Tofty Tin Belt Manley Hot Springs District, Alaska

By RUSSELL G. WAYLAND

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Occurrence and exploitation of cassiterite-bearing gold placer deposits

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TOFTY TIN BELT, MANLEY HOT SPRINGS DISTRICT, ALASKA

By Russell G. Wayland

ABSTRACT

Buried placer deposits in a belt about 8 miles long by 1 mile wide at Tofty, near Manley Hot Springs, Alaska, have yielded a few hundred tons of cassiterite as a byproduct to the recovery of several million dollars in placer gold.

The placer deposits are at the base of unconsolidated gravels of early Quaternary age lying on an erosion surface of moderate relief cut on phyllite of Cretaceous age. The gravels are buried beneath 10 to 170 feet of frozen muck and silt of Quaternary age. The closest known outcrops of igneous rocks are a few small serpentinized mafic dikes about a mile north of the belt of placer deposits, some monzonite masses about 4 miles north of the easternmost placer, and a biotite granite body about 6 miles southeast of the tin belt. Known lode mineralization exposed near the tin belt consists chiefly of small, discontinuous quartz veins containing a few accessory minerals.

The Quaternary gravels consist largely of graywacke, phyllite, sandstone, light and dark quartzite, and quartz pebbles derived locally from the Cretaceous bedrock. The basal gravels which contain placer gold and cassiterite are well rounded and have more pebbles of quartz and light quartzite; they also contain a few cobbles and pebbles of granite and quartz-tourmaline rock. Many pebbles containing brown tourmaline also contain cassiterite; conversely, nearly all cassiterite pebbles also contain brown tourmaline, as well as quartz and altered fragments of country rock. A suite of pebbles grading from predominantly cassiterite to mostly brown tourmaline is brecciated throughout. Chromite is common in gravel from the Deep Creek part of the tin belt.

Many individual placer concentrations are related to details of the drainage system cut on the bedrock surface, particularly to minor gullies and terrace slopes. Nearly all cassiterite particles and most gold particles are well rounded and polished.

Although a major Tertiary stream may have brought cassiterite-bearing gravels and some gold into the tin belt from the Hot Springs Dome area or from some unexposed granite body nearer the tin belt, the writer considers it much more likely that the placer gravels were derived from unexposed quartz veins immediately north of the tin belt which were brecciated and mineralized with tourmaline and cassiterite during Tertiary intrusive activity. Subsequent prolonged erosion of perhaps several thousands feet of the mineralized bedrock by streams of moderately low gradient resulted in residual deposits with local

concentration. The mantle of Quaternary silt now conceals the roots of these lodes.

The total indicated and inferred reserves of cassiterite remaining in the buried placers of the district are estimated to be about 2,000 tons. Recoverable reserves would be a fraction of this figure, depending on mining and recovery methods and economic conditions. However, cassiterite would probably remain a byproduct to gold recovery.

Sampling of tailings piles by the Geological Survey indicates an additional reserve of about 222 tons of cassiterite, and about $118,000 in gold.

INTRODUCTION

Placer deposits (pl. 42 and fig. 48) at Tofty, near Manley Hot Springs, Alaska, yielded about 315 tons of cassiterite concentrates through 1941 as a byproduct to the recovery of gold worth several

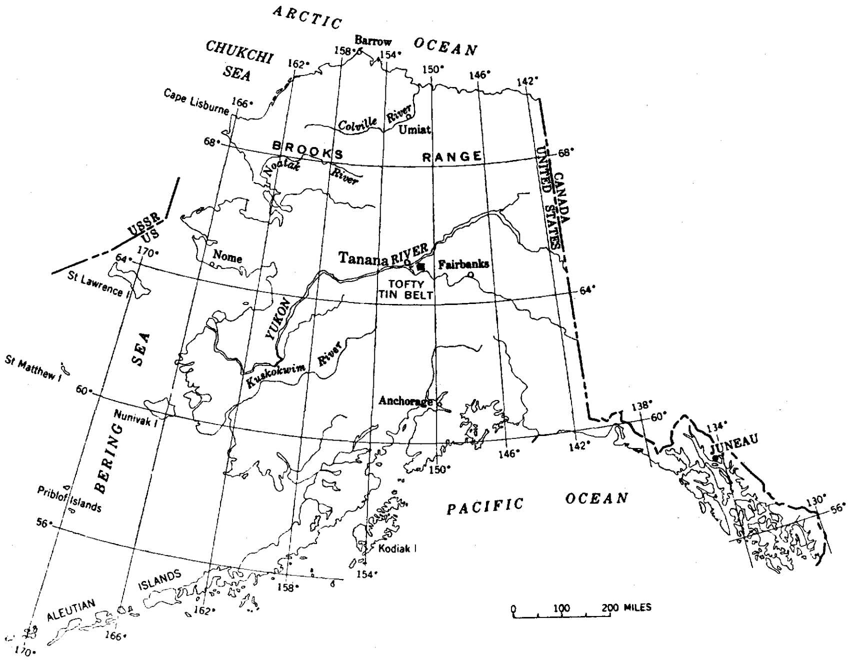

FIGURE 48.—Index map showing location of mapped area.

million dollars. Although gold was discovered in 1907, the first tin shipment was not made until 1911. The most active gold mining and the largest output of tin took place before 1919, by which time 262 tons of cassiterite had been produced. From 1919 through 1941 the most notable mining development in the area was the use of strip-mining methods in two of the shallower pay streaks.

Cassiterite has been produced from many buried placer deposits in a belt about 8 miles long and 1 mile wide. Cache, Sullivan, and

Woodchopper Creeks, and their branches, all tributaries of Patterson Creek, cross the tin belt (pl. 40). A road 20 miles long links the tin belt with the town of Manley Hot Springs on a slough of the Tanana River. In 1941 there were 2 landing fields for small aircraft served frequently from Fairbanks, 95 miles east. The 1941 summer population of the tin-belt area was about 40 persons.

The need for a critical evaluation of the cassiterite reserves of the United States caused the Geological Survey to undertake a field examination of the Tofty tin area during the summer of 1941. The geology and mining operations had previously been described by Eakin (1913), Mertie (1934) and Waters (1934), but it was hoped that a more detailed study emphasizing cassiterite reserves might provide some quantitative data and indicate the feasibility of further exploration and development. Topographic maps (pls. 40 and 41) were made by J. E. Mundine in the early stages of the work, after which all tailings pile in the belt were systematically sampled. Old workings were sketched (pl. 41), and some information on their histories, production, depths, and other features was acquired from the older prospectors and mining operators living in the region. Drill records were collected and studied. The writer was ably assisted in the sampling by Morton C. Smith and by Joseph Wilson, James Lisca, James Noble, and Robert J. Rogers. For other information the writer is indebted especially to Messrs. R. E. Wyer, H. H. Thurston, and S. L. Cotton of the Cleary Hill Mines Co. and to Messrs. Adolph Bock, Otto Hovley, and Fred Hanson of Tofty. The kindness of Messrs. Gus Benson, Jack Donahue, Tom Dean (Dimnic), J. W. Farrell, William Albrecht, James Cessford, and Patrick McLaughlin was also appreciated.

The results of the work were made available to war agencies in early 1942. The mining problem and most of the estimates of tin reserves discussed in this report are still valid (in 1958), because only 2 of the 6 streams discussed have been mined since the fieldwork was done.

GEOLOGY

The placer deposits are at the base of unconsolidated gravels of early Quaternary age lying on phyllite of Cretaceous age, and are buried beneath 10 to 170 feet of frozen muck and silt of Quaternary age. Except for a few small serpentinized and chloritized mafic rocks found locally in a belt just north of the placer deposits, the only igneous rocks cropping out in the region are the Tertiary intrusive rocks of Roughtop Mountain northeast of the area and of Hot Springs Dome to the southeast. The principal relations of these units are shown on plate 40, and are discussed briefly below. Further information on distribution, lithology, structure, thickness, age, and correlation was given by Mertie (1937, p. 156–172, 186–198, 219–226).

BEDROCK

The rocks of Cretaceous age that make up the bedrock of most of the area are generally covered with sphagnum moss and other vegetation and by a heavy creeping mantle of distintegrated rock where they are not buried beneath Quaternary silts. It is possible, however, to study them in mine openings and in a few outcrops along oversteepened banks of streams in the more hilly areas. The predominant rocks are soft, dark-gray phyllite and slates interbedded with discontinuous lenses of graywacke. Some phyllite beds are light greenish gray or light yellowish gray. Less common than the phyllite but more conspicuous among the outcropping rocks are beds of dark, dense quartzite. At the top of the ridge north of the placer belt is a thick massive bed of light-buff or yellow cemented sandstone and quartzite which for part of its length is shown as a separate unit on plate 40. A similar quartzite, interbedded with light-colored phyllite, crops out in the bluffs at the junction of Blowback and Baker Creeks. A lens 100 feet thick of light-yellow crystalline limestone containing magnetite and apatite crystals has been exposed by prospecting at the head of Harter Gulch, and a few pebbles of similar limestone were noted in the gravels of upper Cache Creek.

The intrusive rock of Roughtop Mountain has an outcrop area of about 8 square miles. The rock is dominantly a coarse-grained, porphyritic biotite monzonite. Many large crystals of andesine feldspar stand nearly vertical, suggesting that the present erosion surface has truncated the monzonite body at a level far below its top. Several mafic and aplitic segregations have been described by Mertie (1937, p. 219–226), but these lack both cassiterite and tourmaline, and no cassiterite appears in the gravels of present streams draining the outcrop area.

The intrusive body of Hot Springs Dome, which is somewhat larger than the Roughtop Mountain body, crops out over an area of about 20 square miles. It is elongate and its major axis trends about N. 65° E. The rock is a biotite granite rather than a monzonite, and associated with it are several salic segregations containing conspicuous dark tourmaline needles. No cassiterite has been found in the intrusive body, the adjoining phyllite, or the gravels of the streams draining the outcrop area. However, chemical analyses given by Mertie (1937, p. 222) and the presence of tourmaline show that the granite of Hot Springs Dome is more typical of source rocks of cassiterite-bearing veins than the monzonite of Roughtop Mountain.

The phyllite beds at the south border of Roughtop Mountain are compressed and crenulated for 1,000 feet, and within 200 feet of the border they are recrystallized locally to spotted schist containing brown biotite. At the contact with the intrusive mass the country rock is in some places converted to a dense hornfels. At Hot Springs Dome similar changes occurred in the phyllite northward as far as a mile from the granite. Metamorphism is even more intense of the intrusive rock along the bedding planes of the rocks of Bean Ridge, where garnet, andalusite, tourmaline, brookite, monazite, and zircon were found by Waters (1934, p. 242) in the stream gravels. No phyllite beds that are similarly metamorphosed crop out near the cassiterite-bearing placers or elsewhere in the Tofty area.

The only igneous rocks observed near the placer deposits are three small dense, serpentinized and chloritized mafic dikes, one of which contains a core of metadiorite consisting chiefly of hornblende, albite, chlorite, and epidote. These dikes all lie about 1 mile north of the placer belt, and are shown on plate 40. A fourth dike crops out on the crest of the Boulder Creek drainage divide near the American Creek trail. At two of the outcrops the metamorphism adjacent to the dikes is very slight, but the outcrop at the head of Harter Gulch reveals a poorly exposed zone of serpentinized country rock of undetermined width containing cross-fiber veinlets of serpentine, some soft white chlorite, and a small amount of calcite and magnetite; a bed of crystalline limestone exposed at a point 300 feet to the south contains some magnetite and apatite.

Sporadic cobbles and pebbles of metadiorite in most buried placer gravels of the tin belt indicate that unexposed bodies of metadiorite may occur in several places in the placer belt. In the gravels of Cache Creek oxidized cobbles of a coarse-grained serpentinized gabbroic rock similarly indicate an unexposed gabbroic body. Chromite, picotite, ilmenite, and magnetite found in the buried gravels of Deep Creek, Sullivan Bench, and elsewhere may be derived from serpentinized igneous rocks, but it is unlikely that the cassiterite of the placers was derived from these mafic rocks.

The structure of the phyllite is too complex to be determined from the few available outcrops. Bedding planes are inconspicuous, and the dominant physical feature of the rocks is the foliation. Where observed the bedding is commonly parallel to the principal cleavage. In one outcrop on Sullivan Creek the foliation plane was parallel to the bedding in small drag folds, and in another outcrop the foliation was parallel to the axial plane of the drag folds. In general the strike of foliation is N. 60° to 75° E., nearly parallel to the trend of the placer belt. The dip of the foliation averages about 65° N. in the vicinity of the placers, and the axes of minor folds and crenulations pitch about 15° to 30° NE. North of the light sandy quartzite cropping out along Woodchopper Creek the cleavage and bedding dip southward at moderate angles, indicating a possible syncline.

ALLUVIUM

Most of the material composing the gravel deposits is of local derivation. The gravel deposits vary widely in thickness, in the amount of silt and clay, and in degree of stream wear and polishing. In the cross sections, plate 41, an attempt was made to distinguish deposits of angular gravels containing silt and clay from cleaner, more rounded gravels. The cleaner gravels contain most of the cassiterite and gold, but smaller amounts are contained in the angular, clayey gravels. Both types of gravel consist dominantly of graywacke, phyllite, sandstone, light-colored and dark quartzite, and quartz pebbles and fragments. The well-rounded gravels have more pebbles of quartz and light-colored quartzite and contain a few cobbles of granite and quartz-tourmaline rock. Rounded boulders of quartzite and sandstone were found at altitudes as high as 900 feet along the west side of the canyon of Sullivan Creek.

Angular gravels containing silt, muck and clay and some angular boulders occur most commonly along the hillsides. Some are interbedded with the rounded gravels, others lie on bedrock buried beneath undisturbed Quarternary silts and mucks, and still others are interbedded with the mucks or are forming by disintegration, creep, and wash acting on the bedrock areas. Hence, they have a wide range in age.

The Quaternary silts and mucks that bury much of the Tofty area are partly massive and uniform in texture and partly interbedded in an irregular manner with angular gravels, peaty layers, silts containing much vegetal material, and even buried forests or forest debris. The total thickness along the placer belt ranges from a few feet in Tofty Gulch to 170 feet at Deep and Woodchopper Creeks. The origin and mode of accumulation of these deposits have been discussed by Mertie (1937, p. 186–198), Taber (1943, p. 1464-1548), and Tuck (1940, p. 1295–1310). The massive silts are loess, derived from glaciofluviatile outwash during the Pleistocene epoch. They are characteristically perennially frozen and contain large wedge-shaped, tabular, and irregular masses of clear ice which pinch out downward and are flat topped at the level of summer melting. The interbedded silts, sands, mucks, forest debris, and gravels occur most commonly along the borders of the deeply buried areas, partly in Recent alluvial fans. They are the result of the wash or creep of silt, muck and disintegrating bedrock from the higher areas. In the upland areas, silt forms a veneer a few feet thick.

ECONOMIC GEOLOGY

The Tofty area contains both lode and placer deposits, but as yet only the placer deposits have been worthy of exploitation. Much of the gold in the placer deposits was undoubtedly derived from the known types of lode deposits, but the source of the cassiterite in the placers is obscure.

LODE DEPOSITS

Quartz veins ranging in width from minute seams to veins several feet wide are common in nearly all the exposed Cretaceous rocks of the tin-belt area. Most are small and discontinuous, following the bedding and cleavage planes of the phyllite for short distances. In the quartzite beds they are generally larger and more persistent. A few large bull-quartz veins in the hills west of the upper canyon of Sullivan Creek strike N. 10° E. and dip 35° W., following cross fractures or jointing in the sandstone and graywacke. The veins in the phyllite are easily broken away from their wallrock along graphitic partings, but the quartz in quartzite beds has tight contact with its walls, resulting from partial replacement of the quartzite by vein quartz. Most of the quartz veins consist of milky-white quartz and show little or no sign of metallization. Except for limited local sericitization and silicification such as that a mile upstream from the Sullivan Creek placers, the walls of the quartz veins have not been altered. Some contain a few scattered cubes of pyrite, and several contain localized calcite crystals which weather out of veins leaving irregular cavities. Arsenopyrite occurs rarely in the veins, and galena is probably present since it is seen in some placer concentrates. No cassiterite or tourmaline have been found in place in any of the veins, although both occur in a few angular fragments of phyllite and sandstone in the gravels of several streams. Many veins have been sampled and assayed for gold by miners, but only a few assays have shown more than traces. A random sample collected and assayed by the Geological Survey from a small gossan zone in quartzite at the west side of Idaho Gulch near its head showed a tenor of 1.34 ounces of silver per ton but no gold. No gold particles were seen during the panning of almost every exposed quartz vein or veinlet in the Tofty Gulch pit.

Pyrite cubes, which apparently are not directly related to individual quartz veins, are sparsely disseminated throughout most of the phyllite and graywacke.

At the northwest border of the intrusive mass at Hot Springs Dome are some quartz-siderite-galena veins, one of which was traced for 1,500 feet and another for 500 feet. Calcite, pyrite, chalcopyrite, and pyrrhotite also were noted among the primary minerals, but most of the outcrops consist of a heavy hematite gossan with a few stains of malachite, azurite, and erythrite (cobalt), and a few small anglesite masses formed from galena.

PLACER DEPOSITS

The proved tin-bearing placer deposits of the Tofty area are restricted to a belt about 12 miles long and 1 mile wide, trending N. 60° E., from Woodchopper Creek across Miller Gulch and Deep, Sullivan, and Cache Creeks of the Patterson Creek drainage basin, and extending across a divide to Gold Basin and Killarney Creeks, tributaries of Baker Creek. Most of the tin and gold have come from the 8-mile-long Patterson Creek part of the belt. Nearly all the deposits are buried beneath 10 to 170 feet of frozen Quaternary silt and muck.

The placer deposits within this belt are restricted to several pay streaks[1] which in general are related to the drainage basin that existed before silt buried the area. Some features of the drainage basin are illustrated on plate 41. Many of the richest parts of individual placer deposits were found where an old channel had cut headward into a bench or terrace in the bedrock surface. In Miller Gulch, for example, the channels cut across a system of bedrock terraces causing local enrichment of the gravels at each terrace. But not all such intersections are rich, and conversely some of the richer deposits have no such existing physiographic relations but seem to be simply areas in which gold and cassiterite were concentrated in stream channels after which the adjacent upland surfaces were lowered by continued slow erosion under low stream gradients.

Cassiterite and gold are most frequently found at the base of the lowest gravel. In some places particles of the two minerals, particularly gold, are worked into fractures and foliation in the soft weathered bedrock for several inches or even feet. Most gold particles in pay streaks at bedrock level are rounded and yellow. Cassiterite and gold are not abundant higher in the basal gravels, in gravel lenses in the silt and muck, or in the silt. Much of the gold in the upper part of the Quaternary deposits overlying the bedrock is very fine grained and well rounded, but angular gold with attached quartz particles is common, and some gold of this type has a greenish cast. The cassiterite particles in the silt are as well rounded and polished as those in the pay streaks lying on bedrock.

The shape and relative abundance of the different rock types of gravels and boulders found in tailings piles are summarized in table 1.

[1] The word "pay streak" is used in this report as a convenient term for a natural concentration of gold or cassiterite. Whether a pay streak could be mined profitably would depend upon its grade, the mining method proposed, and economic conditions at the time.

TABLE 1.—*Rock types, shapes, and relative abundance of gravels and boulders in individual placer tailings*

[Numerals indicate relative abundance, in tenths. Letters represent: a, angular, sa, subangular, sr, subrounded, r, rounded. Lack of a numeral indicates less than 1 in 15, or, for boulders east of Idaho Gulch, no estimate of relative abundance]

Locality	Gravels						Boulders				
	Phyllite		Graywacke	Sandstone	Quartzite	Quartz	Quartz	Quartzite		Sandstone	Graywacke
	Dark	Light						Dark	Light		
Cache Creek:											
Ferguson Draw	2sr	1sa	5sa	r	sa	sr	r	sr	--------	sr	--------
Upper workings	4a–sr	sa	4a–sr	sr	sa	sa–r	sr	sa	sa	sr	a
Lower workings	2sa–r	sa	6a–sr	r	sa	sa–r	sr	sa	sa	r	a
Dalton Gulch	1sa–sr	sa	7a–sa	sr	sa	a	sa–sr	sa	sa	sr	a
Harter Gulch (lower)	3a–sr	r	4sa	1r	sa	sa	sa–r	sa	sa	sr	sa
Sullivan Bench	3a–sr	sr	4a–sr	1r	sr	sa	sr–r	sr	sr	sr–r	a
Tofty Gulch:											
Upper workings	3a–sr	sr	5sa	sr	a–sa	a–sr	a–sr	sa	sa	sr	sr
Lower workings	3sa–r	sr	4sa–sr	1sr	sa	sa	a–sr	sa–sr	sa–sr	sr–r	--------
Idaho Gulch	1sa	5sr	3sa–sr	1r	sa	sa	3sa–sr	a–sr	2sr–r	3r	--------
Miller Gulch:											
Upper workings	5a	r	3a–sr	2r	sr	a–sr	sa–sr	sr	sr	8r	1sa
Central workings	4a	sr–r	2a–sr	3r	1sr	sa–sr	3sa–r	sr–r	3sr–r	4sr–r	a–sr
Lower workings	3a	1sr	2sr–r	4r	1sr	sa–sr	4sa–r	1sr–r	2sr–r	3r	a
Innesvale Gulch (Deep Creek):											
Good Hope claim	1a	1sa–r	1r	5r	1r	1r	4sr	--------	1sa–sr	5r	a
Olga claim	3a	1r	3a–sr	2r	sr	1sr	4sa–r	--------	2sr	3r	1a–sr
Borghill claim	6a	sr	3sr	--------	--------	a	4sr	sr	sr	r	5a–sr
Hokeley Gulch (Deep Creek):											
Cleopatra claim	6a	1sr–r	1sr	1r	r	1a–r	5r	1r	4r	--------	--------
Lake claim	3a	2sr–r	1sr	2r	r	1a–r	6sa–r	sa–r	2r	1r	--------
Golden Straw claim	4a–r	1a–r	1sa–r	2r	1a–r	1a–r	4r	2a–r	1r	3r	a
Woodchopper Creek:											
Upper workings	1a–r	3a–sr	r	3r	2r	1sa–r	3r	1a	4r	1r	1r
Central workings	2a	2a–sr	r	3r	2a–r	1a–r	3r	1a	3r	3r	--------
Lower workings	1a	3a	r	3r	2a–r	a–r	3r	sa	1sr–r	5r	--------

In the gravel sizes, angular to subrounded phyllite and graywacke of local derivation predominate, and the ratio of phyllite to graywacke increases westward through Deep Creek. Of the more resistant gravels, subrounded to rounded sandstone predominates and constitutes about a third of all gravels from Miller Gulch west. Along Idaho Gulch and to the east, subangular quartz and quartzite gravels are common in the tailings and pay streaks. West of the creek such gravels are more abundant and better rounded. Boulders on most creeks are subangular to rounded and are composed of quartz. In parts of the Miller and Innesvale Gulches and the Woodchopper Creek workings most of the boulders are rounded sandstone. Rounded light-colored quartzite boulders are common, although some angular dark quartzite boulders are found, especially in Hokeley Gulch and on Woodchopper Creek. Quartz boulders weighing 1 ton or more are common impediments to mining.

The gravels lying on bedrock and containing local concentrations of cassiterite and gold range in thickness from 0 to 4 feet at Ferguson Draw, from 2 to 14 feet at Sullivan Bench, and from 30 to 40 feet in lower Idaho Gulch and on much of Deep and Woodchopper Creeks.

Gravels of the placer deposits are locally iron stained by oxidation of pyrite eroded from the bedrock. For example, the gravels at the northeast corner of the Sullivan Bench pit, as it was in 1941, consisted of subrounded pebbles of phyllite, graywacke, sandstone, quartzite, and quartz interbedded with short gray sand lenses, the whole cemented weakly by reddish-yellow iron oxide. The underlying bedrock consisting of soft, weathered, dark graphitic phyllite was not notably iron stained.

Among the gravels and boulders of the placers are less abundant rock types worthy of special mention because of their possible genetic association with the cassiterite. On lower Deep Creek, in Idaho Gulch, and on Cache and Killarney Creeks, cobbles of coarse-grained biotite granite were found in the tailings and gravels. Monzonite pebbles and cobbles occur in the gravels of Killarney Creek, the headwaters of which drain the Roughtop Mountain monzonite area in the present physiographic cycle, but monzonite has also been found in Cache Creek gravels. Pebbles and cobbles of green and white metadiorite are common in the gravels of most of the creeks. As seen in this section, they consist largely of hornblende partly altered to chlorite and of calcic feldspar partly altered to zoisite and albite; some fresh hornblende crystals have augite cores; and most metadiorite contains small amounts of epidote, titanite, and apatite. In the Cache Creek gravels are cobbles of a coarse-grained gabbroic rock, similarly altered, but also serpentinized.

Well-rounded pebbles and cobbles of equigranular quartz and black tourmaline are sparsely but uniformly distributed throughout the gravels of the tin belt. The uniform texture of many of the cobbles suggests derivation from dikes of quartz-tourmaline rock or tourmalite. Many of the quartz-tourmaline pebbles, however, show relict structures suggesting replacement of folded schistose rocks. One subangular stone found by Waters (1934, p. 241) in Cache Creek tailings showed orthoclase, microcline, and quartz in sharp contact with a band of quartz and tourmaline.

Pebbles containing brown (dravite or magnesian) tourmaline are more closely associated with the cassiterite than the pebbles containing black (schorlite or iron) tourmaline. Nearly all cassiterite pebbles contain brown tourmaline, and a small amount of quartz and altered fragments of country rock. Pebbles in which tourmaline is dominant are abundant in the gravels of Deep Creek and Miller and Idaho Gulches. They may be 6 inches or more in diameter. Some are subangular or subrounded, but most are as well rounded as the pebbles having a high concentration of cassiterite. A graded suite of cobbles ranging from cassiterite containing a small amount of tourmaline to brown tourmaline with a small amount of cassiterite could be assembled readily from the gravels and concentrates of most creeks. The cobbles would show similar brecciated textures throughout, and except for a slightly less metallic luster, stronger brown, and less density at the tourmaline end, the specimens would be difficult to distinguish by eye.

Most cassiterite particles or pebbles range from $\frac{1}{16}$ to $1\frac{1}{2}$ inches in diameter and almost all are well rounded, but a few are definitely subangular. The cassiterite in the pebbles is largely very fine grained and is gray tinged by brown. It has a submetallic luster on wet or freshly broken surfaces. Some cassiterite is coarser grained, showing crystals as large as $\frac{1}{32}$ inch. The coarser grained cassiterite is brown, and specimens may contain small vugs of cassiterite and quartz crystals. The gangue in the cassiterite pebbles commonly is brecciated quartz or tourmalinized sedimentary rocks; the fractures are filled with tourmaline, quartz, and cassiterite, and the breccia fragments are partly replaced. Some cassiterite pebbles contain a small amount of yellow fluorite.

Of particular genetic significance are the rare specimens of altered country rock in the placer gravels that show tourmaline and cassiterite. In a subangular brownish-gray phyllite fragment from Miller Gulch which was studied in thin section, fine brown tourmaline replaces all formerly micaceous layers, and dense tourmaline fills fractures across the schistosity. In and near the fractures are many small irregular elongate cassiterite crystals and also some bladelike, almost opaque, poorly crystallized cassiterite grains. In the Tofty Gulch pit the writer found a rounded cobble of brownish altered phyllite with a quartz-tourmaline veinlet, and a cobble of dark quartzite with an irregular quartz vein and a few coarse crystals of tourmaline. In the Hokeley Gulch gravels an angular piece of sandstone was found containing micaceous layers altered to tourmaline and a few tiny cassiterite grains.

Heavy minerals in placer concentrates include chromite, ilmenite, pyrite, and some magnetite. Chromite was identified in the Sullivan Bench and Tofty Gulch pits and is abundant at Deep Creek, exceeding 10 percent of the concentrates obtained by the Survey sampling of the tailings of the Wild Goose, Golden Straw, and Marietta claims (pl. 41). It occurs as subrounded pebbles and is coarse grained with submetallic luster, lavender alteration, and a parting resembling a poor cleavage. Less abundant minerals in gravel-size concentrates are galena and arsenopyrite. Minerals in the pebble-size or sand-size concentrate, besides those mentioned above, include picotite (chrome spinel), zircon, aeschynite (niobate and titanate, chiefly of cerium metals), monazite, xenotime, apatite, epidote, brookite, anatase, barite, garnet, titanite, andalusite, and hypersthene.

INDIVIDUAL PLACERS

The creeks of the tin belt, particularly in the Patterson Creek drainage basin, were each studied in detail to find similarities or progressive variations that might determine their origin and assist in their further exploitation. Mining operations in 1941 were being conducted on only five of the creeks. All unworked drift mines in the district quickly fill with water and ice and become inaccessible. Thus for most creeks, the sketches, statements, and deductions were made on the basis of the tailings on the surface, the recollections of miners of long experience, records of former Survey investigations, and miscellaneous records. Not even in the open-pit mines currently operating were the exposures, tailings, and records entirely adequate for the study.

CACHE CREEK

Discoveries of cassiterite and gold were made on Cache Creek in 1909 and 1910, and the principal pay streak on upper Cache Creek (pl. 41) was largely worked out between 1911 and 1913 by Sylvester (Jake) Howell and Gene Sullivan. Early work on the lower end of the pay streak was done by Cameron and Midgeley, according to Otto Hovley, owner of most of the claims in 1941. Since the First World War, Hovley and others have prospected on all sides of the original pay streak and in Ferguson Draw, a minor tributary.

Parts of the original pay streak were very rich. Hovley took 26.3 ounces of gold and a large amount of cassiterite from a pillar, in 1 day's work. Other parts were of low grade, restricting early mining to small areas of rich ground. Cassiterite and gold were generally found together, but prospecting showed a small streak 20 feet east of the head of the main gold-cassiterite pay streak that yielded 10 to 12 pounds of cassiterite to the pan or about 1,500 pounds per cubic yard, but it contained too little gold to be of economic interest at the time. On the other hand, some pay streaks worked at the upper end of Cache Creek in the 1920's contained coarse gold and very little cassiterite. The cassiterite occurred as polished pebbles with a brecciated texture similar to that found on other creeks. Most of the gold at the head of the Cache Creek pay streak was the size of bird shot; some nuggets were as large as 4 ounces, whereas at the tail and in Ferguson Draw the gold was finer and in well-worn flakes. One prospector found a cassiterite concentration of low gold content 300 feet south of the southernmost tailings on Cache Creek, under 70 feet of Quaternary muck.

The gravels of Cache Creek are mostly phyllite and graywacke of local derivation and are angular to subangular. For the most part the pay-streak gravels are well stream sorted and are overlain by about 4 feet of poorly sorted graywacke fragments, muck, and ice. The channel of the main pay streak is sharply cut into the phyllite and graywacke bedrock and is buried about 50 feet under Quaternary silt and muck. Parallel to it and sometimes branching from it or returning to it are other channels, about 10 or 20 feet deeper or shallower than the pay-streak channel, in which placer concentrations have not been found.

In Ferguson Draw the gravels are thin or absent, and approximately 40 feet of Quaternary muck lies directly on bedrock placer concentrations in some places. Silicified phyllite is common in the gravels, and several well-rounded boulders of quartzite and quartz as large as 3 feet in diameter have been found. The pay streak yielded approximately 0.3 to 0.4 ounce per square foot in gold and 0.1 to 0.4 pound per square foot in cassiterite. It terminates upstream against bedrock terraces, above which the paystreak is buried by Quaternary muck reduced from 40 to about 18 or 20 feet in the line of the channel. Drilling showed some cassiterite on the shallow north bench of the Ferguson Draw channel.

Unusual gravel fragments and boulders found in the tailings of Cache Creek include biotite granite, weathered monzonite, metadiorite, serpentinized gabbro, tourmalite, chromite, and ilmenite, all mentioned in the general discussion on placer deposits.

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DALTON GULCH

Pay streaks in the Dalton Gulch area were first worked about 1910. Since the First World War they had been neglected except for scattered prospecting. None of the miners and prospectors who did the work remain in the district. The northernmost tailings shown on the sketch, plate 41, were produced by Dick Richards, who made one of the earliest cassiterite shipments from the Tofty district; the other tailings were produced by Dietz, Kobich, and others.

One pay streak was reportedly 60 feet wide, but most were small and discontinuous. The gravel was only 2 to 4 feet thick, and the total overburden was about 60 feet. The bedrock was terraced, with the richest placer concentrations on the steeper slopes. Most of the pay streaks averaged $0.50 per square foot in gold at the old price of $20.67 per ounce, but some yielded $10 per square foot. From the recollection of local residents and from the tailings samples collected by the Survey, it seems that cassiterite was less abundant in Dalton Gulch than on neighboring creeks.

East of Dalton Gulch toward upper Cache Creek are scattered prospect holes reportedly 60 feet deep. Panning by the Survey disclosed cassiterite and gold on two dumps near Dalton Creek and on most dumps near Cache Creek. Observation of the dumps near the shafts verifies the recollection of the miners of the district that the gravels in this area were thin or absent and that the silt and muck deposits lay directly on bedrock and on the local small tin cassiterite and gold concentrations.

Gravels at Dalton Gulch consist largely of angular graywacke and phyllite of immediate local derivation but include some subrounded sandstone and quartz cobbles.

HARTER GULCH

The principal work on Harter Gulch (pl. 41) was done by Richards in the early years of mining in the area. He reportedly produced $90,000 in gold in one summer from one small area but found only low concentrations adjoining it, and comparatively little cassiterite. The Survey tailings sampling indicated a low cassiterite content in the Harter Gulch workings and showed more gold remaining in the tailings than in those from most other creeks. The gravels are largely angular phyllite and graywacke, containing some rounded sandstone.

Half a mile northward from the Richards workings along the center of the valley of Harter Gulch are small gravel piles containing some cassiterite and considerable gold. Their appearance suggests that the gravel piles were not well washed by the prospector and that this accounts for their high cassiterite and gold content.

SULLIVAN CREEK

The principal pay streak on Sullivan Bench 2,000 feet east of the present course of Sullivan Creek (pl. 41) was located shortly after the original discovery of gold in Tofty Gulch in 1907. Its drift mines supplied a large part of the early output of the Tofty district. Ground worth $20 per square foot (gold at $20.67 per ounce) reportedly was mined in one place, although the ground averaged more nearly $3.50 per square foot. More than 16 men filed in August and December 1907 as owners of the several single or association claims that covered the pay streak, but claim ownership was later consolidated. The principal drift mines were operated for several years by Howell. Production was curtailed in 1912 and 1913 by flooded mine workings and from 1918 to 1921 by high cost of labor, material, and freight. Hydraulic operations were started in the early twenties. About 1928, options were taken by the Alaska Gold Dredging Co., Ltd., a British firm which in 1929 conducted extensive testing of Sullivan Bench. Much of their drilling program is shown in plan and in cross section on plate 41. They were not satisfied with the results of their drilling, and the property passed to Hans Tilleson and Arthur L'Heureux who operated from 1929 through 1931. After the price of gold rose from $20.67 to $35 they sold to the Cleary Hill Mines Co., which operated a lode mine in the Fairbanks district. The Cleary Hill Mines Co. started extensive stripping and ditch building in 1934, and brought in bulldozers, dragline, scrapers, and large pumps. Stripping with hydraulic giants was done every summer and mining in the pit was done about every alternate summer.

Much of the area originally drift-mined had been stripped and reworked by 1941; the gold recovery has been $0.40 to $0.55 per square foot at $35 per ounce, and the cassiterite recovery about 0.02 pound per square foot. The old workings are outlined by a network of clear ice tracing the drifts, crosscuts, and small stoped areas; ice impedes open-pit operations because it does not thaw as rapidly as the adjacent virgin gravels. The gravels are 2 to 14 feet thick, averaging about 6 feet, and are overlain by 40 to 50 feet, locally 70 feet, of silt and muck. Almost all the gold and cassiterite are in 1 to 2 feet of gravel lying directly on bedrock, but some cassiterite has worked down into fractures and bedding planes for a few inches, and gold may be found in the bedrock to a depth of 2 feet. The bedrock is largely soft graphitic phyllite, which below a depth of 1 or 2 feet is not weathered enough to oxidize the disseminated pyrite crystals. Some gravels are iron stained or weakly cemented, probably from oxidation of pyrite eroded from bedrock when the gravels were deposited. The gravels are 30 to 40 percent subangular to rounded dark phyllite, 40 to 50 percent subangular to subrounded graywacke similar to some observed in the bedrock of the pit, 10 to 15 percent rounded yellowish sandstone pebbles, and a few percent each of subrounded light-colored phyllite not represented in the pit bedrock, subrounded dark quartzite pebbles, and angular to subrounded quartz pebbles. Boulders up to 30 inches in diameter of quartz, dark and light-colored quartzite, and light-colored sandstone, all subrounded to rounded in shape, are common. Cassiterite pebbles are characteristically well rounded and polished. Many pebbles of quartz and quartzite can be found, even 8 to 10 feet above bedrock, that are as well rounded as the cassiterite. In addition to the abundant cassiterite, the concentrates contain ilmenite, picotite, chromite, pyrite, magnetite, and more rarely galena, arsenopyrite, native copper, zircon, monazite, aeschynite, xenotime, apatite, brookite, and anatase.

The frozen silts and mucks overlying the gravels are nearly uniform in texture and appearance, but show certain minor color differences. At the west edge of the pit in 1941, the silt is predominantly brown and gray. Tints of green and greenish-yellow are less common. At most places the brown-tinted silts lie either directly on the top of the gravel layer or on top of local lenses of mixed gravels and silts, and are about 10 feet thick. Overlying them is a layer of gray-tinted silt 10 to 25 feet thick, followed by 15 to 30 feet of brown-tinted silt up to the moss roots. However, drilling shows rapid and substantial thickening and thinning or pinching out of the various layers, both horizontally and vertically, in a highly irregular manner, also local inversion of the stratigraphic order described above, and local inclusion of lenses of one tint within layers of the other tint. At the northeast corner of the pit as it was in 1941 and on the *M–M′* cross section (pl. 41), the silts are more complex in structure, due particularly to lenses of creep and wash material, mixed with muck and silt, washed down from the higher hillside to the northeast while the more uniform, massive Quaternary silts were accumulating. The remains of extinct vertebrates, including the mammoth, bison, and horse, as well as much forest debris, are common in the muck and silt.

In the Sullivan Bench area, section *L–L′*, plate 41, shows the pay streak to have been on the top and west slope of a bedrock bench, but not to have been in the deeper bedrock channel to the east. The same relatively barren channel was found at the southeast corner of the pit. Drilling shows bedrock altitudes in the barren areas west of the pay streak, sections *K–K′* and *G–G′*, plate 41, to be about the same as those in the pay streak, with the same normal gradient from north to south in the direction of the streak. In general the cassiterite concentration varies directly with the gold concentration, but at the north end of the pit there were notable local variations in ratio, and south of the pit the cassiterite concentration remains the same, whereas the gold concentration lessens.

The bedrock in Sullivan pit shows no direct genetic association with the cassiterite. It consists of dark-gray phyllite, some of which is graphitic, and a few graywacke beds. The bedding and cleavage largely coincide. The dip ranges from 37° to 71° NW., averaging 50° to 55°, and the strike ranges from 47° to 58° NE. Crenulations where present pitch 30° to 33° N., and a drag fold observed at one point has the same pitch. Locally minor fracture or shear zones are parallel to the strike. Discontinuous quartz veins or lenses are present, seldom exceeding 10 feet in length or 6 inches in thickness, and are generally localized in or near zones of fractures and shear. In addition to milky quartz the lenses include some calcite and pyrite, but no biotite or tourmaline was found. The walls of the lenses are sharp and in most places are defined by a graphitic seam, which is a plane of easy parting.

TOFTY GULCH

The first gold discovery in the tin-belt area was made in Tofty Gulch by C. P. Snyder and George Kemper in the winter of 1906–7. Kemper posted his notice for the Discovery claim on July 20, 1907, and filed his claim on September 18 in the Rampart recording district. Snyder also posted a location notice, on the adjacent American Eagle claim, on July 20, 1907. Claims were located by M. Harter and Adolph Bock 3 and 4 days later, respectively, and in August of that year the remaining Tofty Gulch area plus the Idaho Gulch and Sullivan Bench areas were staked by other prospectors coming into the district, especially from Eureka and Rampart. The Discovery and American Eagle shafts were on the lower or south end of the Tofty Gulch pay streak just below a bedrock bench shown on section *D–D′*, plate 41. In 1908 a mile of ditch from Sullivan Creek was constructed, and in 1909 about 75,000 square feet of bedrock was uncovered by Joseph Eglar, H. C. Wallick, and others. These operations upstream on Tofty Gulch from the Discovery claim were described in 1911 by Eakin (1913, p. 33) as follows:

> On Tofty Gulch a considerable open cut has been made on a bench on the hillside about 1,000 feet from Sullivan Creek. The deposit consisted of 4 to 6 feet of gravel covered by several feet of yellow silt and black muck. Large boulders were very common in the top layers of the gravel and some were found in the lower part of the silt. The black muck contained a great many

remnants of trees, which added considerably to the difficulty and expense of mining. In working the deposit the top layers of muck and silt were ground-sluiced off, dynamite being employed to break up the tangle of wood debris in places, after which the gravels were carried to the sluice boxes with a steam scraper.

The first 1,200 pounds of cassiterite was shipped from the district by Eglar in 1911. Ground sluicing of Tofty Gulch continued through 1912, and some drift mining was done in adjacent ground. For many years there was very little mining or exploratory activity, except for the limited drilling program of the Alaska Gold Dredging Co., Ltd., in 1929, until the acquisition of the property in 1934 by the Cleary Hill Mines Co. The pit in 1941 represented a reworking and upstream extension of the old pit. The upper 2 or 3 feet of the soft bedrock was sluiced along with the gravel to recover the gold and cassiterite that had worked down into fractures and cleavage planes. Cleary Hill Mines Co. brought in bulldozers to move the soft bedrock, used hydraulic giants instead of ground sluicing, extended water ditches, and deepened drains. A caterpillar dragline bucket stacked the tailings.

Both in the present erosion cycle and in the older cycle represented by bedrock configuration, Tofty Gulch is a minor physical feature, a small draw entering Sullivan Creek from the northwest. The slope of the gulch in both cycles averages about 5 percent or 4°. No sharply defined channel confines the placer concentrates. Rather, as may be seen on plate 41, the pay streak or streaks have limited accord with terraces a few feet high and with minor channels in the bedrock. The richest pockets are said to have been found on the slopes of the terraces, but as plate 41 shows, concentrations of cassiterite and gold were found both above and below such terraces, with the apparent axes of the pay streaks crossing the terraces at an oblique angle. The terraces are stream cut, forming angles of 30° to 90° with the prevailing strike of the bedrock.

In Tofty Gulch most gravels are angular graywacke, phyllite, and quartz, of immediate local derivation, particularly those gravels near the steeper side slopes of the gulch or off to the side of the pay streaks. Gravels lying directly on bedrock and containing the cassiterite and gold concentrations, however, include a significant percentage of well-rounded, resistant rocks, particularly sandstone and graywacke but also contain quartz and quartzite, especially among the coarser gravel. The abundant boulders of Tofty Gulch are mostly angular to subangular, but a few are subrounded. Yellow-stained milky to glassy quartz boulders predominate and are as large as 2 tons. Large dark quartzite boulders are also abundant, and some are more rounded and polished than most of the quartz. Unusual rock types among the gravels and boulders include metadiorite, tourmalite, and two cobbles of special interest, one of brown altered phyllite containing a quartz-tourmaline veinlet and the other of dark quartzite containing an irregular quartz vein and a few coarse crystals of tourmaline.

Gravel thicknesses are as much as 7 feet, and average about 3 feet. Iron staining of gravels is widespread but not universal. Beneath the stained gravels the upper foot of weathered bedrock at places is also somewhat iron stained.

Bedrock exposures in the Tofty Gulch pit were the best in the district at the time of the investigation, and were studied in detail. The quartz veins observed largely conform with the strike of the cleavage and bedding of the phyllite and graywacke. Except in the vicinity of drag folds and in zones of shearing, the prevailing strike ranges from N. 70° E. to S. 80° E., averaging about N. 85° E., and the dip ranges from 55° to 80° N., averaging about 68°. Crenulations and drag folds where present pitch about 20° to 50° NE. One such drag fold is domed, and has a local pitch of 3° SW. for 10 to 20 feet. Reliable observations on such structures could be made only along the drainage ditches which are dug from 5 to 10 feet into the bedrock, as the bulldozers and dragline scraper have completed the disturbance of the higher bedrock layers that was started by natural processes before burial beneath the gravel and silt, or else they have covered the bedrock with tailings. Zones of shearing occur along these drainage ditches at about 50 feet, 200 feet, and 400 feet north and northwest of the highway bridge in the pit, and 75 feet, 150 feet, and 350 feet southeast of the bridge. Minor shears were observed at many other places. The shear zone 200 feet north of the bridge is comparatively extensive; it is about 60 feet wide and shows displacement in its southernmost 15 feet. Some subsequent minor cross shearing of northwest strike was observed here and in the northernmost shear zone exposed, but most shear planes nearly parallel the phyllite bedding.

The rocks exposed along the drainage ditches in Tofty Gulch pit were studied in detail. The dominant rock is phyllite, which ranges in color from medium gray to black. Interbedded gradationally with the phyllite are beds of graywacke, a few feet thick, spaced 10 to 100 feet apart, similar in color to the gray phyllite, and not much more resistant to weathering. The graywacke beds thicken and thin or pinch out along their strike and are some what difficult to trace. The black phyllite, which occurs especially in the lower 500 feet of the pit area, is more massive and has poorer cleavage than the common gray phyllite, and is relatively free of graywacke. At a point 400 feet south of the bridge, however, it surrounds a lens of light-gray phyllite and light-colored graywacke. These rock types were observed in the gravels but not elsewhere in the bedrock areas of the tin belt proper exposed at the time of investigation. South of the black-phyllite area is a massive graywacke bed.

Biotitization, tourmalinization, or other mineral alteration commonly associated with tin mineralization were not found. The only mineralization consists of small discontinuous quartz veins lying mostly in or near the shear zones and parallel to the bedding, and the abundant, widely disseminated pyrite found everywhere in the phyllite below depths of 1 to 3 feet. The quartz veins are milky and contain a small amount of calcite and pyrite, rarely chlorite. Most of the veins and shear zones were panned by the writer, and none showed either gold or cassiterite. Pyrite is used as a depth index in both mining and drilling in the pit and elsewhere; when the bulldozer, dragline scraper, or drill hits pyrite, it is assumed to be in relatively fresh bedrock below the depth to which placer gold and cassiterite have penetrated.

As in the Sullivan Bench pay streak, the downstream extension shows gold and cassiterite for several hundred feet, but has not yet been worked by open-pit methods because the bedrock is lower there than the existing drainage ditch, preventing the disposal of slimed tailings. Some drill holes indicate local streaks rich in cassiterite and relatively poor in gold. Eastward toward Sullivan Bench the drilling shows that fine gold occurs in traces but that cassiterite is absent except in three drill holes on section *G–G′* (pl. 41).

IDAHO GULCH

Most development on Idaho Gulch was done early in the history of the district by several of the men who made the original discovery on Tofty Gulch. Placer concentrations are distributed over a large area of bedrock but are in general small, discontinuous, and not particularly rich. An exception was a very small area containing an exceedingly rich pay streak from which a quarter of a million dollars in gold were taken in 1911. Such concentrations are called spots and were described by Eakin (1915, p. 240) in 1914 as follows:

> The simplest forms are rudely elliptical in outline and have a relatively rich central area, away from which the gold tenor and the size of particles decrease to the margin of profitable ground. Such placer spots are developed locally on the surface of bedrock terraces. Some of them appear upon a single terrace. More complex forms are in places developed upon several closely spaced terraces, and it is not uncommon to find a great variation in the elevation of bedrock in a single mine, the surface being everywhere sensibly flat except in the terrace scarps. In one mine $200,000 is said to have been produced almost entirely from a space of 5,000 square feet. On higher terraces at the same locality several other small areas of but slightly lower tenor were mined. Still

other mines have shown small areas containing $10 to $30 in each square foot. The minable area of individual spots ranges from a few thousand square feet to a few acres.

Spots are not confined to the Idaho Gulch area and are indeed characteristic of every creek in the tin belt.

In the lower Idaho Gulch area the general bedrock slope is very gentle and no single channel crosses the bedrock terraces to give strong linear control to spot and pay-streak distribution. Furthermore, a gentle southeast slope unbroken by any suggestion of a valley exists on the surface in the area of the spots.

The Idaho Gulch area was not always known widely under that name but was referred to in some earlier reports as "Sullivan Creek valley below Tofty." The history of the area is therefore somewhat confused with that of the other placer areas. The last-recorded extensive drift mining in Idaho Gulch was done in 1912 and perhaps in 1913. Since then several prospecting shafts were sunk and a small amount of ore has been produced. From 1917 to 1919, as elsewhere in the tin belt, the older tailings dumps were reworked for cassiterite. Some drift mining between 1919 and 1921 recovered about 0.77 pound of cassiterite per square foot of bedrock. The ground in the vicinity of the old workings was drilled in 1929 by the Alaska Gold Dredging Co., Ltd., and in 1940 to 1941 by the Cleary Hill Mines Co. Most of the prospecting in Idaho Gulch from about 1916 to 1941 was done by Jack Donahue. Cassiterite was found in small quantities in several of his prospect holes, including several as far up the creek as 1,500 feet above the road; gold, but no cassiterite, was found beyond that point by Donahue. The cassiterite found at the points farthest upstream was similar in most respects to that found in greater concentrations in the principal pay streaks, except that according to Donahue it was all in the sand and fine-gravel size range and did not include a large proportion of the coarser gravel sizes as is common in the pay streaks. The depth of burial at the upper limit of the cassiterite ranges from about 24 to 32 feet, including 8 to 12 feet of gravel-muck wash. At the lower end of Idaho Gulch cassiterite has been found in prospect holes as far as 2,500 feet south of the road (pl. 41), where the overburden is 80 to 85 feet and the gravels are only 2 to 5 feet thick. An 85-foot shaft was sunk and considerable drifting done in 1915 near the small lake between lower Idaho and Miller Gulches; however, no cassiterite and only a very small amount of flour gold were reported. Panning of the dump surrounding this shaft by the Survey showed no cassiterite.

In 1941 a small pay streak or spot in Idaho Gulch north of the old workings was found and outlined by drilling by the Cleary Hill

Mines Co., and was later drift mined under a lease. It was definitely localized by a small buried gully cut back into a bedrock terrace.

Compared with tailings along creeks to the east, the Idaho Gulch tailings contain a higher proportion of light-colored gravels and boulders. In the gravel sizes, angular to subrounded, light greenish-gray chloritized phyllite is more abundant than the typical angular dark graphitic phyllite of the tin belt. Quartz boulders and subrounded to rounded light-colored quartzite and sandstone boulders are common. Subrounded graywacke gravels are the most abundant of the dark gravel constituents. Well-rounded cobbles of brecciated quartz containing brown tourmaline and some cassiterite are common in the boulder piles.

MILLER GULCH

The discovery of the gold and cassiterite placers in lower Miller Gulch was the result of drilling in 1912 (Eakin, 1915, p. 241, 243–244). The successful drilling program was financed by half the net return from the mining of the richest spot in Idaho Gulch the preceding year. Other discoveries were then made by prospect shafts upstream in Miller Gulch, and by the end of the year mines were located at intervals for almost a mile along the stream. The largest operators were Sylvester Howell in lower Miller Gulch, Howell and Stewart on the central workings, and Stewart, McLean, and McKinzie on the upper reaches of the pay streak. In 1914 there were 5 operations in Miller Gulch employing 112 men, but in 1915 the operations were reduced. Except for recovery of cassiterite from the tailings in 1917 to 1920, and prospecting by John Radovich about 1923, the creek received little attention until 1930 and 1931 and again from 1937 through 1940, when there were small drift-mining operations. Recorded recent cassiterite recoveries range from 0.2 to 0.5 pound per square foot of bedrock.

The Miller Gulch pay streak is buried under Quaternary silt and muck, which is 35 feet thick at the north end and 120 feet deep at the south end. The present surface topography is a very gentle southward-facing slope; the bedrock slope is the same, with the exception of some prominent bedrock terraces of which at least 3 have 10- to 20-foot south escarpments. Their approximate locations are indicated on the sketch of the Miller Gulch workings (pl. 41), as reported by Tom Dean who was for many years a resident and prospector on the creek.

The Miller Gulch pay streak is long, narrow, and continuous compared to those on most creeks. This is unusual considering the apparent lack of a confining major bedrock channel. Depths to bedrock for several hundred feet east and west of the pay streak are nearly the same as depths as the comparable points on the pay streak. The only reported channelling consists of some short, sharp gullies cut back into the various bedrock terraces, in or near which the richest gold and cassiterite concentrations were found. In the upper 2,000 feet of workings there were 2 pay streaks about 200 feet apart, lacking rich spots and lying largely on one terrace. Two rich notches were found in the terrace escarpment, below which the channels coalesce.

In 1914 mine operators on Miller Gulch tried to recover cassiterite during gold sluicing. About 30 tons of cassiterite concentrates were recovered at one drift mine. The proportion of cassiterite in the gravels was said to be as high as anywhere in the tin belt, a statement verified by the sampling of tailings by the Survey, particularly in the lower workings.

In the gravel tailings of Miller Gulch, the dominant rock type is angular dark phyllite, constituting half of all gravels at the head of the pay streak and a third at the foot. The proportion of angular to subrounded graywacke in the gravels also drops, from a third at the upstream end to a sixth at the lower end. Rounded sandstone and subrounded quartz gravels are fairly evenly distributed over the mile of tailings dumps. Rounded metadiorite pebbles are common in the upstream tailings, and less common downstream. Among the boulders, rounded sandstone predominates at the head of the creek but quartz and light-colored quartzite boulders are equally abundant in the lower workings. The gravels lying on bedrock are reportedly thick, totaling as much as 40 feet at the south end of the pay streak. It is said that they were freer from silt and muck than gravels on most other creeks, a condition also suggested by the relatively clean, well-sorted tailings piles. Like gravels on the other creeks to the west, the proportion of light-colored quartzite, quartz, and sandstone boulders and pebbles among the gravels is greater than on the creeks to the east. The concentrates contain more heavy minerals, other than cassiterite and pyrite, and the boulder and gravel tailings contain more brecciated quartz cobbles with brown tourmaline and small amounts of cassiterite.

DEEP CREEK

Present day Hokeley and Innesvale Gulches and the east tributary, Willow Creek, rise in inconspicuous gulches west of Miller Gulch and flow southward, then southwestward to form Deep Creek, an equally inconspicuous topographic feature. Ordinarily, as in Idaho, Tofty, Harter, and Dalton Gulches, there is little or no continuous flow of surface water, and the stream channels are lost in the moss and muskeg south of the slope where they rise. However, for lack of any other natural features suitable for geographic reference in describing the location of the placers of the area, it has been the custom to use the names, "Innesvale" for the eastern and "Hokeley" for the western placers along Deep Creek between Miller Gulch and Woodchopper Creek. Some placer mining claims of Deep and Woodchopper Creeks are plotted on plates 40 and 41 for further geographic reference.

The rich ground of Hokeley Gulch at the junction of the Golden Straw, Wild Goose, and Marietta claims was discovered as the result of drilling on the Wild Goose claim by Adolph Bock in March 1913, and was worked through 1916, during which time an average of 50 men was employed. Eakin (1915, p. 243) described the deposit in 1914 as follows:

The shafts penetrate 130 feet to bedrock, most of the way through light-colored stratified and frozen silt. A stratum of gravel 6 to 8 feet thick lies on bedrock beneath the silts. The gold is well concentrated on bedrock and in the lowermost gravels. It is well worn and of fine, even texture, indicating considerable transportation and assortment prior to its deposition in the present placers. Although the deposit has not been fully outlined, margins have been located which indicate that it is not part of a continuous pay streak but is irregularly terminated in all directions. The gravels vary in gold content from place to place, ranging from those that are barely workable near the margin to some of very high tenor about the central shaft. There are considerable areas that yield $4 to $6 or more to the square foot, and the entire minable area is thought to extend over several acres. Stream tin occurs with the gold, but no special attempt was made to recover it. There is considerable difference in depth between the two shafts, though they are only a few score feet apart. To the southeastward bedrock drops off to still lower levels.

The northwestern part of the pay streak on the Wild Goose claim was mined in 1916 by Bock and Danielson. Reworking of cassiterite from tailings took place in the next few years. The less rich workings, which lie southwestward along the line between the Wild Goose and the Golden Straw claims, were operated by Besonen and McKenzie in 1916, by Fred Hanson about 1922–25, and by Henry Besonen and by Jarvi and Linder in 1938–40. The average cassiterite recovery from some of these later operations was about 0.5 to 0.6 pound per square foot of bedrock.

The pay streak northwest of the Cleopatra claim was mined by John Neilson and August Johnson in 1915 and 1916, until it was flooded as mining continued south onto the Cleopatra. They recovered 0.335 pound of cassiterite and 0.1 ounce of gold per square foot of bedrock. The tailings around the lake at the northeast corner of the Marietta claim were produced largely since 1929, by Bock and by Hanson and Albrecht.

In 1941, Hanson was mining the pay streak at the center of the northwest side of the Marietta claim (pls. 41 and 43*A*). The writer was present for a cleanup representing the mining of 1,317 square feet or 292 cubic yards of placer gravels said by Hanson to be only half as rich as other recently mined gravels.[2] The gold recovery was $1.85 per square foot or $8.32 per cubic yard for gold at $35 per ounce troy. The cassiterite concentrate recovery was 0.064 pound per square foot or 0.288 pound per cubic yard, about a quarter of that recovered in recent years from neighboring operations. The mined thickness of gravels was 6 feet, and the overburden, mostly silt, was 134 feet.

Upstream in the Innesvale Gulch area, Dellas and Hanson mined in 1918, and a spot west of the center of the Olga claim was worked by William Albrecht, Pete Mellianic, and Tom Dean in 1925. Some work had also been done in 1924 on the west end of the Cleopatra claim by Sylvester Howell, but most of the mining of the Innesvale Gulch area since 1929 was done by Adolph Bock and by Hanson and Albrecht. Cassiterite recoveries ranging from 0.2 to 0.5 pound per square foot of bedrock were common in these operations. Both the north and the south end of the pay streak on the Rachel, Hard Luck, and Good Hope claims were flooded, causing loss of the mines. The gold and cassiterite pay streaks in the center of the Olga claim are spotty and discontinuous, and toward the south edge of the claim the gravels are thawed, making drift mining impracticable or difficult.

Mertie (1934, p. 20–212) visited the large drift mine of Hanson and Albrecht on the pay streak at the west corner of the Olga and the north corner of the Cleopatra claims in 1931 when it was open and operating. The following is quoted from his description:

The overburden consists of 5 or 6 feet of gravel on bedrock, overlain by 60 feet of muck containing here and there layers of fine gravel, which in turn is composed mainly of quartzite, phyllite and slate but also includes vein quartz, much of which is vuggy and iron-stained. In places cavities may be seen from which pyrite has been dissolved. The gravel is subangular to poorly rounded and is not in general heavy, being composed of cobbles a foot or less in diameter. But here and there in the drift are very large boulders, commonly quartz, and one such boulder of pure vein quartz 6 feet in diameter was observed, underlain by 2 feet of small gravel and cobbles. Also in places great slabs of country rock are found, underlain by gravel. Such conditions indicate that the concentration of the gold occurred almost in place, neither the gold nor the vein quartz having been transported any great distance. The gold occurs in the lower 2 feet of gravel and the upper foot of the bedrock. The surface of bedrock is very irregular and in places rises abruptly as much as 20 feet. On such slopes gravel is usually absent and the muck rests directly upon

[2] The writer is indebted to Mr. Hanson for permission to publish these detailed data concerning a part of his 1941 operations.

bedrock. The best parts of the pay streak are on the tops of such high bedrock reefs, and the next best places are in the low saddles between the reefs. Little or no gold is found on the slopes. The bedrock itself is much weathered phyllite but in places is slate. The pieces of gold will average in weight about a grain or a little more, but nuggets worth as much as $20 have been recovered. * * * Large amounts of cassiterite are also recovered in the concentrates. This material is well rounded and occurs in all sizes from small grains half the size of a small pea up to pieces 6 inches or more in diameter. These larger pieces are usually of low grade—that is, the cassiterite is intimately mixed with vein quartz and country rock. * * * The concentrates also include a variety of other heavy minerals, of which the most common are ilmenite, pyrite, picotite, and magnetite.

The nature of the bedrock surface and the pay streaks of Deep Creek can be only partly understood by reading the descriptions and mining history quoted above or by investigating the underground workings in drift mines that may be open and in operation at any given time. For complete understanding it would be necessary at least to have access to detailed maps of all workings on the creek and to have the location and log of all drill holes. Unfortunately this information is not available. From the records it is possible to locate recent drill holes only by reference to the claim on which they were drilled; this does not permit delineation of bedrock channels and terraces or the reconstruction of bedrock contours.

Only by adding to existing records the recollections of the men who did the work and who remain in the district, Adolph Bock and Fred Hanson in particular, was it possible to draw the rough sketches of the Deep Creek placer deposits shown on plate 41. If the drill holes could have been surveyed, it would be possible to contour the entire bedrock area of Deep Creek and much of Woodchopper Creek. The most useful information the old drilling now affords to others than those who did the drilling is a record of depths of unconsolidated deposits in areas the size of a claim or larger and the frequency of gold and cassiterite in the drill cuttings. Such information is summarized in table 2. Records covering the 15 years of drilling before 1926 were not available for tabulation.

The drilling summary and the sketches on plate 41 show that the richer placer concentrations of Deep Creek were buried about 120 to 140 feet and that they lie in a zone a few hundred feet wide, along a bedrock terrace that trends about S. 60° W., corresponding to the strike of the bedrock phyllites. In general the individual rich spots are localized by gullies cutting across the face of the terrace, but in detail their reference to bedrock configuration is at many places obscure. Mertie is quoted above as pointing out that on steep bedrock slopes in the mine visited by him the muck rests directly on bedrock, and that the pay streaks are on the high bedrock reefs or in the low saddles between reefs. The writer concludes that the rich pay streaks were concentrated by gullying but not necessarily in the particular gullies most prominent at the exact time of burial of the deposits by the muck. After a pay streak was emplaced in a gully where it was later found by mining, either the gullies filled with gravel or, for other reasons, the streams coming from across the major terrace were diverted in many instances and began cutting in the adjacent weathered phyllite. These subsequent gullies concentrated whatever gold and cassiterite happened to lie in their minor drainage areas. If they deepened and grew sufficiently they could start to cut into the principal pay streaks or isolate them on local reefs. Such activity was then interrupted by deposition of muck.

TABLE 2.—*Summary of drilling by Adolph Bock, 1926–41*

Claim or area	Depth of drill holes (feet)			Number of drill holes			
	Minimum	Maximum	Average	Total	With gold	With cassiterite	Cassiterite without gold
Deep Creek:							
Good Hope and Rachel	100	125	109	3	0	0	0
Olga	70	140	104	53	37	36	2
Cleopatra	85	145	121	79	70	62	0
Pearl and southward	115	165	145	21	16	12	0
Marietta	115	160	135	62	56	52	1
Wild Goose	72	120	111	19	7	6	0
Golden Straw	125	130	126	4	4	4	0
Subtotal	70	165	122	241	190	172	3
Danielson	74	95	80	6	0	0	0
West of Danielson	65	85	75	6	2	1	0
South of Deep Creek	130	160	144	8	5	4	0
North of Good Hope	55	95	71	15	14	14	0
North of Olga	64	85	81	8	1	1	0
North of Cleopatra	50	120	76	46	20	15	1
North of Marietta	90	128	115	7	3	4	1
Total	50	165	111	337	235	211	5
Percentage				100	70	63	1.5
Innesvale Gulch [1]	10	80	27	84	36	10	0
Woodchopper Creek:							
Mohawk	85	142	113	21	10	10	0
Lorain	150	170	160	10	7	3	0
West of Mohawk	130	152	145	10	1	6	5
West of Lorain	170	170	170	1	1	1	0
One-half mile southwest of Lorain	220	220	220	1	1	1	0
Total	85	220	135	43	20	21	5
Percentage				100	47	49	12

[1] About 120 additional holes were drilled in this gulch north of the placers in search of a bedrock source of the cassiterite.

NOTE.—Of the 241 holes drilled inside the area of the listed claims on Deep Creek that are shown on plates 40 or 41, 190 of them contained gold whether or not they contained cassiterite; 172 of them contained cassiterite whether or not they contained gold; and 3 contained cassiterite without containing any gold.

The most important topographical feature in localizing the zone of the Deep Creek pay streaks is the terrace along whose frontal scarp most of the spots are distributed. The average depth of burial of the top of this terrace just north of the placers is between 80 and 100 feet. The upper edge of the scarp nearly coincides with the north claim lines of the Good Hope, Olga, Cleopatra, and Marietta, dying out on the Wild Goose. The top of the main, upper terrace contains no large known placer concentrations. Drilling shows that both gold and cassiterite are widespread on top of this terrace, but are dispersed in small concentrations unsuitable for mining under 1941 prices and costs. The relief near the escarpment is in general between 10 and 25 feet, and the slope is as steep as 45° in places. The escarpment is irregular in detail, owing to gullies which cut back into the terrace for as much as several hundred feet. Gold, cassiterite, and gravel concentrations in the gullies cut off sharply at the upper ends, and the top of the gravels in the gullies coincides with terrace level at many places. Pay streaks in general emerge from the gullies and disperse across the lower bedrock to the southwest amid other minor benches, terraces, and ridges.

A lower terrace escarpment starts near the southeast corner of the Wild Goose and follows the Golden Straw claim line southwestward. One rich pay streak, at the junction of the Wild Goose, Marietta and Golden Straw claims, lies along this lower escarpment. In lower bedrock areas, many workings and drill holes penetrate about 150 feet of frozen ground and are flooded with water from the unfrozen ground below. For example, 4 of 12 drill holes were abandoned by Bock for this reason before reaching bedrock.

The location of the principal bedrock drainage course in the Deep Creek area was not known in 1941, and pending geophysical work or more extensive drilling, it may remain uncertain. In the placer area the deepest ground is south of Pearl Fraction where several holes reach a depth of 170 feet or more. Bedrock drainage from the rich pay streak at the Wild Goose-Golden Straw claim corner would apparently have been eastward south of the Marietta claim. The main drainage course probably then swings southward toward the present low silt hill about a mile from the centerline of the tin belt (pl. 40). All that is known of the altitude and nature of the bedrock under this hill is that a few drill holes south of the crest reached bedrock generally at only 80- or 90-foot depth.

The gravels lying directly on bedrock in the Deep Creek placers commonly range from 6 to 8 feet in thickness, but at many places gravels are in the muck as high as 25 to 40 feet above bedrock; they are interbedded with the muck in a manner which indicates that they were swept off the terraces. Mertie (1934, p. 212) observed gravel 40 to 80 feet above bedrock in the Golden Straw workings in 1922. Several drill holes have shown gold in layers of interbedded gravels high above bedrock. A hole drilled 500 feet southwest of the lake on the Pearl Fraction claim showed coarse gold of a greenish cast in a gravelly layer in the muck 30 feet above bedrock. Adolph Bock sunk a shaft on the line of the drill hole, but the extent of the gold in the gravelly layer was found to be very limited.

Gold is also found above bedrock in the following places, among others: 80 feet below the surface in a 116-foot hole on the Cleopatra claim; 130 feet below the surface in a 140-foot hole near the west point of the Cleopatra claim; a rich streak of green gold 120 feet down in a 140-foot hole on the Marietta claim; and at several levels in a second 135-foot hole on the Marietta claim. Cassiterite also occurs above bedrock locally, as in an 80-foot hole on the Olga claim, and 80 feet down in a 105-foot hole on the Wild Goose claim.

In the tailings of Deep Creek, angular dark phyllite is the predominant gravel. It is particularly abundant from workings nearest to or cut into the crest of the terrace escarpment, where it constitutes 40 to 60 percent of all the gravels. A few hundred feet away from the escarpment crest the tailings show a marked decrease in the proportion of angular dark phyllite. At the Innesvale end of the area, angular graywacke makes up most of the rest of the gravel near the terrace crest, but it is not abundant anywhere in Hokeley tailings. If the angular phyllite and graywacke of immediate local derivation are ignored, a pattern is seen in the distribution of the other, more rounded gravels. In the Innesvale area, sandstone gravels are the most abundant, particularly away from the top of the terrace escarpment. Quartz and light quartzite gravels are common, and light-colored phyllite is found. In the Innesvale area, disregarding angular graywacke boulders, rounded and subrounded sandstone and quartz boulders predominate, light-colored quartzite boulders are common and dark quartzite boulders are scarce. Among the uncommon rock types are quantities of quartz-tourmaline rock and some metadiorite. In the tailings from the heads of the gulches cut back into the terrace, such as those north of the Olga and Good Hope claims (pl. 41), rounded gravels are scarce or absent and the tailings show a few boulders and much angular phyllite.

The rounded gravels in Hokeley tailings show an even distribution of rock types, with sandstone slightly predominant. The boulders are mostly quartz. Light-colored quartzite is common on and north of the Cleopatra claim, and sandstone is common on the Wild Goose and Golden Straw Claims. Unusual constituents include much quartz-tourmaline rock, with both black and brown tourmaline represented, much chromite, and rarely coarse-grained biotite granite. Chromite is found in most of the concentrates, but is especially abundant in the rich gravels at the north corner of the Golden Straw claim. It occurs as subrounded, coarse-grained pebbles and cobbles with submetallic luster, fair parting, lavender alteration, and high density, and makes up 5 to 20 percent of the concentrates. Its bedrock source may be some phase of one of the small basic intrusive bodies found in the belt along the slope of the ridge 2 miles to the north. The tailings are among the richest in cassiterite in the Tofty area; sampling by the Survey showed that 1 pile contained 4.3 pounds per cubic yard.

Waters (1934, p. 238–239) found concentrates from both the Hokeley and Innesvale areas to contain cassiterite, ilmenite, picotite, zircon, pyrite, magnetite, aeschynite, and gold. In addition he found well-rounded monazite pebbles in Innesvale concentrates.

WOODCHOPPER CREEK

Gold and cassiterite were discovered on Woodchopper Creek in 1913, and prospected and developed the following year. In 1915 and 1916 the largest operations in the tin belt were those of Sylvester Howell, who worked these mines and others under the name of Howell and Cleveland, with Jennie Cleveland as his partner. They employed more than a hundred men on large-scale drift mining. For a few months they increased cassiterite recovery by duplicating sluicing, that is, by sluicing through one string of boxes while cleaning up a second. The town of Woodchopper grew rapidly, and died just as rapidly when the Howell and Cleveland operations were shut down.

From 1917 until 1919, F. Jorgenson and C. H. Clegg mined in the deep ground of the Lorain claim at the south end of the pay streak recovering much cassiterite, but they found that water flooded all mining attempts south of their workings. They recovered about 1.2 to 1.3 pounds of cassiterite per square foot of bedrock. Jorgenson also worked at the north end of the principal pay streak on the Mohawk claim in 1915, and Hanson and Hasler continued work in this area in 1921. In 1926 and 1927, Hanson, Tilleson, and Linder mined extensively at the northwest corner of the present lake formed by surface subsidence over the lower Howell and Cleveland workings (pl. 41), and in 1941 Matt Jarvi mined for 2 months along the west side of the pay streak on the Mohawk claim.

The ground on all sides of the Woodchopper pay streak has been prospected by drilling and shaft sinking by several people. These operations include the drilling by Adolph Bock summarized in table 2, as well as a line of prospect shafts crossing the Woodchopper

Creek valley on claims of William Bargery 3,000 feet upstream from the north corner of the Mohawk. Cassiterite and gold have been reported at or near Bargery's shafts, and gold is found upstream, reportedly unchanged in character except that it is no longer found with cassiterite. At the upper end of the Mohawk claim 1 drill hole in 7 showed cassiterite and gold.

The nature of the principal pay streak, which was largely worked out by Howell, is shown in the sketch on plate 41 as it was described to the writer by Adolph Bock and others. The bedrock on the Mohawk claim has considerable relief, but southward on the Lorain, except for a minor eastward-trending terrace on the west side it is nearly flat. The head of the Mohawk channel is buried about 100 feet, whereas 0.3 mile south at the Lorain claim line it is buried about 150 feet, indicating about a 5-percent slope (allowing for the gently sloping surface). West of the Mohawk pay streak, bedrock rises rapidly for about 600 feet to the top of a bench that is buried only about 50 feet. The escarpment of this terrace swings away from the pay streak downstream, and west of the north Lorain claim line has a southwesterly trend. Half a mile west of the claims it is said to swing to the northwest, and more deeply buried ground is in line with the projected trend of the tin belt. East of the Mohawk pay streak some local, nearly barren channels were found below the bedrock terrace that extends from the Wild Goose claim on Deep Creek. South and southwest of the pay streak area the present surface is almost flat, sloping gently southward, and spotty records of drilling and shaft sinking indicate that the bedrock surface, buried 170 to 220 feet or more, has about the same slope as the present surface. Many holes in this area were abandoned before they reached bedrock when they penetrated the upper layer of frozen silts and gravels. One 220-foot hole half a mile S. 60° W. from the southwest corner of the Lorain claim showed cassiterite and a small amount of coarse gold in thick gravels.

The gravels in the Woodchopper pay streak are reportedly relatively thick. On the Lorain claim they are 40 feet thick. In the angular gravels of local derivation in the tailings, light-colored phyllite predominates over dark phyllite, and dark quartzite is abundant in the central and lower workings. Angular quartz pebbles are common. The rounded and subrounded gravels consist mainly of sandstone, with small amounts of light-colored phyllite, graywacke, quartzite, and quartz. In the debris of boulder size, rounded quartz boulders are a third of the volume. Rounded light-colored quartzite boulders are abundant in the upper workings and decrease downstream, but the distribution of rounded sandstone boulders is the reverse. Unusual rock types such as the quartz-tourmaline rocks and metadiorite were much less abundant than on the creeks to the east.

WEST OF WOODCHOPPER CREEK

Part of the area west of Woodchopper Creek in the projected course of the tin belt has been discussed in the preceding section. Half a mile west of Woodchopper Creek a bedrock terrace impinges on the north side of the area, and cassiterite and gold were found in a 220-foot hole half a mile west-southwest of the lower Lorain corner. Several holes have been drilled a quarter to a half mile west of the Mohawk workings. Logs of some of these holes are summarized in table 2. Most of them are 130 to 152 feet in depth; 6 of 10 holes showed cassiterite; 5 of them did not show any gold. Mr. Bock reports, however, that cassiterite did not predominate in the heavy concentrate from those holes as it does in concentrates from holes to the east.

In a shaft just west of the southernmost lake 2 miles west of Woodchopper bedrock was reached at a depth of 120 feet but no gold or cassiterite was found. Another shaft a short distance farther west penetrated gold lying on bedrock 210 feet below the surface; a boulder resembling cassiterite, probably brown tourmaline and quartz was found in the shaft, but no cassiterite. Cassiterite reportedly has been found in this area and for miles to the west, but no reliable confirmation could be obtained.

GOLD BASIN AND KILLARNEY CREEKS

In the Baker Creek drainage basin east of the Patterson Creek part of the tin belt (pl. 40), prospectors have found cassiterite and gold in a belt trending more eastward than the belt in the Patterson Creek drainage basin. The earliest recorded prospecting in this area was in 1912, when a large area of very low grade ground with irregular gold distribution was reported on Cooney Creek, tributary of Killarney Creek. Both Gold Basin and Killarney Creeks were drilled in the next few years by Fred Hanson and Adolph Bock and by Sylvester Howell and William Bargery. Many shafts were sunk by different prospectors. Interest subsequently lagged until the price of gold rose, when random prospecting was resumed. The locations and logs of drill holes and prospect shafts were not available. Except for a few muck dumps at the collars of some of the old prospect shafts, a visitor in 1941 saw nothing in the area indicating the nature of the deposits on bedrock. The following comments are taken largely from the experiences of Fred Hanson, Otto Hovley, A. H. Rieder, and others who have worked and lived in the area.

In general cassiterite with gold is found on phyllite bedrock from south of where the main trail crosses Gold Basin Creek, to Killarney Creek (pl. 40). Along Killarney Creek, cassiterite is abundant for 1,000 feet but it is fine. One prospector says that it occurs in a belt half a mile wide north of the junction of Killarney and Gold Basin Creeks. The Survey field party panned a cassiterite pebble from a prospect dump near this stream intersection. Opinions differ on the eastward extension of the tin belt. One may says that there is no cassiterite east of Killarney Creek. Another says it has been found as far east as half a mile beyond the largest of the small lakes east of Killarney Creek but that 2 miles of drilling farther eastward toward Utah Creek showed no cassiterite. Others say that it is found for 3 miles east of Killarney Creek or nearly to Utah Creek and that in this area the concentrate is finer grained, more disseminated, and without much gold; any gold is light and fine.

An east-west line of drill holes reportedly showed the bedrock altitudes to be about equal between Gold Basin and Killarney Creeks in the area of proved cassiterite occurrence. Farther east bedrock altitudes drop. The depth of burial of the bedrock on Gold Basin and Killarney Creeks ranges from 40 to 80 feet, varying more with surface topography than bedrock topography; at Utah Creek bedrock is about 100 feet below the surface.

Compared with the placers in the Patterson Creek drainage basin, the placers of Baker Creek, more particularly those west of Killarney Creek, yield cassiterite mostly in finer sizes. The coarsest piece found by drilling was an inch in diameter. Some drill holes showed as much cassiterite as many of the drill holes in the producing areas to the west, but indications are that the average amount of cassiterite per unit area is less. Furthermore, the accompanying gold is very fine and was not sufficiently plentiful to be mined profitably under 1941 economic conditions.

A divide between Gold Basin Creek and Cache Creek has a minimum altitude of about 930 feet. This divide is about 500 feet higher than surface altitudes at the Woodchopper Creek placers, 200 feet higher than surface altitudes on Cache Creek 1 mile west, and 120 feet higher than Gold Basin Creek. It overlies a bedrock divide indicated by prospecting to be about 900 feet above sea level, or 145 feet above bedrock in Gold Basin where the principal trail crosses the creek, and 220 feet above bedrock in the principal Cache Creek workings. Evidently, no bedrock stream channel connects Gold Basin and Cache Creeks in the line of the tin belt at the level of the principal placer deposits. Cassiterite on this divide has not been reported by the prospectors. The depth of burial ranges from 28 to 65 feet, averaging about 40 feet.

CASSITERITE OUTSIDE THE TOFTY TIN BELT

Outside of the Tofty tin belt the closest placers where cassiterite is relatively abundant are those of Morelock Creek on the north side of the Yukon River, 16 to 20 miles north of the Woodchopper Creek workings. Cassiterite is a minor constituent in placer concentrates from Hunter and Troublesome Creeks north of Wolverine Mountain in the Rampart area and about 34 miles northeast of Killarney Creek (Waters, 1934, p. 232, 235–6). There the cassiterite occurs as dark-amber to golden-yellow or nearly colorless crystals, or as wood tin, in either form unlike the Tofty cassiterite. In the Eureka Creek area east-northeast of the Tofty tin belt and in line with it geographically and structurally, cassiterite has not previously been reported. However, according to A. H. Rieder, a few pebbles of cassiterite were found by Johnson and Johnson on Glen Creek 14 miles from Killarney Creek in 1939, and appear to be the same as the Tofty cassiterite. In 1941 Samuel L. Cotten, engineer for the Cleary Hill Mines Co., showed the writer a small pebble of cassiterite panned from the area then being prepared for sluicing at the junction of Eureka and Pioneer Creek 15 miles east-northeast of Killarney Creek. The cassiterite pebble is dense, is well rounded, and includes dark breccia fragments, like much of the cassiterite at Tofty. It is possible that these few pebbles were planted by pranksters, but the writer is inclined to agree with the finders that the occurrences are genuine.

Mining and prospecting on the streams a few miles north and south of the Tofty tin belt have thus far failed to show cassiterite of the Tofty type. A few small angular clear-brown grains of cassiterite were reported by Waters (1934, p. 240) from the bottom of a prospect pit on the Quartz Creek bench 2 miles north of the Sullivan Bench pit. This area was drilled and prospected extensively in about 1940 by the Cleary Hill Mines Co., but cassiterite was not mentioned in the logs of 185 drill holes. The gold in the basin of upper Sullivan and Quartz Creeks, which was developed by this drilling program, has a greenish cast and is more angular than most of the gold in the tin belt 2 to 3 miles to the south. The depth of burial between streams in the area is only 5 to 10 feet; most of the overburden is creep and wash material.

In the Boulder Creek drainage basin which parallels the tin belt 6 or 7 miles to the north and rises on Roughtop Mountain, no cassiterite was found in the concentrates from the several placer operations conducted there in the past 30 years. American Creek, south of lower Boulder Creek and about 6 miles northwest of the Woodchopper Creek workings, also shows no cassiterite. It has been extensively dredged for gold since 1917.

South of the tin belt most of the bedrock is so deeply buried by Quaternary alluvium that it has received only a fraction of the testing that was given areas to the north. No placer concentrates were available in 1941 to the Survey for study from deposits on bedrock of lower Sullivan, Cache, and Patterson Creeks or from Big Denver (Rock) and Little Denver Creeks. Together these streams drain the area from 1 to 6 miles south of the tin belt (pl. 40), including the northwest slope of Hot Springs Dome. Sands from the present streambeds evidently contain no cassiterite. Prospectors who reached bedrock in this area have never reported finding cassiterite, according to the 1941 inhabitants of the Tofty and Hot Springs districts. Nevertheless this mineral could possibly occur here. The same statements apply to Blowback Creek which drains northward from Hot Springs Dome into Baker Creek.

In the 2-mile-wide belt occupied largely by shallow muck and creep material, immediately north of the tin belt, there has been much prospecting for the lode source or sources of the cassiterite and gold. In the early days of the district, Eakin (1913, p. 37–8, and 1915, p. 93–4) repeatedly stated that the source of the cassiterite was veins and dikes in the immediate area of the placers. He directed the attention of the miners and prospectors to the bedrock in the neighboring hills and to that exposed in the mines rather than to the Roughtop Mountain area which was then receiving much attention. Mertie (1934, p. 207–9, 216–17) also directed attention to the neighboring area, but added that the quartz-cassiterite veins in this belt may have been removed by erosion, leaving the heavy cassiterite behind as residual deposits. Thus encouraged, many men have spent much of their time and resources prospecting this area since the early days of the district.

The negative results thus far (1941) attest either to the effectiveness of muck and creep material in concealing the character of the bedrock, to the correctness of Mertie's hypothesis that cassiterite lodes no longer exist, or to the incorrectness of the general theory. For most of the work done on the hillside area, neither actual records nor first-hand recollection are available. The best existing records are those of Adolph Bock which relate to the drilling of about 200 unsurveyed holes in the upper Innesvale Gulch area, 84 drill holes of which are briefly summarized in table 2. In the summer of 1941, a few drill holes were sunk in the upper Hokeley Gulch area and on the west side of Tofty Gulch by Cessford, Albrey, and Amalon. From time to time prospect shafts have been sunk in upper Idaho Gulch by Jack Donahue and in the Cache Creek area by Otto Hovley, but almost all reported observations of bedrock showed only the common dark phyllite or sporadic graywacke, sandstone, quartzite, and rarely a barren quartz stringer.

Exceptions to this generalization are seen in small mafic intrusive bodies uncovered by Donahue in upper Idaho Gulch and by Patrick McLaughlin on the ridge between Harter Gulch and Sullivan Creek (fig. 48). The Idaho Gulch intrusive body appears from the limited exposure to be a very small plug with a serpentinized diorite or gabbro core and a finer grained shell, but the Harter outcrop is dikelike in shape and is conformable with the country rock. McLaughlin also exposed a crystalline limestone bed a hundred yards south of the metadiorite, containing magnetite and hematite. The writer found a metadiorite dike along the west side of Woodchopper Creek valley, 20 feet wide, exposed for 150 feet, and apparently conformable with the bedding. But mafic rocks, although they may be the source of the chromite, picotite, ilmenite, magnetite, and several other minerals in the placer concentrates, are not known sources of cassiterite. However, they show limited igneous intrusion in the belt just north of the placers and strengthen the possibility that complementary acidic dikes, perhaps containing tourmaline, and quartz-tourmaline veins, will also ultimately be found.

As an estimate, it may be said that despite 30 years of prospecting and the evidence obtained from outcrops, shafts, and drill holes, probably less than 1 in 300 square feet of bedrock of this 2-mile-wide tin belt had been seen or tested by 1941. It is true that much of the covered area near outcrops and test holes may be excluded by inference, but a very large, unknown area still exists that could contain narrow dikes, veins, or beds of cassiterite-bearing rocks.

ORIGIN OF THE CASSITERITE

Although one hypothesis of the origin of the cassiterite is preferred, two must be considered until the discovery of conclusive evidence such as a bedrock source of the ore.

The hypotheses briefly are:

1. A Tertiary stream brought the cassiterite into the area of the tin belt from an outside source.
2. A primary bedrock source exists, or formerly existed, in the line of the tin belt or within a mile or more north of the belt.

According to the first hypothesis, a major Tertiary stream flowing above the 900-foot altitude of the present Cache Creek-Gold Basin Creek divide brought the cassiterite-bearing gravels and some gold into the line of the tin belt. This master stream subsequently changed its course or was captured during the lowering of regional base level in late Tertiary time. Headwater tributaries of the then entrenching Patterson and Baker Creeks cut back into bedrock in the belt of the main placer deposit and redistributed the cassiterite and gold into placers related to their own courses and nearly at right angles to the older major placer belt. This process of redistribution was interrupted in early Quaternary time by a raising of regional base level and by heavy aggradation of glaciofluviatile deposits from the Alaska Range, resulting in burial of the placers. The area of quartz-tourmaline-cassiterite veins from which the major Tertiary stream derived the cassiterite is generally assumed under this theory to have been Hot Springs Dome or an unexposed granite body nearer the tin belt. The monzonite intrusive rocks of Roughtop Mountain are not as acidic as those generally associated with tin mineralization and they furthermore lack the abundant tourmaline of the ores and of the Hot Springs Dome intrusive rocks.

This hypothesis accounts for the almost universal rounding and polishing of the cassiterite pebbles with no notable increase in angularity upstream in individual gulches; for tourmaline dike rocks, granite, monazite, aeschynite, and large zircons among the gravels and sands; and in general for placer deposits along what was perhaps the course of a major stream in Tertiary time, which can be inferred from the lineation of bedrock valleys west of the Tolovana River region.

The weaknesses of the hypothesis are several. The most significant is the failure to find cassiterite of the Tofty type outside the tin belt, with the rare exception of a few pebbles in the Eureka area. Hot Springs Dome has much tourmaline and quartz but thus far cassiterite has not been found in either its outcrops or its drainage area. The length and narrowness of the tin-belt area and the sharpness of the upstream tin cutoff cannot easily be explained under the hypothesis of a major Tertiary stream, which would not normally be expected to confine itself for such a distance to such a narrow, comparatively straight channel throughout the entire period of its cassiterite deposition. The presence of larger amounts of low-grade, less dense, cassiterite-bearing pebbles in the gravels of the creeks at the west end of the tin belt has been cited as evidence of major stream deposition from east to west, but the pebbles are as easily accounted for by variation in mineral deposition under the other hypothesis. There is no increase in angularity of cassiterite pebbles toward a supposed remote source; the cassiterite of Gold Basin and Killarney Creek is fully as rounded as the cassiterite of Woodchopper Creek. A few subangular tourmalinized phyllite fragments with quartz-tourmaline-cassiterite veinlets in the placer gravels are also not explained.

Another difficulty with the hypothesis is that of stream grade. To move coarse cassiterite pebbles and coarse gold for 5, 10, or perhaps

15 miles downstream requires either a very large stream with a moderate grade or a fairly large stream with a steep grade. A detailed geomorphic study of Tertiary drainage may possibly show that such a stream might have flowed over the site of the tin belt, but a combination of such conditions seems unnecessary in explaining the general Tertiary drainage. A confined major stream large enough or steep enough to erode a cassiterite deposit and transport it for miles might be expected to have left other evidence in the region such as prominent high-altitude terraces and scattered, thick boulder and gravel deposits of rounded resistant rock types such as quartzite. The known gravel and boulder deposits of rounded, resistant rock types are comparatively limited and local in distribution and derivation, with the possible exception of rare igneous types. Such gravels may exist, however, in the lower Patterson and Baker Creek valleys, having been swept there by later Tertiary runoff related to the present stream pattern.

According to the second hypothesis, certain quartz veins in the area of the tin belt or in a narrow belt immediately north of the tin belt were brecciated not long after their emplacement in Tertiary time. The openings thus created were filled during a brief intense period by tourmaline with cassiterite, more quartz, and a small amount of fluorite emanating from an unexposed granitic magma of the Hot Springs Dome type formed somewhere under the tin belt. Minor tourmalinization of the intruded phyllite and other sedimentary units of the Lower Cretaceous country rock occurred near the brecciated quartz veins, accompanied by some filling and replacement of these altered rocks with cassiterite, tourmaline, and quartz. However, such mineralization was not extensive.

Later in Tertiary time, after a lowering of the regional base level of erosion, the several thousand feet of Cretaceous sedimentary rocks above the present bedrock surface were slowly eroded by streams of various sizes but of moderately low gradient. The cassiterite had originally been deposited largely in the upper parts of the quartz veins which were eroded away during this period. Most of the Cretaceous country rock disintegrated comparatively rapidly under conditions of weathering and erosion. Very little of the phyllite and softer graywacke resisted weathering and abrasion long enough to become rounded, so that at any given time the existing gravels of such material, whether rounded or not, were comparatively recently exposed and could be expected to break down quickly to sand and silt sizes and to be carried away in suspension in the Tertiary streams. On the other hand, some of the more indurated sandstones, quartzites, and vein quartz, and especially the cassiterite, resisted disintegration. Under the relatively low stream gradients, fragments of such material remained intact and moved only comparatively short distances from the sites of their host veins, some of the cassiterite pieces gradually moving down with the eroding surface for as great a distance as they were moved laterally by streams. Although they moved such short distances, the cassiterite pebbles and a few of the other boulders, gravels, and pebbles were rounded and polished by abrading action of lighter weight, detrital material under the influence of creep, sheet wash, and stream action. Gold from the quartz veins of the belt, not necessarily the same veins as those containing cassiterite, underwent the same treatment and also remained behind in residual deposits. Stream action during the Tertiary period concentrated the gold and cassiterite into several placer deposits of different sizes. Fluctuations in regional base level and other changing local conditions caused several periodic changes in the rate of erosion, resulting sometimes in aggradation for a period and in changes of stream course. Thus, a concentration of cassiterite, gold, and gravels could be abandoned temporarily by its parent stream which might then cut another channel nearby leaving the placer on a minor bench, later to be reconcentrated as the lateral drainage into the new stream course cut back into the older placer area.

By early Quaternary time the topography of the region corresponded to the present bedrock topography of the region. The cassiterite-bearing parts of the quartz veins had been largely eroded away, leaving the cassiterite behind, whereas almost all other rocks except those recently exposed were disintegrated and carried from the region by the streams. At this time the regional base level was raised, with some fluctuation, and the glaciofluviatile silts were deposited, burying all the valleys and the low hills including the slopes of those north of the tin belt. Owing to the subsequent lowering of base level, the hillside areas have been freed of much of their Quaternary silt cover but are masked with weathering detritus and creep material several feet thick that impinge upon the edges of the remaining Quaternary silt deposit.

The greatest difficulty with this theory is that cassiterite-bearing quartz-tourmaline veins, or their roots, have not yet been recognized in or just north of the tin belt. It has also been argued that the cassiterite pebbles are too rounded and polished to be residual and that there is an absence of the fine cassiterite that is generally found in a residual deposit. Another stated objection is that the cassiterite pebbles are larger, lighter, and lower grade at the west end of the belt, indicating sorting from east to west.

The first objection, that the veins have not yet been found, has at present two answers, both previously discussed: first, that only about 1 in 300 square feet of the hillside belt has been seen by man or tested by drilling, and second, that the cassiterite-bearing parts of the quartz vein system have been eroded away, leaving the residual cassiterite, whereas the quartz veins and lenses now exposed were formed at greater depths and are not necessarily representative of the particular group or belt of veins that were brecciated, and then filled by the cassiterite and associated minerals. Strongly supporting evidence for the existence of such veins, even in the present bedrock area, is the small amount of angular cassiterite-quartz-tourmaline fragments in the gravels and concentrates, and the rare angular pieces of tourmalinized, cassiterite-bearing country rock. The argument that the pebbles are too rounded to be residual is answered by the previous explanation, and by the realization that the Tofty cassiterite pebbles are at least 2.7 times as heavy in water as the country rock fragments. A headwater stream of small volume and relatively low gradient could round them and leave them behind more readily than it could move them. The widespread belief that there is an absence of fine cassiterite probably results from the failure of prevailing sluicing methods to recover much of the cassiterite. The Survey sampling found small amounts even in the coarse tailings on every creek in the district, and samples of much of the rest of the fine cassiterite that was mined and lost may be panned short distances down the drains from the lower end of sluice boxes.

That the density of the cassiterite is less on the western creeks is true; otherwise the cassiterite concentrate recovered by Survey sampling from Woodchopper Creek tailings was nearly the same as that from Cache Creek. From Idaho Gulch to Deep Creek the gravels contain more than the usual amounts of pebbles from the tourmaline end of the tourmaline-cassiterite scale. Most of these are too light to be caught in the riffles, but a few are intermediate in density, and their inclusion in the cassiterite concentrates handpicked from the riffles by the miners lowers the grade. However, as such hybrid pebbles are uncommon in the tailings of Woodchopper Creek, the westernmost creek of the belt, variations in the regional distribution of tourmaline-rich cassiterite-bearing pebbles are perhaps better explained by differences in local sources than by east-to-west sorting by a master stream.

Additional factors supporting the second hypothesis are the sharp upstream cutoff of the deposits on individual creeks and the discovery of altered intermediate and mafic igneous intrusive rocks in the bedrock area north of the placers. The intrusive rocks, although of types not directly associated with cassiterite deposits, nevertheless indicate igneous activity and strengthen the possibility that small acidic igneous dike rocks, notably tourmalite, may later be found.

The granite cobbles and the monazite, aeschynite, apatite, and zircon can be accounted for under either hypothesis. Quartz veins, pyrite, and the rare arsenopyrite and galena cannot be shown to be restricted to the tin belt.

RECOVERY OF THE CASSITERITE

Factors governing the recovery of cassiterite in the tin belt are the richness of the gravels being mined, the physical properties of the cassiterite, and particularly the sluicing method (pl. 43*A*). Concerning the richness of the gravels, the foregoing discussions of the nature and history of the individual placers need only be summarized. The tin belt yielded about 315 tons of cassiterite concentrates through 1941 as a byproduct to the recovery of several million dollars in gold. The richest placers were discovered and worked out before 1919, yielding a total recovery of about 262 tons of cassiterite concentrates, much of which came from reworking tailings (pl. 43*B*). Only scattered records are available to indicate the richness of the placer gravels. In 1918 one rich pay streak on lower Woodchopper Creek yielded 1.2 pounds of cassiterite per square foot of bedrock or assuming that 6 feet of gravel was removed, about 5.4 pounds per cubic yard of mined gravel. Small pay streaks of bonanza richness in cassiterite are said to have yielded as much as 8 pounds per square foot or 36 pounds per cubic yard, and it is reported that a tiny area yielded 70 pounds of recovered cassiterite per cubic yard of gravel. The average yield from the rich pay streaks found in the early days of the district, where an effort was made to save the cassiterite, was probably more nearly 0.5 pound per square foot or 2.3 pounds per cubic yard. Corresponding bonanza gold values were $10 to $40 per square foot at the price of gold then prevailing, and many of the richer placers reportedly averaged $4 to $6 per foot over large areas. Since 1919 more complete records indicate a total cassiterite recovery of 53 tons, mostly from original operations rather than from reworking of tailings. The drift mines of the district recovered during this period an average of about 0.3 pound per square foot of bedrock mined or about 1.4 pounds per cubic yard, but the large open-pit operations on Tofty Gulch and the bench of Sullivan Creek have recovered only 0.02 pound per square foot from ground previously drift mined.

The foregoing figures are based on the amount of cassiterite actually recovered from the placer gravels and do not account for the loss of cassiterite in sluicing operations. Records from which to compute the total cassiterite content of the individual pay streaks are almost entirely lacking. Rough calculations on combined statistics from drift mines in the last 20 years and on sampling results of the tailings indicate an average recovery of about 57 percent, including recovery from tailings. The only specific tests on percentage recovery were done by the Cleary Hill Mines Co. during the sluicing operations in the Sullivan pit from July 19 to August 9, 1941, with the following results:

	Test 1	Test 2	Combined
Gravels sluiced, cubic yards	9, 000	4, 840	13, 840
Cassiterite in gravels, pounds per cubic yard	.81	.85	.82
Cassiterite in gravels, total content in tons	3.64	2.07	5.71
Cassiterite recovered, pounds per cubic yard	.27	.26	.27
Cassiterite recovered, total in tons	1.22	.63	1.85
Gravel tailings, cubic yards	4, 100	2, 900	7, 000
Cassiterite in tailings, pounds per cubic yard	1.18	.99	1.10
Cassiterite in tailings, total content in tons	2.42	1.44	3.86
Recovery, percent	33.5	30.4	32.3

Test 1 was made largely on old tailings that were left on the original surface from drift mining and were washed down during strip mining. Because the cassiterite content of the gravels treated during these tests was higher than the average found in the open-pit operations, an extraordinary effort was made to save it. The cross riffles were hand picked for cassiterite twice daily, which accounted for two-thirds of the cassiterite actually saved. Thus, it may be noted that the percentage recovery by methods ordinarily used in this pit would have been much lower, or perhaps 10 percent. In these tests, the tails were tested frequently by panning as they formed, and the cassiterite content of the heads was computed with due consideration of the recovered cassiterite and the sliming ratio. The volumes of the heads and tailings were estimated by Mr. H. H. Thurston, manager. As the cut was 56,000 square feet in area, the indicated cassiterite content of the heads per square foot was 0.203 pound and the recovered cassiterite 0.066 pound.

The Cleary Hill Mines Co. tests show not only that two-thirds of the cassiterite was lost under comparatively favorable conditions for this type of operation but also that the tenor of the tailings is higher than that of the original gravels. This is explained by the high sliming ratio of the virgin gravels, perhaps 45 to 60 percent as mined in the Sullivan Bench pit. It also seems that the content of cassiterite in tailings from operations with 50 percent slimes may be a fair index of the tenor of cassiterite in the gravels being sluiced.

Normally the operations in the tin belt area were designed to recover gold. Where cassiterite could also be saved by using existing equipment without loss of gold and without increasing costs prohibitively, an effort was made to increase its recovery. In many operations no cassiterite was saved during sluicing, but many of the tailings piles so deposited have since been reworked for cassiterite and gold by resluicing the drop areas around the ends of the original sluice boxes (pl. 43*B*). Only rarely has cassiterite been actively sought primarily in the original operation. Such instances occured chiefly during the First World War. The most notable example was the double sluicing on Woodchopper Creek by Howell and Cleveland at which time the district produced more than 100 tons. The price of tin at that time more than made up for the increased labor costs of the frequent cleanups of a double-sluicing system.

A common practice in the tin belt in 1941 and earlier was to give sluice boxes from 10- to 12.5-percent slopes and to use mostly longitudinal riffles. This was necessary to break frozen clumps of sandy and silty gravel, free the gold, and carry away most of the coarser cobbles that would otherwise have to be removed by hand from the boxes. Gravels were sluiced for 3 or 4 weeks between cleanups, and the riffles were quickly packed with angular and rounded gravels and cassiterite after a cleanup. The result is that although gold recoveries were fairly satisfactory to the operators, the rounded pebbles of cassiterite were rolled over the top of the packed riffles by swift sluicing currents 4 to 7 inches deep. Where cross riffles were used, the amount of cassiterite saved in a cleanup increased. On longitudinal riffles, cassiterite has been observed to accumulate for a time during sluicing periods and then slide down and out of the boxes as a mass, sometimes carrying a few gold nuggets with it.

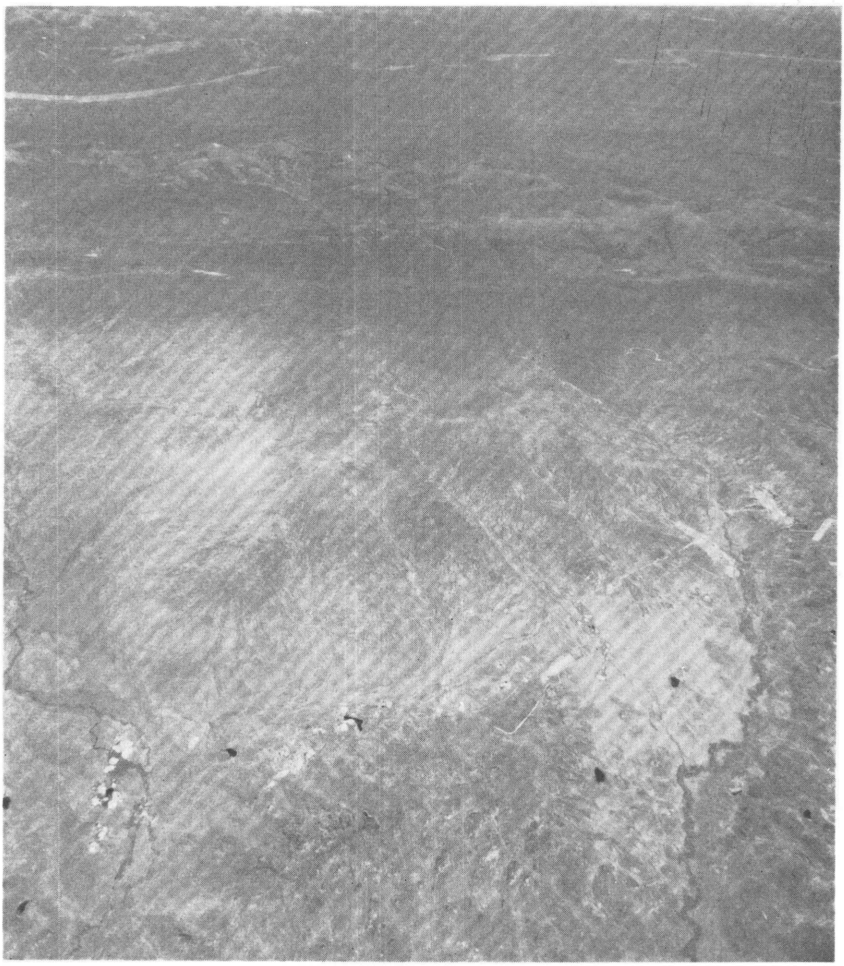
The cleanup in the Tofty Gulch pit on June 18, 1941, by the Cleary Hill Mines Co. will serve as an example of larger scale sluicing practice and riffle arrangement in the district. The cleanup terminated 25 days and nights of sluicing and bulldozing of a bedrock area of 70,000 square feet, 23 feet deep including 17 feet of muck, 3 feet of gravel, and 3 feet of bedrock. Nine metal sluice boxes, each 10 feet long, had been in place in a steep trench excavated in bedrock during the sluicing period. The lower end was 10 feet below normal bedrock level and beyond it was a sump 4 feet lower. The drop from head to foot of the sluice was about 10 feet, or 11 percent. The first 30 feet had 12-pound steel rails placed lengthwise, alternate rails being upside down; the next 10 feet had 26 thick rubber cross riffles made of old tire casings; the next 20 feet had more longitudinal steel rails, after which there were 15 feet of more rubber cross riffles and 5 feet of steel-rail cross riffles. The last 10 feet of the sluice had a cocoa-matting undercurrent arrangement protected by a sheet screen with half-inch holes. The riffles were all tightly packed, mostly with angular phyllite fragments of sand to gravel sizes but with conspicuous cassiterite pebbles. Of the total tin recovered in the cleanup, 37 percent was in the upper 55 feet of the boxes and 63 percent was in the lower 35 feet including the undercurrent. The gold was about 4.6 percent in nugget size and most was caught in the upper longitudinal riffles.

Equally steep grades but shorter sluice lengths, ranging from about 40 to 60 feet, were used in several sluicing operations observed at drift mines operating in 1941 (pl. 43*A*). Longitudinal pole riffles were common, and any cross-pole or steel-rail riffles used were generally put in the lower end of the sluice boxes where the grade might also be somewhat decreased. The depth and swiftness of sluicing current were less than in larger scale sluicing practice.

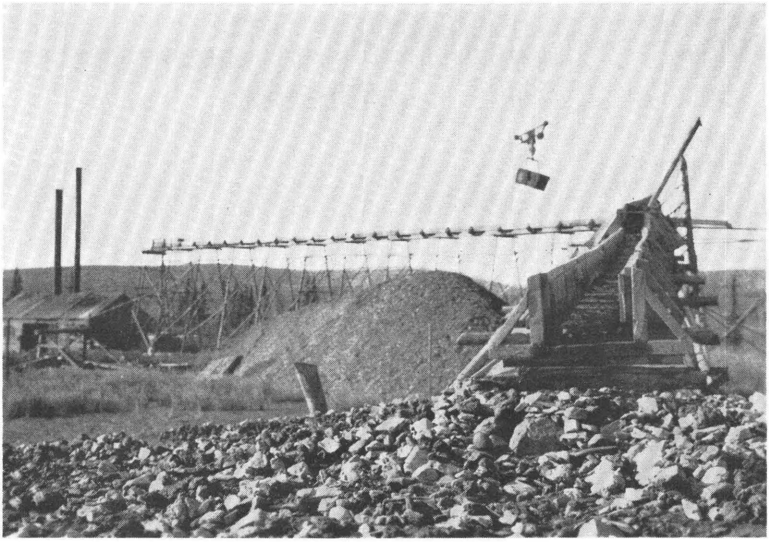
Most operators agreed that recoveries could be doubled by the more extended use of cross riffles, longer sluices, lower grades, much more frequent cleanups, and particularly by handpicking the cross riffles for cassiterite every few hours during interruptions in sluicing. The reasons why these things were not done were largely economic, partly operational. Under normal conditions many operators doubted that the added income from tin would offset the cost of the increased necessary labor. There was some fear of the high-grading of gold nuggets by the tin pickers. Longer, flatter sluices with slower currents would mean more frequently clogged sluices and much more work for a sluice attendant. The same type of reasoning was applied to duplicate sluicing, which requires extra equipment and much cleanup labor.

Cassiterite concentrates were normally shipped in 125-pound canvas sacks to Seattle for reshipment to Singapore. Approximate measurements and determinations of density made on cassiterite concentrates from the Sullivan Bench and Tofty Gulch pits in 1941 by the Survey gave the following results:

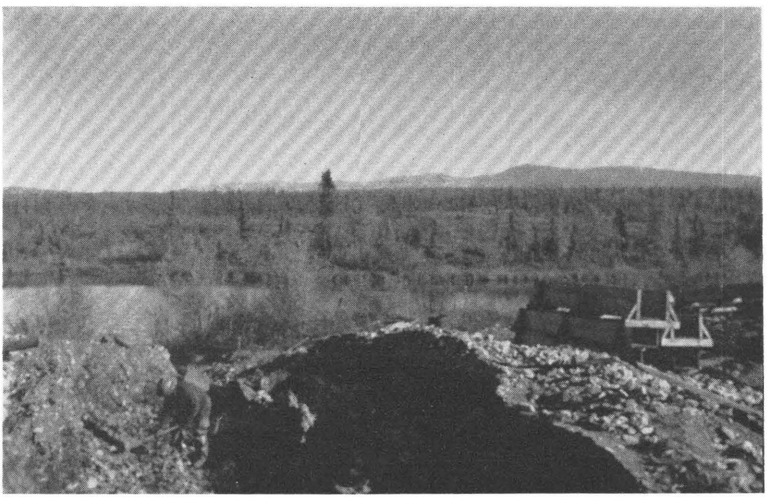
Material	Size range, in inches			Percent foreign particles (pyrite and other minerals, and metal scrap)	Density, including voids	
	Maximum	Minimum	Average		Pounds per cubic foot	Specific gravity
Shipping concentrate	2.00	0.05	0.50	5	225	3.60
Do	2.00	.05	.50	2	230	3.68
Hand-picked coarse concentrates	2.00	.50	1.30	0	222	3.55
Hand-jigged black sands	.20	.06	.10	15	255	4.08
Do	.20	.06	.10	20	247	3.95



Aerial photograph of Tofty tin-belt workings in 1941, light areas from Woodchopper Creek on the lower left to Sullivan Bench on the right center. Yukon River in the background. (Courtesy U.S. Air Force.)



A. Sluicing on Deep Creek, 1941. Surface plant of Hanson and Albrecht on the Marietta claim; the boiler and pumphouse are behind the low shaft headframe. The elevated flume carries returned water to the head of the sluice where the bucket is about to dump against shear boards at the automatic tipple. Typical tailings in the foreground.



B. Reworking a Deep Creek tailings pile, 1941. Tailings near the center or drop area of this old pile on the Marietta claim are being resluiced. Hot Springs Dome is in the background.

The above figures indicate cassiterite in the black sand sizes is more nearly pure than cassiterite in the gravel sizes. The regular shipping concentrate, though it contains fewer impurities such as pyrite and metal scrap and is apparently comparable in percentage of voids to the black sands, is nevertheless of lower density and therefore lower tin content. The impurities in the coarse pebbles are dominantly quartz and tourmaline.

A true specific gravity determination, excluding voids, of 24 pounds of hand-picked coarse cassiterite pebbles from the Sullivan pit gave a value of 5.8 compared to 6.8 to 7.1 for pure cassiterite, indicating that the coarse pebbles are about 70 percent cassiterite.

A common practice is to amalgamate the gold in the few tens or hundreds of pounds of black sands accumulated in a season at a given property and then to throw the sand away. Such sand is amenable to treatment in a simple Joplin jig, as shown in experiments by the writer. The jig used was a simple, screen-bottomed can placed in a barrel of water and operated by hand in a jigging motion. An 8-pound sample screened to the size range between $1/16$ and $3/16$ inches was originally 41 percent cassiterite grains, the rest pyrite and gravel. In 45 minutes of hand-jigging, including the retreatment of middlings and tailings, a concentrate 84 percent cassiterite weighing 3.5 pounds was obtained, representing an almost 90 percent recovery and a grade suitable for shipment.

SAMPLING OF TAILINGS

The tin belt was studied in 1941 primarily to find a basis for estimating the reserves of cassiterite in view of the war-time need for tin from domestic sources. As the tailings from former operations represented a sizable reserve of the most immediate availability in the district, and as a systematic study of their cassiterite content presented one approach to the problem of the buried placers, the writer chose to adopt a sampling system suitable for use on all tailings in the district. It was necessary to process a large volume of tailings because of their coarseness and the coarseness of the cassiterite. The apparatus had to be portable and inexpensive and the sampling crew small because of fund and transportation limitations. A rocker seemed to be the answer, and after some study of the tailings and of a few rockers used in the district in prospector's clean-ups, the writer modified a standard Malay design and had one made in Fairbanks. This rocker was in everyday use from July 11 through September 19, 1941, ordinarily with a crew of three men. It gave excellent recoveries of both cassiterite and gold down to fine sizes. Fifty-nine separate sample cleanups were made, ranging from 3 each in Dalton and Idaho Gulches to 13 on Deep Creek and 10 in the Sullivan Bench pit.

A summary of the results is given in table 3, in which a liberal tenor of 65 percent tin is assigned to the cassiterite concentrate and the tin value is assumed to be $0.52 per pound. The gold is assumed to be 800 fine or $28 per ounce for these calculations. The ratio of the total volume of the samples to the estimated volume of all tailings in the district is about 1 in 10,000. The sampling results cannot be presented in greater detail without revealing the holdings of individual owners.

TABLE 3.—*Cassiterite and gold in tailings from the Tofty tin belt*

	Woodchopper and Deep Creeks	Miller Gulch to Tofty Gulch	Sullivan Bench to Ferguson Draw	Total (average or range)
Estimated total tailings, cubic yards	105, 600	131, 200	186, 700	423, 500
Volume of sample, cubic feet	249	357	554	1, 160
Indicated total cassiterite, tons	84.7	78.7	58.9	222.3
Cassiterite, pounds per cubic yard:				
Average	1.60	1.20	0.63	1.05
Range	0.0–4.3	0.2–3.8	0.0–4.7	0.0–4.7
Gold, grains per cubic yard:				
Average	10.55	3.62	2.55	4.88
Range	0.8–34.9	0.0–13.0	0.3–25.2	0.0–34.9
Value of tailings, dollars per cubic yard:				
Cassiterite	0.54	0.41	0.21	0.35
Gold	.62	.21	.15	.28
Total	1.16	0.62	0.36	0.63

In sampling sluiced tailings, numerous small pits 3 to 5 inches deep were dug and half a shovel full of gravel was taken from the bottom of each pit. The spacing of the individual sample pits ranged from 5 to 20 feet, being closer where the underlying gravels were thicker. The entire surface of a tailings pile would be thus sampled, and if it was a moderately large pile a rocker cleanup would then be made giving a composite sample of the tailings pile. For smaller tailings piles, several might be surface sampled before a cleanup was made. Pipe samples or auger samples were not used because of the coarseness of the gravels and the numerous boulders. Shafts and trenches were not used in sluiced tailings because they are costly, time consuming, and too concentrated in sample location. A shaft located accidentally in the middle of a drop would give very high, unrealistic results.

In the Sullivan Bench pit the tailings had mostly been restacked by bulldozers and were therefore sampled by larger, deeper pits dug at greater intervals. In the Tofty Gulch pit the tailings had been stacked into cones by a dragline and could be sampled by deep pits dug at the apex of each pile. The sampling methods used are open to criticism but were considered to give reliable average figures representative of tailings in large areas of the district.

As a check on the structure of sluiced piles and on the applicability of surface sampling to the older sluiced tailings, vertical samples were taken by the Survey on a pile on upper Cache Creek. This pile of Howell's had been thoroughly reworked for cassiterite and gold about 1915 by Ed Erickson, who according to Otto Hovley recovered 200 pounds of cassiterite and 20 ounces of gold from a cut which by 1941 estimate contained about 370 cubic yards of gravel; this represented about 0.54 pound of cassiterite and $1.51 in gold per cubic yard at the 1941 prices. Sampling of the surface of the rest of the pile by the Survey indicated cassiterite and gold contents of only 0.19 pound and $0.28 respectively per cubic yard remaining in the less-rich parts of the pile. Along the edge of the reworked cut the Survey dug 2 vertical pits for the thickness of the pile and took samples of ½ cubic foot every 6 inches. A similar test pit was dug by the Survey at a suitable place on another tailings pile. The results of these tests are shown in table 4.

TABLE 4.—*Vertical samples through Cache Creek tailings*

[Pounds of cassiterite per cubic yard and dollars in gold per cubic yard]

Depth below the surface of the tailings pile (feet)	Test pit A		Test pit B,[1] gold	Test pit C	
	Cassiterite	Gold		Cassiterite	Gold
0.0–0.5	0.69	$0.01	$0.01	0	$0.02
0.5–1.0	.60	.04	.01	0	0
1.0–1.5	1.38	.12	0	0	0
1.5–2.0	.05	.03	.01	0	0
2.0–2.5	0	[2] 4.98	.01	.93	0
2.5–3.0	.08	.23	0	.21	0
3.0–3.5	.22	0	0	.19	0
3.5–4.0	.16	0	0	.08	0
4.0–4.5	.06	.50	0	0	0
4.5–5.0	0	0	0	0	0
5.0–5.5	0	.02	.01	0	0
5.5–6.0	.22	0	0	0	0
6.0–6.5	0	0	0	0	0
6.5–7.0	0	0	0	.12	0
7.0–7.5	0	0	0	0	0
7.5–8.0	0	0	.01	0	0
8.0–8.5	0	0	0	0	0
8.5–9.0	--------	--------	--------	0	0
Average	.204	.349	.004	.085	.001

[1] No cassiterite found in test pit B.
[2] Includes a small nugget.

The average cassiterite and gold content shown by test pit A correspondents closely with that indicated by surface sampling. The position of this test pit apparently was about 15 feet from a drop that existed during the accumulation of the top 4.5 feet of tailings. On the other hand, test pit B was evidently not near a drop, as it shows no cassiterite and only a trace of fine gold. Test pit C, in another pile, was located near a drop that existed when tailings 2 to 4 feet below the present surface were accumulating.

The erratic distribution of cassiterite and gold vertically, as shown by the Cache Creek test pits, indicates that the location of cassiterite and gold within a sluiced tailings pile is determined chiefly by drops, that is, the position of the end of the sluice at the time of deposition of the tailings. It is recognized, however, that residual concentration of cassiterite pebbles at the surface of the piles is a factor that would result in the salting of surface samples if nothing had offset it. On most of the tailings piles in the district, but particularly on the richer piles of Miller Gulch and Deep Creek, pebbles of cassiterite exposed at the surface are easily found. Each year more are exposed by the washing away of lighter material around them. On the other hand, the tiny round pieces of cassiterite of buckshot to pea size are washed from the surface and settle into voids between the loose larger gravel fragments, offsetting naturally the concentration of larger pieces of cassiterite at the surface. It would therefore seem that surface sampling is reasonably safe from residual concentration, but the sampling crew had instructions to scrape the surface from each sample and throw the top shovelful away.

In Tofty Gulch pit, tailings were sampled by a panner of the Cleary Hill Mines Co. for 6 consecutive days during sluicing in 1941. The total volume of samples was 84 pans or about 17 cubic feet. The lowest content of cassiterite shown by the tailings in any 1 day was 0.36 pound per cubic yard. The highest was 4.26 pounds and the average was 1.92 pounds per cubic yard. These results are 75 percent higher than Survey figures for the entire pit, but the gravels sluiced during the 6 days in reference were considered by the manager to be richer than normal in cassiterite.

In the Sullivan Bench pit a U.S. Bureau of Mines party under the direction of Mr. R. L. Thorne, working under adverse weather conditions in the winter of 1943, sampled the tailings by shafts, gopher holes, and channels.[3] They determined the content of cassiterite to be 0.37 pound and gold $0.042 per cubic yard, less than ⅔ and ½ respectively, of Survey figures. However, their estimate of yardage

[3] Sullivan Creek tailings, Manley Hot Springs, Tofty, Alaska: U.S. Bur. Mines War Minerals Rept. 467, 1945.

is much greater. The apparent discrepancy may be explained as resulting from the avoidance by the Survey party of sampling or including in tonnage estimates any material in the pit that could be distinguished as bedrock excavated for drains or sumps as opposed to bedrock sluiced for its included gold and cassiterite. The Survey party did not include for sampling about 150,000 tons of alluvium which covers much of the bedrock in the south end of the pit. Some of this alluvium consists of sluiced gravels and slimes from slucing, but most of it is barren muck and hillside ceep material washed into the lower end of the pit during hydraulic-stripping operations at the upper end. The Bureau of Mines data show that the inclusion of this alluvium would increase the Survey estimates of total cassiterite reserves in the Sullivan Bench tailings and would lower the average grade to about that shown by the Bureau of Mines. Results of sampling by the Survey and the Bureau of Mines in the cleaner, sluiced gravels in the north end of the pit checked very closely.

CASSITERITE RESERVES

The three categories of reserves in the tin-belt area are tailings, remaining placers, and lodes. The tailings reserves have now been roughly measured by the sampling described in the foregoing section. Excluding that in secondary alluvium in the lower end of the Sullivan Bench pit, they total about 222 tons of cassiterite, and about $118,000 in gold, distributed as shown in table 3. Any lode reserves must be dismissed as entirely speculative in 1941. The remaining buried placer reserves are estimated in the following paragraphs.

In appraising remaining placer reserves it is necessary, in the absence of quantitative tin-sampling data, to use the grade of gravels found by mining in the district as a yardstick. For operations with high sliming ratios and with drains to carry away the slimes, it was noted that the tailings are a fair index to the grade of the gravels being sluiced. This suggests that the remaining Tofty Gulch and Sullivan Bench gravels range from 0.1 to 0.2 pound of cassiterite per square foot. These gravels of Sullivan Bench and Tofty Gulch had already been drift mined of their highgrade streak. The drift mines of the rest of the tin belt had recovered about 1.5 pounds of cassiterite per cubic yard on the average in recent years, including recovery by reworking of tailings, and their tailings still contain an average of 1.42 pounds of cassiterite per cubic yard. Assuming a 20-percent sliming ratio for sluicing without a drain, as is customary at drift mines in the district, the average original gravel sluiced in recent years would contain 1.5 plus 80 percent of 1.42 or 2.64 pounds per cubic yard, the approximate equivalent of about 0.59 pound of cassiterite per square foot.

Considering the foregoing appraisal as well as available drilling records, it was estimated in 1941 that the proven and indicated reserves of buried placer cassiterite in areas with systematic drilling and in the immediate vicinity of mined pay streaks were about 900 tons at 0.1 pound per square foot over an area of 18,000,000 square feet. Additional inferred reserves between creeks in the drainage basins of Patterson and Baker Creeks, and west of Woodchopper Creek, were estimated at about 1,100 tons at perhaps 0.05 pound of cassiterite per square foot. Recoverable tin-belt reserves would be a fraction of this total indicated or inferred reserve of 2,000 tons, depending upon mining and recovery methods and especially upon future economic conditions.

As a byproduct to placer gold production and to reprocessing of tailings, limited cassiterite shipments were profitable through 1941, but the production of cassiterite in quantity as the primary product from virgin placers had not been the principal objective of any successful operation up to that time. Except for local concentrations, the cassiterite placer deposits were subeconomic because of their deep burial under frozen silts, their low grade and small reserves, their discontinuity, the poor water supply and tailings disposal gradient, and high cost of labor and freight.

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