells and squeezes into the drift. Even the track is pushed up by the swelling clay.

Kaolinized dike rock is easier to mill than the hard greisen. Mill capacity falls off and grinding equipment wears rapidly when the mill feed consists of greisen containing topaz. Cassiterite probably slimes badly during grinding of the very abrasive greisen.

On the other hand, much fine cassiterite is coated with clay and lost in tailings when kaolinized dike rock is milled. Microscopic examination of samples of mill tailings showed innumerable grains of cassiterite coated with clay. Some of the cassiterite occurs in minute colorless crystals resembling zircon, and several samples of mill tailings contained a high proportion of these crystals.

The tungsten occurs almost entirely as wolframite and most of the wolframite observed by the writer, especially within those parts of the dike that were badly kaolinized by the intense post-mineral clay alteration, was soft and powdery and could be smeared out between the thumb and finger. This friability suggests that the wolframite would slime badly, and economic recovery might be difficult.

FAULTING AS EXPOSED UNDERGROUND

Faults are not easy to identify in the Lost River mine, because alteration along all fractures has obscured them. Most clay seams that show slickensides probably do not represent faults with appreciable movement and, except for the slickensides, are not distinguishable from others along which no movement has occurred. In the absence of definite proof the mere presence of clay in a fracture should not be considered an indication of faulting.

Only one strong fault, or zone of faulting, has been recognized within the mine; it follows the Cassiterite dike and locally curves through the dike and follows the clay-gouge zone along the walls of the dike. This fault probably was active recurrently. The latest movement on it was postmineral, and locally formed a breccia consisting of rounded nodular fragments of altered dike rock, tactite, fluorite, and hard dike rock encased in finer angular breccia with a clay matrix.

The fault influences mining by producing along one or both walls local gouge zones that usually slough into stopes; moreover, the fault movement ground up parts of the tin-rich dike and diluted them with lower grade contact rock or limestone. It also caused abrupt variations in the thickness of the dike as shown on the geologic maps of the No. 1 adit (pl. 4), the west drift of the 195 level (pl. 6), and the 294 level from the inclined shaft (pl. 7).

The strong fault that follows the Cassiterite dike has not been found in the granite, and this fact raises some questions. The fault is easily recognized on both drifts of the 195 level and in the 294 level from the inclined shaft. At the 294 level the dike is almost faulted out. Shearing is also evident in the dike on the 365 level, although obscured by intense kaolinization in both the dike and wallrock. Neither the dike nor the fault was recognized in the granite along the 195 crosscut west, which was driven to find the fault in the granite and ore indicated by Bureau of Mines drill hole 23. Most of the movement along the fault could be pregranite, and the small displacements necessary to produce the postore breccias might not be recognized in the granite. A zone of slightly richer tin ore in diamond-drill hole D.M.E.A 1 that is in line with the projection of the dike and fault may be coincidental, or it may mark mineralization along the continuation of the fault into the granite. The writer is inclined to the former interpretation.

It is impossible to tell the extent or magnitude of faults along the contact of the granite cupola, for slight movement in the zones of clay alteration at the contact has produced abundant slickensides that superficially resemble large faults. The contact, where exposed in the 32 crosscut south, was mapped by Houston as a fault; where it was later exposed by sloughing and by the 190 raise, it appears to be a normal intrusive contact, although there certainly was a little movement in the zone after the clay alteration.

No major transverse faults cut the Cassiterite dike within the mine. The dike nowhere is offset more than a few inches by cross faults, except at one place in the B-1 stope where a fault offsets the dike about 5 feet (see A, pl. 8). Although the No. 3 adit has been advanced considerably beyond the projected location of faults shown cutting the dike on older surface geologic maps, none of these faults has been recognized underground. The fault shown on the east side of the old Greenstone lode adit and one shown on older maps near the portal of the old No. 3 adit cannot be examined because both areas are caved, but they were not found in the new No. 3 adit.

RESOURCES

Using the same basic data, both the U.S. Geological Survey and the U.S. Bureau of Mines estimated ore reserves for the Lost River mine. These estimates were in general agreement although different in some classifications. In this report, the two estimates have been combined to present an overall interpretation of the resource data. The main divergences in opinion center around the classification of reserves in blocks H and I of table 6. The samples used to compute these reserves are from widely spaced areas compared to those used to compute reserves in other blocks, and would be classed by the writer as inferred ore. Resources are considered to include ore reserves, as well as material potentially significant under favorable conditions.

A cutoff grade of 1 percent tin or 1 percent combined tin and tungstic oxide was used in all calculations. In ore containing less than 1 percent tin, only tungsten-bearing material containing more than 0.2 percent WO_3 was considered

MEASURED AND INDICATED RESERVES

All measured and indicated ore reserves containing at least 1 percent tin or combined tin and WO_3 at Lost River mine are in the Cassiterite dike. The grade of measured and indicated ore was computed by standard methods using weighted samples. Short tons of measured and indicated ore were obtained by determining the volume of the dike within the blocks of reserves, based upon measurement on the geologic maps of the thickness of the dike where fully exposed, and

TABLE 6.—*Measured and indicated reserves*

Block	Short tons	Sn		WO_3	
		Percent	Pounds	Percent	Pounds
Tin ore only					
1	100,000	1.47	2,940,000	0.15	
2	6,500	1.55	201,500	.10	
3	6,000	1.20	144,000	.10	
4	17,000	1.22	414,800	0	
5	11,000	1.12	246,400	.20	
I	60,000	1.06	1,272,000	.20	
Total or average	200,500	1.30	5,200,000	0.125	
Mixed tin-tungsten ore					
A	14,400	0.85	244,800	0.83	239,000
F	20,000	1.16	474,000	.69	276,000
H	71,000	.63	984,600	.53	752,600
Total rounded or average	105,000	0.76	1,600,000	0.60	1,250,000

then dividing this by a tonnage factor of 12 cu ft per short ton. All available sample data indicate that the tin is erratically distributed within the dike but that a computed average of multiple samples from any longitudinal section represents the average value of the dike in the section. Because actual sample widths would give an unrealistically conservative volume, average dike widths and computed assay data from multiple samples were used in determining tonnage.

The measured and indicated ore reserves are tabulated in table 6 and the ore blocks are shown on plate 10.

INFERRED RESERVES

All inferred ore reserves of more than 1 percent combined tin and WO_3 are in the Cassiterite and the Ida Bell dikes. Several geologic factors bear directly upon these inferred ore reserves. The two most important are (a) that the one known ore shoot rakes to the east and probably continues below and beyond the east heading of the 195 level, and (b) that the dike is somewhat altered and fluoritized to the east as far as Tin Creek, a distance of about a mile from the easternmost mine openings. Of secondary importance is the fact that the kaolinization of the dike is postmineral, and the dike potential, therefore, cannot be assessed from soft kaolinized areas on surface exposures. Hard dike rock, if greisenized, may be ore, or may indicate ore at depth. Also to be considered is the fact that the ore shoot extends beyond the area of most intense marmarization of the limestone as exposed on the surface of the ground.

If the ore shoot shown on plate 10 continues from the 195 level to the 365 level at the projected rake, it may contain as much as 80,000 tons of inferred ore that will average about 1.5 percent tin. However, no operation depending upon inferred ore should be undertaken until sufficient exploration is done to verify this tonnage estimate.

Inasmuch as the Cassiterite dike is traceable to the east for at least a mile beyond the mine and is slightly fluoritized in places at altitudes considerably above the highest mine workings, drifting to the east might disclose additional ore shoots comparable in size and tenor to that presently known. If ore shoots are confined to a restricted zone in the dike, the upper limit of which lies 800–1,000 feet vertically above the granite, the area of the dike that can be considered favorable for exploration depends upon the configuration of the underlying granite. For this report, it may be assumed that the dike is metallized to the east beyond the mine openings for an additional distance equal to that in which the dike is now known to be metallized, or 2,100 feet, and it may contain a second ore shoot similar in size and tenor to the known one. The inferred ore in the extension to the east would equal the combined total of ore mined and remaining in the ore zone in the explored part of the dike, and the total known and inferred ore in the dike would equal twice the ore originally in the explored part minus the ore mined, or about 430,000 tons.

The possibility of the occurrence of an ore shoot in the dike to the west of the cupola should not be overlooked. The lack of information concerning that area and the complex dike relations make the existence of an ore shoot there problematical.

POTENTIAL RESOURCES

As defined here, potential resources are resources whose average assay value is less than 1 percent tin or combined tin and tungstic oxide. Under favorable economic conditions or in the event of strategic necessity, these tin-tungsten resources, together with other metal byproducts, might be utilized.

DIKES

Cassiterite dike.—A low-grade section of the Cassiterite dike extends from the intersection of the Cassiterite and the Ida Bell dikes eastward for about 1,500 feet. This section is defined as extending from a point 415 feet vertically below Cassiterite Creek to within 100 feet of the outcrop. The average grade of the dike in all drill holes of the Bureau of Mines in this section is about 0.4 percent tin and about 0.2 percent WO_3. This grade approximates the average grade of the dike exposed underground outside the boundaries of the ore shoot. Assuming that this section of dike averages 12.6 feet in thickness, as indicated in drill holes, the block should contain a maximum of 650,000 tons. Included in this block is a small vein splitting off the Cassiterite dike at trench 36, the average width of which is 4.7 feet, which is projected along a length of 150 feet, and from which three sampled areas gave an average assay value of 3.00 percent tin.

Ida Bell dike.—The Ida Bell dike has been explored by trenches and by four diamond-drill holes from its intersection with the Cassiterite dike to a point about 950 feet east. The average exposed thickness of the dike is 28.5 feet, and the average tin content, excluding trench 8 near the intersection of the dikes, is 0.26 percent tin. At the intersection, the Ida Bell dike is 55 feet thick and contains 1.39 percent tin. In Bureau of Mines drill hole 17, about 483 feet vertically below trench 8, the dike is about 40 feet thick and averages 0.33 percent tin, although a 7-foot section of core from the dike assayed 1.13 percent tin. No assay data are available from an old caved adit and winze on the Ida Bell dike.

The Ida Bell dike is thoroughly kaolinized in places, especially near the intersection with the Cassiterite dike, but petrographic evidence indicates that harder facies of the original dike rock contained only small amounts of topaz, sericite, fluorite, and arsenopyrite. The lack of greisenization in exposures and the low assays indicate that the dike probably is not as strongly mineralized as the Cassiterite dike.

The drill holes and trenches on the Ida Bell dike outline a block of ground roughly 900 feet long, 400 feet deep, and 28.5 feet thick containing about 840,000 tons and averaging 0.26 percent tin and less than 0.1 percent WO_3. Of this block, one section at the Cassiterite-Ida Bell junction (block I) is calculated to contain 60,000 tons of indicated reserves assaying 1.06 percent tin.

CUPOLA AREA

The cupola area overlies the granite cupola intersected on the 365 level and extends from that level to the surface. It includes the following components:

Tungsten lode.—This term is applied to the irregular light-colored dike exposed by the U.S. Tin Corp. in 1953 (fig. 4). The dike was channel-sampled by K. J. Kadow, U.S. Tin Corporation, and J. R. Houston. Samples for 100 feet along the dike have a weighted assay value of 0.54 percent tin and 0.14 percent WO_3 across an average width of 14.1 feet. The dike is traceable about 280 feet, and, assuming the grade of the sampled part is representative of the whole, it could contain about 32,000 tons per hundred feet of depth. However, it should be emphasized that the dike is irregular and is considered merely as a part of the intrusive complex in the cupola area.

Greenstone lode.—Assays from Bureau of Mines trenches across the Greenstone lode show a tin content ranging from an average of 0.12 percent in trench 5 to an average of 0.89 percent in trench 9. The tenor of the lode probably averages less than 0.5 percent tin and less than 0.1 percent WO_3.

Quartz-porphyry lode.—A light-colored dike exposed in Bureau of Mines trench 10 has been named the Quartz-porphyry lode. The dike has not been traced beyond the limits of the trench. Where exposed, it is about 12–14 feet thick and contains 0.56 percent tin. A crosscut (215 crosscut, pl. 5) driven by the U.S. Tin Corporation failed to find the Quartz-porphyry lode at this point.

Other dikes.—Numerous small dikes in the cupola area were intersected in Bureau of Mines drill holes, and a few are exposed on the 365 level of the mine, especially in and near the 125 crosscut (pl. 7). Assays of the dikes in the 125 crosscut show a tin content of as much as 0.6 percent, and assays from a light-colored dike exposed in the 294 level from the old shaft showed a tin content of less than 0.2 percent (pl. 7). None of these dikes is wide enough or contains enough tin to be of interest by itself.

Granite.—An attempt to assess ore potential in the granite involves several complex factors, chiefly the adequacy of sampling, the distribution of greisen in the granite and the reliability of information from diamond-drill holes.

Numerous channel samples were taken of the granite along the 32 crosscut south, and channel and muck samples of the granite were taken in the Calcite drift. Only four channel samples were taken in the 195 crosscut west; these contained less than 0.1 percent tin and less than 0.05 percent WO_3. Samples from drill holes in this general area of ungreisenized granite and samples studied with the petrographic microscope indicate this entire part of the granite is not greisenized and is lower in grade than the granite elsewhere. The granite where sampled in the various workings on the 365 level contains tin in the range from 0.1 to 1.30 percent, the higher assays being obtained from greisenized and veined rock; where veinlets are absent, the granite contains less than 0.3 percent tin.

The grade of the granite computed from channel, muck, and drill core samples is about 0.25 percent tin and less than 0.03 percent WO_3. Although assays are not sufficient to establish the base-metal content, it seems likely that the greisenized granite contains a maximum of 1.0–1.5 percent combined lead and zinc, and some copper. The assay data suggest that the border of the granite may be slightly richer in tin than the interior, but probably not more than 0.1 percent richer. This increase in the border zone is probably related to the small veinlets and should not be extrapolated for any great distance. For example, the contact in the 195 crosscut west contains less than 0.1 percent tin, and diamond-drill hole D.M.E.A. 7 shows no rise in tin content at the west contact, but diamond-drill hole D.M.E.A. 8 shows 0.50 percent tin in a 15-foot section of core from the contact into the granite. Further, as in crosscuts from the top of the 190 raise (pl. 7), the contact area contains 0.34 percent tin over a width of 50 feet, although diamond-drill hole D.M.E.A. 2 shows less than 0.1 percent tin in the granite near the contact. There may be some locally enriched spots, but apparently no significant tonnage of granite contains more than 0.3 percent tin.

The Calcite vein contains in its western part an estimated 1,000 tons of ore containing about 1.25 percent tin and 1.0 percent WO_3. This tonnage is not tabulated separately but is included in the estimates for the cupola area.

Marmarized limestone.—The tin content of the marmarized limestone is estimated from drill-hole data and surface samples. Drill holes in the limestone showed less than 0.30 percent tin for any potentially minable block of ore. On the other hand, Mertie and Coats (written communication, 1941) chip-sampled a section of marmarized limestone along the east bank of Cassiterite Creek from a point almost due west of the portal of the Greenstone adit to a point 360 feet south that assayed 0.41 percent tin and less than 0.03 percent WO_3. This section, however, included some higher grade samples of dike material. From the same beginning point west of the Greenstone adit, another chip sample taken northward for 400 feet assayed 0.14 percent tin and less than 0.03 percent WO_3. All available assay data indicate that the marmarized limestone alone, above the cupola, assays less than 0.30 percent tin.

Evaluation.—The above-mentioned components of the cupola area could not, under any circumstances, be mined separately; therefore, for purposes of this report, they are evaluated as a unit. Based on the weighted average of all available samples, the area is estimated to contain 3 million short tons averaging 0.30 percent tin. Because of the lack of assay and geologic data for large parts of this area, the estimate may be in error by as much as 50 percent.

SUGGESTIONS FOR ADDITIONAL EXPLORATION

Additional exploration at Lost River mine to find ore containing at least 1 percent combined tin and WO_3 should be directed along the Cassiterite dike to the east of existing mine openings. Exploration on the No. 3 adit level would have the advantage of straight haulage without hoisting, but if the tin ore occurs in a zone related to the granite and if the granite slopes down eastward, the No. 3 adit, if extended, might pass above the ore. Exploration eastward on the 195 level would have the twofold advantage of delineating the extent of the known ore shoot on this level and of being near the granite. Exploration to the east on the 365 level would determine the downward extension of the ore shoot and would provide more information on the relation of dike ore to granite.

The possibility of an ore shoot in the Cassiterite dike on the west side of the granite should be tested by additional drill holes or by drifting westward on the 195 level.

Additional exploration of the Ida Bell dike at depth and east of the intersection with the Cassiterite dike might find ore shoots similar to the one in the Cassiterite dike. Exploration of the Ida Bell dike at depth by a crosscut from the No. 2 shaft would have the advantage of providing a site for exploring the underlying granite, should findings in the crosscut warrant it. This exploration should be preceded by surface drilling from east of Cassiterite Creek.

Exploration of the intersection of the Ida Bell and Cassiterite dikes could be done either by extending the 195 or 365 levels westward in the Cassiterite dike or by sinking a shaft from the Randt adit and drifting westward. Either of these projects would have the double advantage of exploring both the westward continuation of the Cassiterite dike and the Cassiterite-Ida Bell junction. Drifting, however, should be preceded by more surface drilling.

Additional exploration within the granite would be warranted only if the objective was the development of large tonnages containing not more than 0.3 percent tin, less than 0.03 percent WO_3, possibly 1.5 percent combined lead and zinc, and lesser amounts of copper. One distinct vein of better grade material has been found in the cupola area (Calcite vein) but the finding of additional veins will be blind exploration. Geologic evidence indicates that if exploration is undertaken it should be directed toward the outer shell of the granite and overlying rocks.

OTHER PROSPECTS

DOLCOATH DIKE

The Dolcoath dike (pl. 1) has been traced for 7,000 feet from the east side of Lost River valley to the westernmost headwater branch of Cassiterite Creek. The dike roughly parallels the Ida Bell dike and is vertical or dips steeply north. Several prospect pits, a shallow shaft, and one adit expose the dike beneath the surface rubble. In these exposures, the dike is seen to consist of admixed light- and dark-colored dike rock or of two or more narrow dikes. The maximum width of the dike in the opencuts is 2.5 feet, although in the adit the dike consists of two dikes 2 and 5 feet thick separated by limestone.

Cassiterite occurs in the Dolcoath dike and in the altered wallrock in close association with abundant arsenopyrite, and lesser danburite, topaz, and fluorite. Available assays of the Dolcoath dike indicate a tin content ranging to as much as 1.15 percent. If a sustained mining operation ever is established at Lost River mine, the Dolcoath dike should be explored further. Diamond-drill holes could probe the dike at depth, for it crops out on a fairly steep hillside.

BESSIE-MAPLE

The Bessie-Maple (commonly known in 1962 as Bessie and Mabel) prospect is on the west side of Lost River valley opposite the mouth of Tin Creek (pl. 1), near two persistent dikes that Mertie (written communication, 1940) mapped as faulted segments of the Ida Bell and Bonton dikes. Prior to 1918, several pits and trenches and two drifts more than 150 feet long had exposed a complex zone at least 1,500 feet long which strikes about N. 70° E. and consists of altered light-colored dikes and of brecciated and veined limestone. South of the prospects, there is an eastward-trending fault contact between thin-bedded limestone and massive gray limestone.

The ore minerals in the metallized dikes and the brecciated limestone include galena, stannite, chalcopyrite, wolframite, stibnite, and sphalerite. The principal gangue minerals are fluorite, topaz, and mica. Many of the dikes exposed are extensively kaolinized.

Various assays of samples from pits, tunnels, and dumps on the Bessie-Maple prospect are tabulated below:

TABLE 7.—*Assays of samples from the Bessie-Maple prospect*

Sample location	Au (oz. per ton)	Ag (oz. per ton)	Percent					
			Pb	Cu	Zn	Sn	WO_3	Sb
Dump, west tunnel, grab [1]	--------	9.6	7.56	1.53	3.00	1.60	0.34	3.82
Dump, west tunnel, grab [2]	0.01	6.8	6.6	.48	2.90	.46	--------	--------
East tunnel [3]	Tr.	19.8	9.1	--------	--------	1.45	3.20	--------
Opencut NW. of east tunnel [3]	Tr.	4.2	.5	--------	--------	.30	.00	--------
Pit 150 ft W. of east tunnel [3]	.03	25.6	4.6	--------	--------	.77	Tr.	--------

[1] Assay by Paul Hwang, U.S. Tin Corp.
[2] Assay by U.S. Bur. Mines, Juneau.
[3] As reported by Steidtmann and Cathcart (1922, p. 80).

Although the samples show a substantial metal content in parts of the metallized zone, the continuity has not been established, and no substantial tonnage of ore should be inferred. If a sustained mining operation is established at Lost River, the Bessie-Maple prospect deserves sufficient trenching to determine the continuity and tenor of the metallized zone.

Potentially economic beryllium ore was found by the writer in 1962 on the south side of the small drainage that heads against the Bessie-Maple prospect, roughly 150 yards from the pits discussed here; this ore will be discussed in separate reports. The finding of the beryllium ore considerably enhances the value of the Bessie-Maple prospect area.

UPPER TIN CREEK

Several small prospects are known near the granite on Tin Creek (pl. 1). None show persistent or large metallized dikes or fissures, and most work in the area was done on fissures containing base-metal sulfide minerals. Four prospects in the limestone lie along the western margin of the granite, the principal ore minerals being galena, cerussite, arsenopyrite, and chalcopyrite, although Steidtmann and Cathcart (1922) described cassiterite in the sulfide ore from one of those prospects. The north margin of the granite contains pyrite and cassiterite in quartz veins or silicified fractures, and one assay made in 1903 showed 0.3 percent tin from an area of greisenized granite on the northeast end of the granite.

During geologic mapping in 1962, the writer and Thomas E. Smith found veins and veinlets of beryllium ore in the limestone on the south and southeast margins of the granite. The beryllium deposits will be described in separate publications.

Purple fluorite was found at several places along the margins of the Cassiterite dike in the area between the head of Tin Creek and the high peak north of the upper end of Camp Creek. Although no cassiterite was identified with the fluorite, the writer attaches some importance to the fluorite, for it indicates that the Cassiterite dike may be metallized throughout its entire length. The alteration of the Cassiterite dike decreases with increasing altitude to the east of Lost River mine, but the possibility exists that exploration at depth might disclose tin ore beneath unaltered dike rock exposed on the surface.

Geologic mapping in 1962 demonstrated that beryllium ore similar to that found on Tin Creek and at the Bessie-Maple prospect exists at several places within the drainage of Camp Creek (pl. 1), and continues eastward to the ridge between Camp Creek and Tin Creek. Additional prospecting may find beryllium ore on the hill northwest of the granite on Tin Creek.

MISCELLANEOUS

Tin or tungsten minerals are found at other scattered places in Lost River valley, but on the basis of available data none appears to merit exploration.

Near the mouth of Tin Creek, on the north bank, fluorite occurs in limestone associated with lepidolite veinlets containing arsenopyrite, cassiterite, and sphalerite.[1] At the old Idaho claim on the edge of the terrace several hundred yards south of the mouth of Tin Creek, fluorite occurs with pyrrhotite and chalcopyrite in an eastward-striking shattered zone in limestone. The percentage of the ore minerals is low.

Cassiterite occurs near the headwaters of Crystal Creek in a dike 10 feet thick composed of fine-grained granite and pegmatite. The cassiterite is in the pegmatitic parts of the dike. The occurrence is of importance only in that it shows cassiterite much closer to the granite of Brooks Mountain than previously known.

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[1] Geologic mapping in 1962 by the writer and Thomas E. Smith, resulted in the discovery of numerous zones of beryllium ore in the area north of the mouth of Tin Creek, and extending westward as far as the Bessie-Maple prospect. The discovery of beryllium ore gives added importance to this entire area.

SPECIAL GEOLOGIC PROBLEMS

WATER SUPPLY

During the operation of the mine from 1952 to 1955 major delays were caused by insufficient water for milling, especially during the winter and early spring. Water was obtained during the winter months from a sump in the valley of Lost River; water was pumped from there to the mill through an insulated pipe along which heat cables were strung. This arrangement was satisfactory until late winter, when the water flow diminished to the stage where the pumps could not maintain suction.

Because water will be difficult to obtain in winter, it is recommended that in future operations the ground-water resources of the mine, which heretofore were neglected entirely, be developed. The flow of mine water decreases in winter and late spring, and new drill holes which at first yield a good flow of water gradually decrease. In summer months the lower levels of the mine are quite wet, and during the last period of inactivation of the mine, water rose in the inclined shaft to about the 195 level, or 170 feet above the 365 level. The flow of water into the mine probably depends largely on channelways in the limestone, and the rate varies during the year because the rate of recharge of ground water varies. In permafrost areas, such as the Seward Peninsula, the ground-water table is charged through thawed channels in the permafrost, which at Lost River probably are restricted to the river valleys. When the water in the creek gravels is frozen, the rate of recharge is slow, and continued pumping gradually lowers the water table around the mine.

If the inclined shaft were mucked out to the bottom, which is at least 50 feet below the 365 level, and if a few diamond-drill holes were fanned out for about 200 feet from the bottom of the shaft, the flow of water probably could be increased substantially. A constant-speed pump in the bottom of the shaft could deliver water from a cone of depression that would have a base diameter of 400 feet and a head of 50 feet or more, and much water probably could be obtained.

PERMAFROST

The permafrost zone at Lost River mine extends at least 200 feet below the surface, as shown by permafrost in the 365 E. raise below the No. 1 adit. The face of the No. 1 adit is in permafrost, as is the entire B–1 stope. The temperature of the ground is sufficiently below freezing in the permafrost zone in No. 1 adit to refreeze the walls in summer after they have been thawed by heat from miners' bodies and from machinery.

Permafrost affects mining in several ways. It increases mining costs by causing water and air lines to freeze up and by causing broken ore in stopes in the permafrost zone to refreeze and hinder drawing of the stopes. Openings in frozen ground do not require much timber, but when circulating warm air thaws the ground, the walls are likely to cave badly.

During mining, the main stopes in permafrost remained open with only slight caving until openings reached the surface and allowed air to circulate. During the summer, warm air in the stopes melted the permafrost and caused uncontrolled ore dilution by caving from the dike walls. In stopes that enter the permafrost zone, warm air circulation should be kept to the minimum necessary to keep broken ore from refreezing.

SAMPLING

The sampling of the stopes should be adequate to orient the breakage of ore. The importance of adequate sampling of this deposit cannot be overemphasized, for adequate samples taken at geologic contacts will enable an operator to control stope dilution and to increase yield by mining tactite along the dike that may contain several percent of tin and by locating stope pillars in lower grade ore.

Sample data from diamond-drill holes must be interpreted with great caution, especially data on sludge samples from holes that penetrate kaolinized limestone or granite. The logs of the D.M.E.A. drill holes (table 8) show extreme variation in sludge amounts and assays with respect to corresponding core samples. No cores were available to the Geological Survey for laboratory studies, hence only the main constituents of the cores, determined at the mine, are reported in the logs.

No attempt has been made to determine what percentage of the tin in assay is represented by stannite. The stannite observed by the writer normally occurs as a sooty coating on arsenopyrite, and it undoubtedly slimed badly in the mill and probably was not recovered. The cleaning of the mill concentrate by flotation before shipment to the smelter probably insures removal of most of the stannite that may have entered the concentrate. However, since any operation at Lost River must be sustained on ore that contains from 1 to 2 percent tin, it would seem desirable in the future to determine the amount of tin in assay that is represented by stannite, which probably is not recovered, and cannot be used in computing recovery rates and amounts, for only the cassiterite will be recovered.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*

[Drill holes 1-3 logged by G. Donald Eberlein, modified slightly by C. L. Sainsbury; drill holes 4-7 logged by Sainsbury; drill hole 8 logged by Sainsbury and A. E. Weissenborn; all of the U.S. Geological Survey. Assay data from U.S. Bureau of Mines]

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
Drill hole 1, 195 crosscut west												
[Location collar, station 314+22 feet; bearing, N. 25° E., −45°; length, 187.0 feet]												
0.0	0.6	95	Marble, white, with epidote and hornblende veinlets	------	------	------	------	------	------	------	------	------
.6	3.5	95	Tactite, dark green, with patches of epidote, idocrase, quartz, and carbonate; coarsely crystalline. Minor garnet, pyroxene(?), and chlorite.									
3.5	5.0	95	Tactite of similar lithology with sparsely disseminated pyrite and chalcopyrite.	------	------	------	------	------	------	------	------	------
5.0	8.5	95+	Tactite, coarsely crystalline locally vuggy, with some clear quartz.	------	------	------	------	------	------	------	------	------
8.5	11.0	95+	Tactite, with clear quartz and pale-lavender fluorite	5.0– 10.0	0.05	0.18	<0.05	------	<0.05	------	------	------
11.0	15.0	95+	Tactite; lighter green color caused by increase of quartz and pale-brown to tan idocrase.	10.0– 19.5	.1	.05	<.05	------	<.05	------	------	------
15.0	17.0	95+	Dike rock, dark kaolinized and chloritized; texture ranges from fine grained equigranular to porphyritic with phenocrysts(?) of nonelastic dark green mica; disseminated pyrite and chalcopyrite.	------	------	------	------	------	------	------	------	------
17.0	18.7	95+	Limestone, marbleized; contains quartz, wolframite, chalcopyrite, subordinate galena, molybdenite, and fluorite. Granite contact at 18.7 ft.	------	------	------	------	------	------	------	------	------
18.7	20.4	95+	Biotite-muscovite granite, fine-grained, kaolinized, with disseminated wolframite, marmatite, and subordinate chalcopyrite.	19.5– 23.8	.2	<.03	<.05	------	<.05	------	------	------
20.4	22.0	95+	Granite, kaolinized with abundant sericite and disseminated sulfides.	------	------	------	------	------	------	------	------	------
22.0	23.0		Granite, kaolinized, with disseminated wolframite and unidentified cinnamon-brown mineral.	------	------	------	------	------	------	------	------	------
23.0	49.0	84	Muscovite granite, highly kaolinized with only local patches of disseminated sulfides; punky; transition from fine- to medium-grained at approximately 26.0 ft.	23.8– 27.5	<.05	<.03	<.05	------	<.05	------	0.11	0.02
				27.5– 33.0	.05	<.03	<.05	------	<.05	------	<.02	<.02
				33.0– 38.0	.05	<.03	<.05	------	<.05	------	<.02	<.02
				38.0– 44.0	.05	<.03	<.05	------	<.05	------	.05	<.02
				44.0– 49.0	.1	<.03	<.05	------	<.05	------	<.02	<.02

49.0	51.5	80	Biotite granite, medium- to fine-grained, with disseminated wolframite(?), galena, chalcopyrite, and pyrite.	--------	--------	--------	--------	--------	--------	--------	--------	--------
51.5	54.0	80	Biotite-granite, fine-grained, with very little or no sulfides	49.0– 54.0	.3	<.03	<.05	--------	<.05	--------	.26	<.02
54.0	55.8	50	Biotite-granite, fine-grained, with abundant sericitic alteration. Sulfides at 55.0 ft.	--------	--------	--------	--------	--------	--------	--------	--------	--------
55.8	58.5	60	Granite kaolinized, sericitized, with quartz phenocrysts, and subordinate muscovite, biotite, and scattered pyrite.	54.0– 59.0	.1	<.03	<.05	--------	<.05	--------	.92	<.02
58.5	61.9	86	Granite, very fine grained, kaolinized	--------	--------	--------	--------	--------	--------	--------	--------	--------
61.9	62.4	86	Quartz-zinnwaldite-cassiterite veinlet	59.1– 64.0	.05	<.03	<.05	--------	<.05	--------	1.71	.02
62.4	63.5	86	Quartz-zinnwaldite-cassiterite zone, coarse-grained	--------	--------	--------	--------	--------	--------	--------	--------	--------
63.5	64.0	86	Muscovite granite, medium-grained, equigranular, kaolinized.	--------	--------	--------	--------	--------	--------	--------	--------	--------
64.0	65.0	88	Muscovite-quartz zone, coarse-grained	64.0– 69.0	.05	<.03	<.05	--------	<.05	--------	.55	<.02
65.0	[1] 82.0	73	Firm, partly kaolinized, medium-grained, white, muscovite granite, with scattered wolframite crystals and locally disseminated pyrite; quartz patches as wide as 10.0 mm.	69.0– 73.0	.2	<.03	<.05	--------	<.05	--------	.39	<.02
				73.0– 79.0	.05	<.03	<.05	--------	<.05	--------	.26	<.02
				79.0– 84.0	.05	<.03	<.05	--------	<.05	--------	.34	<.02
82.0	86.0	68	Muscovite-biotite granite, medium to dark greenish-gray, greisenized; not kaolinized.	84.0– 88.6	.4	<.03	.67	--------	.07	--------	.74	.02
86.0	109.0	95+	Muscovite granite, light to medium gray-green, partly kaolinized, greisenized, with disseminated pyrite, chalcopyrite, galena, and subordinate marmatite. Best sulfide concentration at 86.0–93.6 ft; local kaolin veinlets.	88.6– 93.8	.71	.05	.98	--------	.15	--------	1.00	<.02
				93.8– 99.0	.3	.05	.40	--------	.07	--------	.63	.07
				99.0–104.0	.2	.27	.80	--------	.05	--------	.66	.29
				104.0–109.0	.5	<.03	.83	--------	.05	--------	.37	.04
109.0	111.2	68	Hornblende-muscovite granite, chloritized, with sparsely disseminated pyrite and galena; local thin kaolinite veinlets.	109.0–114.0	.2	<.03	<.05	--------	.05	--------	.17	.03
111.2	171.0	90	Muscovite granite, kaolinized; punky; most breaks down to constituent mineral grains upon handling; local compact zones 139.0–141.0, 156.5–159.0, and 162.7–168.0 ft; limonite stains from oxidation of pyrite.	114.0–119.0	.05	<.03	.20	--------	.05	--------	.20	.08
				119.0–124.5	.05	<.03	.12	--------	<.05	--------	.10	.03
				124.5–130.5	.2	<.03	.06	--------	<.05	--------	.05	<.02
				130.5–137.0	<.05	<.03	.2	--------	.05	--------	.05	<.02
				137.0–141.0	.05	<.03	.09	--------	.05	--------	<.05	<.02
				141 0–146.0	.05	<.03	.09	--------	.05	--------	<.05	<.02
				146.0–150.0	<.05	<.03	.09	--------	.05	--------	<.05	<.02
				150.0–155.0	<.05	<.03	<.05	--------	<.05	--------	<.05	<.02
				155.0–167.0	<.05	<.03	<.05	--------	<.05	--------	<.05	<.02
171.0	187.0	95+	Muscovite granite, relatively fresh, medium-grained, light-gray, silicified(?), with sparsely disseminated pyrite, arsenopyrite, and wolframite(?).	167.0–177.0	.05	<.03	<.05	--------	<.05	--------	<.05	<.02
				177.0–187.0	.05	<.03	.12	--------	.05	--------	<.05	<.02
END.												

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
				Assay interval (feet)	Core					Sludge		
From—	To—				Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
Drill hole 2, 195 crosscut west												
[Location collar, station 314+22 feet; bearing, S. 5° E.—60°; length, 173.0 feet]												
0.0	[2] 21.8	95±	Marble, locally fractured, white to light-gray, with regular ⅛–⅝ in. veinlets and patches containing epidote, chlorite, idocrase, biotite, and garnet, similar in mineralogy to tactite zone in hole 1. Broken zone 12.3–13.4 ft may reflect minor fault. Sparsely disseminated pyrite throughout. Carbonate (mostly calcite) vug at 14.0 ft contains clear crystals of triboluminescent fluorite, but core elsewhere in this interval shows no triboluminescence; core 15.0–21.8 ft contains relatively few chlorite-idocrase veinlets generally less than ¼-in. thick.	0.0– 10.0	0.05	<0.03	<0.02	--------	--------	0.0– 10.0	--------	--------
				10.0– 21.8	.05	<.02	<.02	--------	--------	--------	--------	--------
21.8	26.0	95±	Broken zone of dark-green tactite with sharp upper contact; abundant biotite, epidote, chlorite, and honey-yellow mineral (sphene?); carbonate vugs contain minor fluorite; pyrite, chalcopyrite, galena and arsenopyrite disseminated throughout; entire core moderately calcareous.	21.8– 26.0	.2	<.02	<.02	--------	--------	10.0– 28.0	<0.05	<0.02
26.0	34.5	90±	Lithology same as preceding unit, but rock hard and unbroken; tactite banded, becoming mottled at 30.0 ft. Local carbonate vugs; large biotite crystals at 29.5 ft. Core 14.0–34.5 ft very fine grained, lavender brown; and contains much biotite; resembles chilled contact zone in an igneous rock.	26.0– 34.5	.15	<.02	<.02	--------	--------	28.0– 33.0	.05	<.02
34.5	35.6	95+	Mottled, sheared contact zone between tactite and marble; zone contains fragments of both units; marble fragments highly kaolinized; abundant disseminated molybdenite.	34.5– 37.4	1.0	<.02	.08	--------	--------	33.0– 37.6	.36	.25
35.6	37.4	95+	Banded, light greenish-gray marble, with disseminated pyrite, arsenopyrite and wolframite(?).	--------	--------	--------	--------	--------	--------	--------	--------	--------

37.4	42.6	65	Broken zone of fine-grained dark-green biotite-rich tactite(?); may be dark porphyritic dike; mottled zone 41.6–42.6 ft contains abundant kaolinite patches. Sharp contact at 37.4 ft.	37.4– 42.6	.05	<.02	<.02	--------	--------	37.6– 43.0	.30	<.08
										43.0– 48.0	.12	<.02
42.6	45.0	95+	Thin band of greenish-gray altered marble with abundant large biotite crystals similar to those in overlying zone.	42.6– 45.0	.15	.02	.07	--------	--------	------------	--------	--------
45.0	49.0	80+	Chloritic rock very fine grained, dark-green, with minor disseminated pyrite, arsenopyrite, galena, and chalcopyrite; scattered carbonate in irregular patches as wide as 10.0 mm; 2–4 in. dull lavender mica-rich contact zone at 45.0 and 49.0 ft. local fluorite (may be igneous rock).	45.0– 49.0	<.05	<.02	<.02	--------	--------	48.0– 53.0	.18	<.02
49.0	50.5	95+	Calcareous zone with coarse crystals of calcite, biotite, and chlorite; subordinate disseminated sulfides and fluorite.	49.0– 50.5	.1	.03	.02	--------	--------	------------	--------	--------
50.5	62.5	90	Tactite, fine- to medium-grained, dark green to lavender-brown, with local concentrations of golden-brown mica; veinlets and disseminations of sulfides (chiefly pyrite); abundant chlorite and talc or sericite.	50.5– 62.5	0.5	<.02	<.02	--------	--------	53.0– 58.0	.12	<.02
62.5	65.8	94	Tactite with red-brown garnet, green idocrase, red-brown mica, and radiating dark-green tourmaline.	62.5– 65.8	.1	<.02	<.02	--------	--------	62.5– 68.0	.18	<.02
65.8	76.0	95+	Tactite, banded, fine-grained to coarsely crystalline, dark-green; abundant red-brown mica, chlorite, idocrase, and tourmaline; especially rich in mica at 70.0–72.0 feet; core generally noncalcareous except for local calcite patches; low in disseminated sulfide minerals.	65.8– 76.0	.1	<.02	<.02	--------	--------	68.0– 73.0	.18	<.02
76.0	81.0	90	Altered zone, white to pale green, with abundant kaolinite and talc or sericite. Granite contact at 80 ft.	76.0– 81.0	0.5	<.02	<.02	--------	--------	73.0– 78.0	.07	<.02
81.0	94.0	85	Biotite,muscovite granite, light greenish-gray to buff, kaolinized, greisenized, with disseminated pyrite, chalcopyrite, galena; core somewhat punky, but core recovery good; local tourmaline aggregates; kaolinite veinlets at 81–84.0 ft; pale-green fluorite at 90.0 ft.	------------	--------	--------	--------	--------	--------	------------	--------	--------
94.0	173.0	69	Granite, completely altered, buff to cream-colored sugary; crumbles to individual mineral grains; disseminated sulfides; limonitic staining from oxidation of pyrite; wolframite (?) at 117.5 ft.	94.0–103.4	.05	<.02	<.02	--------	--------	93.4– 98.4	.12	<.02
				103.4–115.0	.05	<.02	<.02	--------	--------	98.4–103.4	.12	<.02
				115.0–125.0	.05	<.02	<.02	--------	--------	108.4–115.0	<.05	<.02
				125.0–135.0	.05	<.02	<.02	--------	--------	115.0–120.0	<.07	<.02
				135.0–145.0	.05	<.02	<.02	--------	--------	120.0–173.0	<.05	<.03
				145.0–154.0	.1	<.02	<.02	--------	--------	------------	--------	--------
				154.0–164.0	.05	<.02	<.02	--------	--------	------------	--------	--------
				164.0–173.0	.05	<.02	<.02	--------	--------	------------	--------	--------
End.												

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Drill hole 3, 195 crosscut west

[Location collar, station 314+22 feet; bearing, vertical; length, 225.5 feet. Engineer in charge of drilling said all sludge assays are doubtful owing to bad caving]

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
0.0	1.0	50	Marble, white	0.0– 5.0	0.66	0.28	------	------	------	------	------	------
1.0	14.5	95	Tactite, massive, dark-green, locally fractured; veinlets filled with calcite; honey-brown idocrase, epidote, chlorite, and amphibole or pyroxene; local disseminated pyrite, arsenopyrite, and other sulfide minerals; scattered fluorite in irregular patches and veinlets as much as one-eighth in. wide; small radiating aggregates of dark-green tourmaline and green mica.	5.0– 10.0	.05	.24	------	------	------	------	------	------
				10.0– 14.5	.05	.17	------	------	------	------	------	------
14.5	28.0	82	Tactite, dull gray-green, and marble, highly fractured and sheared; partly kaolinized; numerous thin calcite veinlets with local mica-rich concentrations; disseminated pyrite, chalcopyrite, and galena; may be gougy.	14.5– 20.0	.1	.02	------	------	------	------	------	------
				20.0– 28.0	.05	.02	------	------	------	------	------	------
28.0	35.5	79	Tactite, red-brown to dark-green, with abundant garnet, chlorite, epidote, and calcite; no sulfide minerals.	28.0– 34.5	.1	.02	------	------	------	------	------	------
				34.5– 39.8	.2	<.02	0.05	------	<0.05	------	0.1	<0.03
35.5	36.8	85	Marble, medium-grained, mottled green, with abundant chlorite and iron sulfides and galena; patches of kaolinite.	------	------	------	------	------	------	------	------	------
36.8	39.2	95+	Tactite, garnetiferous grading into relatively garnet-poor tactite, with local calcite veinlets and disseminated sulfide minerals; radiating tourmaline aggregates at 38.2 ft.	------	------	------	------	------	------	------	------	------
39.2	39.8	83	Probable shear zone; gouge and fragments of tactite.	------	------	------	------	------	------	------	------	------
39.8	46.2	93	Tactite, banded, white to pale-green and dark-green in 1-ft zones; locally coarsely crystalline; pale-green zones contain abundant fluorite, white zones contain abundant sericite and muscovite; interval 42.6–45.0 ft shows abundant sulfide minerals as ⅛–¼-in. veinlets and disseminations; pyrite and galena predominate; interval 45.6–46.2 ft highly kaolinized adjacent to contact. Granite contact at 46.2 ft.	39.8– 46.8	.75	<.02	.98	------	<.05	------	.45	<.03

46.2	52.0	95+	Granite, fine-grained, white to pink, kaolinized, with pale red-brown biotite as only obvious ferromagnesian mineral; no visible mineralization.	46.8– 52.0	.1	<.02	>.05	--------	<.05	--------------	.2	<.03
52.0	59.0	95+	Biotite granite, medium to fine-grained, partly kaolinized, with abundant disseminated pyrite and galena; kaolinized and sheared at 50.0 and 54.0 ft.	52.0– 58.7	.4	<.02	1.5	--------	.06	--------------	.3	<.03
59.0	61.5	70	Granite, becoming coarser in grain and relatively hard (greisenized?); local kaolinization and disseminated sulfide minerals.	58.7– 63.2	.25	<.02	1.2	--------	.06	--------------	.1	<.03
61.5	65.5	70	Biotite granite, dark greenish-gray, greisenized; biotite locally altered to chlorite; little kaolinization; disseminated pyrite and minor hornblende.	63.2– 68.0	.35	<.02	1.6	--------	.08	--------------	.3	<.03
65.5	86.4	95+	Biotite and hornblende decrease and granite becomes light greenish gray; disseminated pyrite and galena (subordinate) to 80.0 ft where their content falls sharply.	68.0– 73.0	.4	.02	1.6	--------	.03	--------------	.35	<.03
				78.2– 83.9	.2	<.02	<.05	--------	<.05	--------------	.4	<.03
86.4	85.5	57	Muscovite-granite, soft, light-gray, kaolinized; no visible cassiterite or sulfide minerals.	--------------	--------	--------	--------	--------	--------	--------------	--------	--------
85.5	92.0	57	Muscovite granite, greenish-gray, partly kaolinized silicified, with disseminated pyrite and galena; relatively unaltered 85.0–86.4 and 87.0–87.6 ft.	83.9– 89.0	.1	<.02	<.05	--------	<.05	--------------	--------	--------
				89.0– 93.5	.05	<.02	<.05	--------	<.05	--------------	--------	--------
92.0	114.4	77	Light-gray, highly kaolinized medium-grained muscovite-biotite granite; no visible sulfide minerals except rare specks of pyrite; abundant sericite and (or) talc.	93.5– 98.2	<.05	<.02	<.05	--------	<.05	--------------	.25	<.03
				98.2–104.8	<.02	<.02	<.05	--------	<.05	--------------	.15	<.03*
				104.8–109.8	<.05	<.02	<.05	--------	<.05	--------------	--------	--------
				109.8–114.4	<.05	<.02	<.05	--------	<.05	--------------	<.05	<.03
114.4	133.0	82	Altered light-gray granite, medium-grained(?); local limonite; few to no sulfide minerals; local sphene; fluorite veinlets as much as ¼ in. wide at 119.2 ft and some quartz and calcite veinlets (127.6, 126.0 ft); honey-yellow grains may be cassiterite(?) or sphene.	114.4–118.9	.05	<.02	<.05	--------	<.05	--------------	<.05	<.03
				118.9–125.0	<.05	<.02	<.05	--------	<.05	--------------	.4	<.03
				125.0–130.1	<.05	.06	<.05	--------	<.05	--------------	.15	<.02
				130.1–134.5	<.05	<.02	<.02	--------	<.02	--------------	.15	<.02
				[4] 138.5–151.6	<.05	.02	<.05	--------	<.05	--------------	--------	--------
133.1	138.2	83	Lithology similar to preceding unit, but core harder------	--------------	--------	--------	--------	--------	--------	--------------	--------	--------
138.2	147.5	72	Crumbly kaolinized muscovite granite, with minor sericite; no visible sulfide minerals except pyrite, which is local.	141.6–150.3	<.05	<.02	<.05	--------	<.05	--------------	.2	<.02
147.5	172.1	66	Muscovite-biotite granite, moderately kaolinized; only locally crumbly; ore stands well; no visible sulfide minerals or cassiterite.	150.3–155.5	<.05	<.02	<.05	--------	<.05	--------------	.35	<.02
				155.5–160.0	<.05	<.02	<.05	--------	<.05	--------------	.1	<.02
				160.0–164.7	<.05	<.02	<.05	--------	<.02	--------------	.25	<.02
				164.7–169.7	<.05	<.02	<.05	--------	<.05	--------------	.75	<.02
				169.7–175.0	<.05	<.02	<.05	--------	<.05	--------------	.30	<.02
				175.0–178.5	<.05	<.02	<.05	--------	<.05	--------------	1.0	<.02
172.1	225.5	95+	Biotite-muscovite granite, relatively hard, partly greisenized; practically no kaolinitic alteration beyond 175.0 ft; locally disseminated pyrite, chalcopyrite, and galena. Limonite in carbonate vein at 207.3 ft.	178.5–183.6	<.05	<.02	<.05	--------	<.05	--------------	1.1	<.02
				183.6–188.7	<.05	<.02	<.05	--------	<.05	--------------	.65	<.02
				188.7–193.8	.1	<.02	<.05	--------	<.05	--------------	<.05	<.02
				193.8–198.0	<.05	<.02	<.05	--------	<.05	--------------	.7	<.02
				198.0–205.4	.05	<.02	<.05	--------	<.05	--------------	1.0	<.02
				205.4–211.0	<.05	<.02	<.05	--------	<.05	--------------	.4	<.02
				211.0–215.5	<.05	<.02	<.05	--------	<.05	--------------	<.05	<.02
				215.5–220.5	<.05	<.02	<.05	--------	<.05	--------------	.80	<.02
				220.5–225.5	<.05	<.02	<.05	--------	<.05	--------------	2.0	.07
End.												

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
			Drill hole 4, 125 crosscut									
			[Location collar, station 308+55 feet; bearing, vertical; length, 174.0 feet]									
0.0	1.6	90+	Marble, pale gray-green, silicated, with abundant gray-green fluorite; local chalcopyrite at 2.5 ft.	-----	-----	-----	-----	-----	-----	-----	-----	-----
1.6	2.2	90+	Highly altered, light-colored bone-gray dike consisting of fluorite, straw-colored mica, and kaolinized feldspars(?); scattered topaz.	-----	-----	-----	-----	-----	-----	-----	-----	-----
2.2	15.6	90+	Marble, pale gray-green, silicated; similar to 0.0–1.6 ft	-----	-----	-----	-----	-----	-----	-----	-----	-----
15.6	16.2	90+	Red-brown dike with amygdules of calcite and chlorite. Pyrite replaces calcite in amygdules locally.	-----	-----	-----	-----	-----	-----	-----	-----	-----
16.2	22.2	99+	Marble, silicated; similar to 0.0–1.6 ft with local color variations white to green to red brown. Crystalline calcite locally abundant; fluorite common.	-----	-----	-----	-----	-----	-----	-----	-----	-----
22.2	34.0	90+	Badly altered mafic dike locally converted to tactite and (or) fluorite. Rock varies from a red-brown amygdaloidal facies similar to 1.6–2.2 ft to rock consisting of calcite, fluorite, and chlorite (or chloritoid?) to rock consisting of garnet set in matrix of fluorite. Local clay alteration at 24.2 ft.	31.5– 35.5	0.15	-----	-----	-----	-----	35.5– 35.5	0.2	0.02
34.0	37.8	90+	Dark brown-to-black altered tourmalinized dike with flakes of biotite.	35.5– 36.1	.10	-----	-----	-----	-----	35.5– 39.8	.1	<.02
37.8	39.8	90+	Tactite, green or pink. Four-inch veinlet of garnet, pink mica, topaz(?), and hornblende at 39.2–39.6 ft; inclined to hole 40°.	36.1– 39.8	.25	-----	-----	-----	-----	39.8– 45.0	.25	<.02
				[5] 31.5– 50.5	.15	<0.02	<0.05	<0.05	0.07			
39.8	40.5	90+	Dark dike rock similar to 34.0–37.8 ft	39.8– 45.0	.15	-----	-----	-----	-----	-----	-----	-----
40.5	66.3	85+	Tactite, gray-green, medium soft, with abundant fine flakes of green mica, local patches pink calcite, and ¼-inch veinlets calcite inclined to hole at all angles; light gray-green fluorite at 51.8 ft. Tourmaline crystals as much as 0.3 in. wide replace calcite locally; "sandy" zone of green fluorite, biotite, and marmatite at 57.2–57.6 ft.	45.0– 48.0	.15	-----	-----	-----	-----	-----	-----	-----
				48.0– 50.5	.30	-----	-----	-----	-----	40.5– 50.5	.15	.08
				50.5– 55.5	.15	<.02	<.05	<.05	.07	50.5– 55.5	.2	.05
				55.5– 57.4	.50	-----	-----	-----	-----	-----	-----	-----
				57.4– 59.2	.05	-----	-----	-----	-----	55.5– 59.2	.25	.02
				59.2– 61.3	.15	-----	-----	-----	-----	59.2– 66.3	.25	.05
				61.3– 66.3	.35	-----	-----	-----	-----	59.2– 66.3	.25	.05

66.3	70.0	85+	Tactite, gray-green, soft, similar to 40.5–66.3 ft, but with abundant clay minerals, often as thin bands that suggest original bedding or clay-filled seams.	66.3– 67.7	.05	--------	--------	--------	--------	66.3– 72.0	.2	.02
				67.7– 72.7	.10	--------	--------	--------	--------	--------	--------	--------
70.0	71.2	90+	Light red-brown tactite zone of garnet, pink mica, and knots of chlorite(?).	72.7– 77.0	.15	--------	--------	--------	--------	72.7– 77.0	.25	.03
71.2	95.0	90+	Tactite, similar to 40.5–66.3 ft with local kaolinized areas. Degree of clay alteration increases rapidly at 93.0 ft, where clay becomes predominant. Calcite at 94.5–95.0 ft.	77.0– 79.2	.15	--------	--------	--------	--------	--------	--------	--------
				79.2– 82.0	.10	--------	--------	--------	--------	--------	--------	--------
				82.0– 87.0	.10	--------	--------	--------	--------	82.0– 87.0	.15	<.02
				[5] 55.5– 87.0	.15	<.02	<.05	<.05	.06	--------	--------	--------
				87.0– 88.7	.05	--------	--------	--------	--------	--------	--------	--------
				88.7– 91.0	.15	--------	--------	--------	--------	87.0– 92.0	.05	<.02
				91.0– 92.0	.15	--------	--------	--------	--------	92.0– 97.0	<.05	.02
				92 0– 97.0	<.05	--------	--------	--------	--------	--------	--------	--------
95.0	99.0	85±	Limestone, almost completely altered to clay, with light apple-green kaolinite; 4 in. white calcite (later than clay alteration?) at 98.6–99.0 ft.	97.0– 99.0	.10	--------	--------	--------	--------	97.0– 99.0	.1	.02
				[5] 87.0– 99.0	.05	<.02	<.05	<.05	<.05	--------	--------	--------
99.0	100.0	<30	Clay, white to gray, with small fragments of greasy lustrous apple-green kaolinite(?). Granite contact at 100 ft.	99.0–105.5	<.05	--------	--------	--------	--------	99.0–105.0	.1	.10
100.0	138.0	85–90	Highly kaolinized, bone white to gray white granite, with enough amber mica to give distinctly resinous reflections. In solid parts, a porphyritic texture is noticeable. Local variations at 104.0–104.8 ft (increase in amber mica, and noticeable pyrite, galena, marmatite, and cassiterite); at 128.0–131.0 ft (almost entirely apple-green kaolinite); at 131.5–131.6 ft (enrichment in cassiterite, tourmaline, and wolframite). Close examination shows no tendency for heavy mineral concentration on periphery of core.	105.5–110.6	<.05	--------	--------	--------	--------	106.8–110.6	.05	.02
				110.6–115.6	<.05	--------	--------	--------	--------	110.6–115.6	.05	<.02
				115.6–120.0	.05	--------	--------	--------	--------	115.6–120.0	.05	<.02
				120.0–125.5	<.05	--------	--------	--------	--------	120.0–125.5	.05	<.02
				99.0–125.5	<.05	<.02	<.05	<.05	.07	--------	--------	--------
				125.5–132.0	<.05	<.02	<.05	<.05	.07	125.5–132.0	<.05	<.02
				132.0–138.0	<.05	--------	--------	--------	--------	132.0–138.0	<.05	<.02
138.0	174.0	85–90	Highly kaolinized, bone-white granite, similar to 100–138.0 ft, but containing at least 10 percent rounded clear quartz grains and noticeable sericite. No distinct lithologic variations.	138.0–143.5	<.05	--------	--------	--------	--------	138.0–143.5	<.05	<.02
				143.5–147.5	<.05	--------	--------	--------	--------	143.5–174.0	<.05	<.02
				147.5–152.5	<.05	--------	--------	--------	--------			
				152.5–157.5	.05	--------	--------	--------	--------	--------	--------	--------
				157.5–162.5	<.05	--------	--------	--------	--------	--------	--------	--------
				162.5–167.5	<.05	--------	--------	--------	--------	--------	--------	--------
				[5] 132.0–167.5	<.05	<.02	<.05	<.05	.07	--------	--------	--------
				167.5–172.5	.15	<.02	<.05	<.05	.12	--------	--------	--------
End.				172.5–174.0	.05	<.02	<.05	<.05	.09	--------	--------	--------

Drill hole 5, face of Calcite drift

[Location collar, face −10 feet, north wall; bearing, N. 25° E.; −35°; length: 328.0 feet]

0.0	7.8	--------	Core missing	0.0– 9.3	0.2	<0.02	0.46	--------	<0.05	--------	--------	--------
7.8	18.1	95+	Granite, quartz-rich, white-to-gray, medium-hard, with fine specks of biotite; kaolinized topaz crystals resembling feldspars, scattered specks of black marmatite, pyrite, and galena; few small specks of wolframite. Some kaolinite patches may be altered feldspar.	9.3– 14.2	.15	<.02	.76	--------	.14	--------	--------	--------
				14.2– 18.0	.10	--------	--------	--------	--------	--------	--------	--------
				18.0– 19.4	.75	--------	--------	--------	--------	--------	--------	--------

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
				Assay interval (feet)	Core					Sludge		
From—	To—				Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
Drill hole 5, face of Calcite drift—Continued												
18.1	24.3	95+	Same as 7.8–18.1 ft, except galena more abundant (<.02 percent).	19.4–24.3	0.25							
24.3	25.5	95+	Sulfide-rich zone with more than 30 percent sulfide minerals including arsenopyrite, marmatite, and a few tabular crystals of wolframite.	24.3–26.0	.15							
25.5	58.5	95+	Same as 7.8–18.1 ft, with local sulfide-rich patches less than 4 in. at 26 and at 34 ft: at 55.2–55.6 ft, a vuggy zone with incrustations of pyrite and a network of minute pyrite veinlets, enclosing a soft black unidentified mineral (manganese compound?), some chalcopyrite, and stibnite(?) with clear albite(?) intergrown.	26.0–30.0	.35							
				[5] 14.2–30.0	.85	<.02	.63	<.05	.06			
				30.0–35.0	.10						0.2	<0.02
				35.0–40.0	.20						.2	<.02
				40.0–45.0	.10						.1	<.02
				45.0–50.0	.10						.1	<.02
				50.0–55.0	.25						.45	<.02
				[5] 30.0–55.0	.20	<.02	.46	<.05	.04			
				55.0–59.8	.25							
58.5	67.5	95+	Granite, gray, medium-hard; quite similar to 7.8–18.1 ft, but fewer dark specks of marmatite and wolframite; pink mica more common. Transition is abrupt.	59.8–64.9	.15							
67.5	70.5	95+	Granite, similar to 7.8–18.1 ft with sulfide enrichments at 69.2–69.6 ft, preceded by 2 in. of green tourmaline.	64.9–70.2	.15						.25	<.02
70.5	95.4	95+	Granite, similar to 58.5–67.5 ft, but with fewer fine flakes of biotite; noticeable pyrite and some limonite after pyrite.	70.2–75.4	.30						.60	.06
				75.4–80.6	.45						.35	.13
				80.6–85.8	.10						.30	<.02
				85.8–91.2	.15						.25	.04
				91.2–95.3	.10						.1	<.02
				[5] 55.0–95.3	.25	<.02	.59	<.05	.03			
95.4	105.0	95+	Granite, similar to 7.8–18.1 ft, with sulfide-rich pod at 99.4–100 ft containing pyrite veinlets surrounding same black mineral as at 55.2–55.6 ft.	95.3–100.2	.10						.2	<.02
				100.2–105.2	.15						.15	<.02
105.0	140.4	95+	Granite, hard, containing both sulfide-rich and sulfide-poor phases.	105.2–110.4	.10						.1	<.02
				110.4–115.4	.25							
				115.4–120.4	.05						.1	<.02
				120.4–125.4	.15						.2	<.02
				125.4–131.4	.10						.7	<.02

				131.4–134.0	.50	------	------	------	------	----------	------	------
				134.0–139.0	.10	------	------	------	------	----------	.45	<.02
				139.0–144.0	.05	------	------	------	------	----------	.05	<.02
140.4	145.0	95+	Potash-granite, slightly altered, with much quartz; feldspar partly sericitized or kaolinized; very little sulfide; amber-colored mica increases.	144.0–149.1	.15	------	------	------	------	----------	.20	<.02
145.0	149.0	90+	Granite, similar to 7.8–18.1 ft. but less alteration; some feldspar crystals still fresh.	----------	------	------	------	------	------	----------	------	------
149.0	328.0	----------	Granite, hard to somewhat crumbly, with slightly to completely kaolinized feldspar crystals, much quartz, some pink mica (lepidolite or bleached biotite?), and few sulfide minerals. Degree of alteration increases locally but no major changes except at 178.4–179.2 ft. where some 1-in. zones are entirely clay.	149.1–150.4	.05	------	------	------	------	----------	.05	<.02
				150.4–154.0	.10	------	------	------	------	----------	------	------
				154.0–159.0	<.05	------	------	------	------	----------	.05	<.02
				[5] 95.3–159.0	.15	<.02	.61	.37	.06	----------	------	------
				159.0–164.9	.30	------	------	------	------	----------	.35	.10
				164.9–168.0	<.05	------	------	------	------	----------	.1	<.02
				168.0–173.0	<.05	------	------	------	------	----------	.2	<.02
				173.0–178.0	.10	------	------	------	------	----------	.1	<.02
				178.0–185.3	.05	------	------	------	------	----------	.05	<.02
				185.3–190.5	<.05	------	------	------	------	190.5–272.6	<.05	<.02
				190.5–195.6	.10	------	------	------	------	272.6–277.8	.10	<.02
				195.6–200.8	.05	------	------	------	------	277.8–297.1	.05	<.02
				200.8–205.5	.05	------	------	------	------	297.1–302.1	.10	<.02
				205.5–211.0	.05	------	------	------	------	302.1–307.3	.10	<.02
				211.0–216.2	.05	------	------	------	------	307.3–312.5	.05	<.02
				216.2–221.4	<.05	------	------	------	------	312.5–317.7	.10	<.02
				[5] 159.0–221.4	.05	<.02	.09	<.05	<.02	317.7–323.0	.05	<.02
				221.4–226.6	<.05	------	------	------	------	323.0–328.2	.10	.02
				226.6–231.8	<.05	------	------	------	------	----------	------	------
				231.8–237.4	.1	------	------	------	------	----------	------	------
				237.4–273.6	<.05	------	------	------	------	----------	------	------
				273.6–328.2	<.05	------	------	------	------	----------	------	------
End.												

Drill hole 6, face at Calcite drift

[Location collar, face −4 feet; bearing, N. 25° E.; −60°; length, 366.2 feet]

0.0	76.2	95+	Granite, light gray-white, medium-hard, with pyrite, arsenopyrite, marmatite, and galena; much quartz, some white mica, feldspars faintly to slightly kaolinized; limonite stains on fractures. Broken zone 2 in. wide at 23.5 ft with limonite and manganese stains; at 29.2–29.6 ft core is broken and feldspars kaolinized; at 35.3–35.4 ft core is fractured.	0.0– 3.8	0.36	------	------	------	------	----------	------	------
				3.8– 10.0	.12	------	------	------	------	----------	------	------
				10.0– 15.0	.09	------	------	------	------	----------	------	------
				[5] 0.0– 15.0	.25	<0.02	0.73	0.48	0.02	----------	------	------
				15.0– 20.0	.1	------	------	------	------	----------	<0.05	<0.02
				20.0– 25.0	.2	------	------	------	------	----------	.1	<.02
				25.0– 30.1	.05	------	------	------	------	----------	.1	<.02
				30.1– 35.4	.05	------	------	------	------	----------	.05	<.02
				35.4– 40.5	<.05	------	------	------	------	----------	<.05	<.02
				40.5– 45.7	.15	------	------	------	------	----------	.1	<.02
				45.7– 77.1	.05	------	------	------	------	45.7– 50.8	.1	<.02
76.2	77.0	90+	Granite, similar to above, but feldspars entirely kaolinized to bone-white clay.	----------	------	------	------	------	------	----------	------	------

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
			Drill hole 6, face at Calcite drift—Continued									
77.0	82.0	90+	Granite, similar to 0–76.2 ft; broken at 79.1–81.8 ft	77.1– 82.1	0.15	--------	--------	--------	--------	50.8– 66.5	1.05	<0.02
										66.5– 71.7	<.05	<.02
				[5] 15.0– 82.1	.10	<0.02	0.11	0.05	<0.02	71.7– 77.0	.05	<.02
										77.0– 87.3	.2	<.02
										87.3– 92.4	.1	<.02
82.0	86.5	95+	Granite, similar to 0–76.2 ft, but noticeable increase in sulfide minerals, particularly pyrite; contains chalcopyrite, marmatite, and minor wolframite. At 83.8–84.1 ft a green tourmaline zone with cassiterite crystals as much as one-quarter in. is perpendicular to hole. Feldspars badly kaolinized in zone.	------------	--------	--------	--------	--------	--------	------------	--------	--------
86.5	87.3	90+	Postsulfide vitreous quartz vein; small vugs contain quartz crystals.	------------	--------	--------	--------	--------	--------	------------	--------	--------
87.3	111.6	90+	Granite, quite similar to 0–76.2 ft, except less sulfide minerals. Kaolinization varies from slight to faint, and grain size is generally smaller.	87.5–122.4	<.05	<.02	<.05	<.05	<.02	92.4–97.4	.05	<.0
										97.4–117.4	.1	<.02
111.6	126.7	90+	Hole enters a series of small limonite-coated fractures parallel to it. Near veinlets, alteration increases; white mica more abundant, and small specks SnO_2(?) locally visible.	122.4–126.7	.05	<.02	<.05	.43	<.02	117.4–122.4	.05	<.02
										122.4–126.7	.1	<.02
126.7	137.0	95+	Granite, similar to 87.3–111.6 ft	126.7–131.7	<.05	--------	--------	--------	--------	126.7–131.7	.8	.08
				131.7–137.0	<.05	--------	--------	--------	--------	131.7–137.0	.15	.05
137.0	141.8	95+	Granite, slightly kaolinized with notable increase of sulfide minerals similar to 82.0–86.5 ft.	137.0–142.1	.40	--------	--------	--------	--------	------------	.20	<.02
141.8	147.6	95+	Granite, altered with kaolinized feldspars. Kaolinization more pronounced than at 0.0–76.2 ft, but less than at 76.2–77.0 ft.	142.1–147.7	<.05	--------	--------	--------	--------	142.1–153.0	.15	<.02
147.6	156.0	90+	Granite, similar to 137.0–151.8 ft; sulfide minerals may be as much as 7 percent of core except in small zones not over 18 in. long. At 140.1–140.6 ft a zone of green tourmaline, topaz(?), and cassiterite in small crystals; from there to 152.8 quartz increases.	147.7–153.0	.10	--------	--------	--------	--------	------------	--------	--------
				153.0–158.3	.05	--------	--------	--------	--------	------------	--------	--------
				[5] 126.7–158.3	.05	<.02	<.05	.12	<.02	------------	--------	--------
										155.0–158.3	.1	<.02

156.0	303.0	90+	Granite, slightly to medium-altered, similar to 141.8–147.6 ft. Alteration varies slightly, sulfide minerals increase at 165.0–172.0 ft, and core is broken locally, but variations are not considered significant.	-----	-----	-----	-----	-----	-----	158.3–163.6	.05	<.02
				158.3–191.3	<.05	-----	-----	-----	-----	163.6–177.0	.1	<.02
				191.3–196.5	.10	-----	-----	-----	-----	177.0–191.3	<.05	<.02
				196.5–211.8	<.05	-----	-----	-----	-----	191.3–211.6	.05	<.02
				211.6–216.8	.17	-----	-----	-----	-----	211.6–216.8	.15	<.02
				216.8–221.9	.38	-----	-----	-----	-----	216.8–221.2	.3	<.02
				227.0–232.2	<.05	-----	-----	-----	-----	221.2–227.0	.05	<.02
				232.2–237.5	.17	-----	-----	-----	-----	227.0–232.2	.1	<.02
				237.5–250.1	.06	-----	-----	-----	-----	232.2–237.5	.15	.03
				250.1–260.3	<.05	-----	-----	-----	-----	237.5–245.8	.1	.02
				260.3–265.5	.06	-----	-----	-----	-----	245.8–260.3	<.05	<.02
				265.5–292.9	<.05	-----	-----	-----	-----	260.3–265.5	.1	<.02
				292.9–298.0	.09	-----	-----	-----	-----	265.5–292.0	<.05	<.02
				298.0–303.0	.06	-----	-----	-----	-----	292.9–298.0	.3	.06
303.0	306.0	90+	Granite, highly kaolinized, with no sulfide minerals, consists of corroded quartz or topaz grains in mushy clay matrix.	303.0–308.0	.09	-----	-----	-----	-----	298.0–303.0	<.05	<.02
306.0	366.3	-----	Granite, quartz-rich, moderately kaolinized, often with scattered sulfide minerals and sphene(?); bleached pinkish biotite. No zones of marked lithologic or mineralogic changes.	308.0–313.3	.12	-----	-----	-----	-----	303.0–308.0	.05	<.02
				313.3–318.5	.20	-----	-----	-----	-----	308.0–313.3	.1	<.02
										313.3–318.5	.25	.03
				318.5–323.7	.06	-----	-----	-----	-----	318.5–323.7	.05	<.02
				323.7–338.6	<.05	-----	-----	-----	-----	323.7–329.3	<.05	<.02
				328.6–345.2	.06	-----	-----	-----	-----	329.3–338.6	<.05	<.02
				345.2–355.8	<.05	-----	-----	-----	-----	338.6–345.2	.1	<.02
				355.8–366.3	.06	-----	-----	-----	-----	345.2–350.6	.05	<.02
										350.6–355.8	<.05	<.02
				[5] 158.3–366.3	.06	<.02	.08	.12	<.02	355.8–361.0	.05	<.02
End.												

Drill hole 7, face of Calcite drift

[Location collar, face of drift; bearing, S. 83° W., horizontal; length 242 feet]

0.0	51.0	95+	Hard, gray-white, medium-grained quartz-muscovite granite with slightly kaolinized feldspars (or topaz?); sulfides aggregate about 0.1 percent of core and include marmatite, chalcopyrite, pyrite, and arsenopyrite; some wolframite(?). Minor fractures coated with limonite.	0.0–15.0	<0.05	<0.02	<0.05	0.12	<0.02	15.0–25.0	0.1	<0.02
				15.0–20.0	.15	-----	-----	-----	-----	25.0–30.3	.05	<.02
				20.0–25.0	.09	-----	-----	-----	-----	30.3–35.5	.05	<.02
				25.0–30.3	.05	-----	-----	-----	-----	35.5–40.7	<.05	<.02
				30.3–35.5	<.05	-----	-----	-----	-----	40.7–45.9	.05	<.02
				35.5–40.7	<.05	-----	-----	-----	-----			
				40.7–45.9	.05	-----	-----	-----	-----	-----	-----	-----
				45.9–51.0	.18	-----	-----	-----	-----	-----	-----	-----
51.0	58.3	95+	Granite, same type as 0.0-51.0 ft, with noticeable increase in disseminated sulfide minerals and quartz. Fractures inclined to hole at angles of 30–50°.	51.0–58.4	.24	-----	-----	-----	-----	-----	-----	-----
58.3	83.0	95+	Granite, greisenized, harder and darker than preceding unit but with slight decrease in sulfide minerals; fractures intersect hole at angles of 30–70°.	58.4–63.6	.06	-----	-----	-----	-----	-----	-----	-----
				63.6–79.2	<.05	-----	-----	-----	-----	45.9–51.0	.1	.02
				79.2–84.1	.15	-----	-----	-----	-----	51.0–58.4	.15	<.02
				81.4–89.1	.09	-----	-----	-----	-----	58.4–74.0	.1	<.02
83.0	94.1	95+	Granite, similar to 51.0–58.3 ft.	89-1–97.8	.06	-----	-----	-----	-----	74.0–94.2	.1	<.02

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
Drill hole 7, face of Calcite drift—Continued												
94.1	97.5	85–90	Granite, quartz-rich, with abundant limonite stains and few sulfide minerals; cut by ¼-in. limonite veinlet inclined 50° to hole.	-----	-----	-----	-----	-----	-----	-----	-----	-----
97.5	99.0	95+	Granite, sulfide-rich, similar to 51.0–58.3 ft.	97.8–99.2	0.09	-----	-----	-----	-----			
				515.0–99.2	.06	<0.02	0.21	0.38	<0.02	-----	-----	-----
99.0	105.6	95+	Granite, slightly kaolinized, similar to 94.1–97.5 ft.	99.2–111.0	.06	-----	-----	-----	-----	97.8–103.0	0.1	<0.02
105.6	115.5	90+	Granite, midway in sulfide mineral content and kaolinization between 0–51 and 51.0–58.3 ft.	111.0–121.7	<.05	-----	-----	-----	-----	103.0–111.0	.1	<.02
				101.1–121.7	.6	<.2	.1	.32	<.02	111.0–116.5	<.05	<.02
115.5	121.0	85–90	Granite, like preceding unit, but hole penetrates zone of limonite-stained fractures 1⁄16–¼ in. wide trending parallel to it. Fractures contain a few white fluorite crystals.	-----	-----	-----	-----	-----	-----	-----	-----	-----
121.0	132.0	95+	Granite, predominantley sulfide-rich, similar to 51.0–58.3 ft. with small section of sulfide-poor granite at 121.0–122.5 ft.	121.7–127.0	.06	-----	-----	-----	-----	116.5–121.7	.1	<.02
				127.0–130.4	.06	-----	-----	-----	-----	121.7–127.0	.1	<.02
				121.7–130.4	.12	<.02	.09	.67	<.02	127.0–130.4	.15	<.02
										130.4–135.5	.1	<.02
										135.5–146.0	.1	<.02
										146.0–156.0	<.05	<.02
132.0	140.5	95+	Granite, dark-gray, hard, greisenized with abundant flakes of pinkish mica (bleached biotite?); some specks sulfide minerals, principally pyrite.	130.4–146.0	<.05	-----	-----	-----	-----	-----	-----	-----
140.5	160.5	90+	Granite, moderately kaolinized, with veinlets as much as ¼ in. thick of limonite generally trending along hole or at angles of 10–40° to it. At 151 and at 152.5 ft, two quartz-zinnwaldite(?) veinlets with an unidentified hard black mineral intersect hole at 40° and 70°. At 153–154 ft, a veinlet as much as ¼ in. thick containing unknown black mineral (manganese compound?) trends along core.	146.0–151.0	.06	-----	-----	-----	-----	-----	-----	-----
				151.0–161.0	<.05	-----	-----	-----	-----	-----	-----	-----
160.5	161.0	90+	Granite, light-gray to gray; similar to 105.6–115.5 ft.	-----	-----	-----	-----	-----	-----	-----	-----	-----
161.0	162.7	<20	Pronounced core loss in badly kaolinized phase of 160.5–161.0 ft.									
162.7	170.0	90+	Granite, similar to 105.6–115.5 ft; ¼-in. veinlet at 170 ft	161.0–168.0	.06	-----	-----	-----	-----	156.0–168.0	.1	<.02

			containing limonite and unidentified black mineral (manganese compound) inclined about 40° to hole.	168.0–173.0	.35	--	--	--	--	168.0–173.0	.25	<.02
										173.0–178.0	.1	<.02
				[5] 130.4–173.0	.06	<.02	.12	.25	<.02	178.0–188.5	.15	<.02
170.0	178.8	90+	Granite altered containing more than 10 percent tawny to pinkish mica (bleached biotite), very few sulfide minerals, and small specks of unknown black mineral. Kaolinization moderate; no apple-green kaolinite as at contact in hole 4. At 177.6–177.8 ft, unidentified black mineral forms 50 percent of core. At 178.3–178.6 ft, a quartz-zinnwaldite zone. Granite-limestone contact at 178.8 ft.	173.0–178.9	<.05	<.02	<.02	<.05	<0.3	188.5–193.6	.2	<.02
										193.6–198.8	<.05	<.02
										198.9–204.1	.05	<.02
										204.1–209.4	.1	.03
										209.4–214.5	.1	.02
										214.5–218.0	.05	.03
178.8	215.0	90+	Limestone, marbleized, cut by irregular thin veinlets of tourmaline; some green tactite parts as much as 2 in. wide; some fluorite. At contact a small patch of clear fluorite. Note total absence of clay alteration except for 2 in. at 214.3 ft.	178.9–183.3	.17	<.02	<.05	.2	<.03	--	--	--
				183.3–188.5	.09							
				188.5–198.9	<.05	--	--	--	--	218.0–228.6	.05	<.02
				198.9–290.4	.09	--	--	--	--	228.6–234.6	.05	.02
				209.4–218.0	.06	--	--	--	--	234.6–242.0	.05	.03
215.0	218.0	20±	Core loss in fluoritized rock that could be either altered dike rock or limestone.	218.0–223.0	<.05	--	--	--	--	--	--	--
				[5] 183.3–223.0	.06	<.02	.05	.2	<.03	--	--	--
218.0	232.0	65±	Moderately soft to mushy altered dike or apophyses of granite. Contains sooty-black mineral, but no sulfide minerals. This core cannot be differentiated megascopically from core in hole 4 at 100–174 ft. Core loss of 45 percent between 223–228 ft and 231.1–234.6 ft indicates badly crumbled zone of clay.	332.0–228.6	.06	<.02	.05	<.05	<.03	--	--	--
				228.6–234.6	<.05	--	--	--	--	--	--	--
232.0	242.0	50±	Limestone, dark gray-green, marbleized, similar to 178.8–215.0 ft.	234.6–242.0	<.05	--	--	--	--	--	--	--
				[5] 228.6–242.0	<.05	.03	<.05	<.05	<.03	--	--	--
End.												

Drill hole 8, 125 crosscut, face

[Location collar, extreme face, 125 crosscut; bearing, S. 30° W.; −45°; length, 288 feet]

0.0	20.0	85+	Marble, white to slightly greenish, semi-hard, broken by small veinlets and by calcite; contains irregular patches and veinlets of gray-green clay.	--	--	--	--	--	--	12.7–17.0	0.25	<0.02
										17.0–25.0	.15	<.02
										25.0–30.0	.15	<.02
20.0	42.0	90+	Same as 0.0–20 ft, but degree of clay alteration increases so that core is quite soft and clay-rich.	--	--	--	--	--	--	30.0–35.0	.2	<.02
										25.0–39.8	.25	<.02
42.0	47.0	50±	Same as 20.0–42.0 ft, but greater core loss may indicate a very soft or broken zone.	--	--	--	--	--	--	39.8–47.0	.1	<.02
										47.0–65.0	.3	<.02
47.0	54.6	50±	Limestone, clayey, irregularly brecciated; at 47.0–48.2 ft many thin calcite veinlets, inclined to hole about 50°.	--	--	--	--	--	--	65.0–69.6	.15	<.02
54.6	60.0	50±	Limestone, completely kaolinized, consisting almost entirely of clay; very soft at 54.6–56.0 ft.	59.7–65.0	0.06	<0.02	0.06	<0.05	<0.03	69.6–74.0	--	<.02
										74–0–79.2	.15	<.02
60.0	91.0	33±	Limestone, light-gray to white, completely kaolinized	65.0–91.0	<.05	--	--	--	--	79.2–96.5	.1	<.02
										96.5–103.8	.15	.05
91.0	96.5	45±	do	91.0–96.5	.09	--	--	--	--	103.8–127.0	.15	<.02

See footnotes at end of table.

TABLE 8.—*Geologic logs and assay data of D.M.E.A. diamond-drill holes, 365-foot level, Lost River mine, Alaska*—Continued

Footage		Percent core recovery (estimated)	Description of core	Assay data								
					Core					Sludge		
From—	To—			Assay interval (feet)	Sn	WO_3	Pb	Zn	Cu	Assay interval where different from core interval	Sn	WO_3
Drill hole 8, 125 crosscut, face—Continued												
96.5	137.2	75±	Clay, dark-gray, derived from limestone; with 1-in. patch of garnet, topaz, and pink mica at 117.6 ft. Granite contact at 137.2 ±2 ft.	[5] 65.0– 96.5	<0.05	<0.02	<0.05	0.1	<0.03	----------	-------	-------
				96.5– 98.5	.06	<.02	.08	.4	<.03	----------	-------	-------
				98.5–103.5	.32	-------	-------	-------	-------	----------	-------	-------
				103.5–109.2	.24	-------	-------	-------	-------	----------	-------	-------
				109.2–116.0	.06	-------	-------	-------	-------	----------	-------	-------
				116.0–121.5	<.05	-------	-------	-------	-------	----------	-------	-------
				121.5–127.0	<.05	-------	-------	-------	-------	----------	-------	-------
				127.0 130.8	.38	-------	-------		-------	127.0–130.8	0.2	<0.02
				130.8–136.0	.06	-------	-------	-------	-------	130.8–136.0	.15	<.02
137.2	146.8	80±	Granite, sulfide-rich, medium coarse-grained, with euhedral topaz (or feldspar?) completely kaolinized. Sulfide minerals constitute at least 10 percent of rock and include pyrite, chalcopyrite, arsenopyrite, some rutile(?).	136.0–151.2	.73	-------	-------	-------	-------	----------	-------	-------
										136.0–141.2	.15	<.02
				[5] 98.5–141.2	.24	.04	.19	.8	<.03	141.2–146.8	.25	<.02
				141.2–146.8	.70	<.02	2.8	2.5	.09	146.8–152.3	.15	<.02
146.8	152.3	55±	Core size reduced to EX at 153 ft; highly altered and kaolinized fine-grained granite with pyrite and chalcopyrite(?) throughout; local galena and marmatite.	146.8–152.8	.32	<.02	1.2	.7	.03	152-3–158.0	.3	<.02
152.3	190.0	45±	Granite, highly kaolinized, with few harder sections; sulfide minerals decrease noticeably, and grain size increases slightly.	152.3 158.0	.09	<.02	1.5	1.5	<.03	158.0–163.5	.65	.05
										163.5–169.5	.05	.02
										169.5–179.4	.1	<.02
				158.0–163.5	.20	<.02	.13	.2	<.03	179.4–185.0	.15	<.02
				163.5–169.5	<.05	-------	-------	-------	-------	185.0–190.4	.35	.03
				169.5–174.4	<.05	-------	-------	-------	-------	190.4–195.5	.2	.03
				174.4–190.4	.26	-------	-------	-------	-------	195.5–201.0	.3	.04
190.0	230.0	40±	Granite, moderately soft, with noticeable quartz; little to no sulfide minerals; some sericite and chlorite. Feldspars(?) badly kaolinized. Last 1 ft badly broken.	194.5–195.5	.50	-------	-------	-------	-------	201.0–205.8	.1	<.02
				195.5–201.0	<.05	-------	-------	-------	-------	205.8–211.0	.15	.06
				201.0–205.8	.06	-------	-------	-------	-------	211.0–221.7	.1	<.02
				205.8–211.0	<.05	-------	-------	-------	-------	221.7–227.0	.1	.10
				211.0–216.5	<.05	-------	-------	-------	-------	227.0–235.8	.15	.08
				216.5–221.7	<.05	-------	-------	-------	-------	235.8–239.8	.05	.03
				221.7–227.0	<.05	-------	-------	-------	-------	239.8–245.4	.1	.05
				227.0–235.8	.09	-------	-------	-------	-------	245.4–253.5	.2	.11

230.0	273.5	90±	Granite, crumbly, quartz-rich, with feldspars; completely kaolinized; no sulfide minerals; numerous flakes straw-colored mica.	235.8–239.8	<.05	--------	--------	--------	--------	253.5–258.8	.15	.08
				239.8–245.4	.12	--------	--------	--------	--------	258.8–264.1	.15	<.02
										264.1–269.0	.15	.04
				245.4–282.5	<.05	--------	--------	--------	--------	269.0–282.5	.1	<.02
										282.5–288.0	.05	<.02
				[5] 163.5–282.5	.09	.04	<.05	<.05	<.03	------------	--------	--------
273.5	288.0	90±	Quartz-biotite granite, medium hard; little to no sulfide minerals.	282.5–288.0	<.05	<.02	.05	.05	<.03	------------	--------	--------
End.												

[1] Considerable influx of water at 73.0 feet; flow gradually increased during drilling from 73.0 to 85.0 feet.
[2] Error in measurement of core during drilling through interval 0.0 feet to 20.8 feet in amount of 1.7 feet.
[3] Sludge sample does not correspond exactly with core sample.
[4] Includes 2 core samples.
[5] Composite.

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