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MERCURY OCCURRENCES IN ALASKA

By Kevin Malone

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

1962

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by

Kevin Malone[2]

INTRODUCTION AND SUMMARY

Mercury, or quicksilver as it is often called, has many applications in modern technology. Used principally in electrical apparatus, industrial contol instruments, insecticides and fungicides, electrolytic preparation of chlorine and caustic soda, chemical processes, pharmaceuticals, and dental preparations, the liquid metal has unusual properties that make it a preferred material for many industrial uses.

United States consumption of mercury during the past 40 years shows a rising trend. In all except 4 years, U.S. production has been less than the domestic requirement, and imports, principally from Spain, Italy, and Mexico, have supplied most of the deficit. After World War II, domestic output decreased rapidly until 1950, when it was the lowest in the 100 years covered by production records. Higher mercury prices since 1950 have reversed the decline in domestic output and reduced the gap between U.S. production and consumption. Domestic output in 1958 was the highest in peacetime since 1883; however, the nation still imported 28 percent of its mercury requirements. From 1950 to 1960 the price of mercury was high as a result of industrial applications of the mercury cell, the impact of the cold war and the Korean war, and the Government stockpiling program. The stockpiling program, in effect, put a floor under mercury prices even though only 9,428 flasks of domestic mercury went into the stockpile under the original program which ran from July 1954 to December 31, 1957. Under an extension of the program, an additional 17,463 flasks was purchased.

Defense Minerals Exploration Administration (DMEA) contributed to the improvement in the nation's production-consumption ratio by encouraging exploration and development of deposits. The DMEA (superseded in 1958 by Office of Minerals Exploration) loaned as much as 75 percent of the cost of exploration

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1 Work on manuscript completed March 1962.

2 Physical scientist, Alaska Office of Mineral Resources, Bureau of Mines, Juneau, Alaska.

on mercury deposits; repayment was based on a royalty charge against production resulting from the ore found. Where the work failed to discover new ore, the loans were canceled without further obligation to the owner or operator.

Since World War II, production of mercury in Alaska has followed the trend of that of the nation. Although mercury occurrences in Alaska were noted in the literature as early as 1884, no appreciable output was recorded until World War II needs resulted in the development of deposits in the Kuskokwim River and Yukon River regions. The Red Devil and DeCoursey Mountain mines produced notable quantities of metal during and immediately following the war. When the war demand was met, reductions in price made the mercury mining industry nearly dormant until 1954. Since then, higher prices have led to increased production. Alaska ranked third among the mercury producing states in 1960; the output was 13 percent of the domestic total.

Cinnabar occurs in the gravels of many widely scattered placer mining camps in the State; in some cases the mineral has been traced to its source. Production of mercury from placers in Alaska, however, has been negligible; the State's mercury output has come almost entirely from lode deposits. The only area in which substantial lode developments have been made, and which has had an appreciable output of metal, is the Kuskokwim River Valley and adjacent DeCourcy Mountain.[3] The DeCoursey Mountain mine, a few miles over the line in the Yukon River region,[4] has operating conditions and other factors affecting mining similar to those in the Kuskokwim River region; hence, it is considered with deposits in that region. The principal producers have been the Red Devil mine, northwest of Sleetmute; the DeCoursey Mountain mine, at DeCourcy Mountain; and the Cinnabar Creek deposits, southwest of Sleetmute. Recorded mercury production from Alaska through 1960 was 25,986 flasks.

Adverse operating conditions in the Kuskokwim area seriously handicap mine operations. These include severe winters with temperatures to 40° below zero, lack of transportation and communication services, scarcity and high cost of labor, and an almost complete lack of nearby service and supply facilities. The small, erratic, and discontinuous nature of ore shoots found up to now increases exploration, development, and mining costs. Alaska's Kuskokwim River region shows geological evidence of containing important mercury resources. When some of the handicaps now facing the Alaskan operator are reduced and a period of high demand is sustained, Alaska could contribute materially to the nation's mercury supply. Given a more favorable cost-price relationship, the Kuskokwim and perhaps other regions of the State could probably support a major mercury mining industry.

ACKNOWLEDGMENTS

Acknowledgment is made to Robert F. Lyman, manager; Roger A. Markle, resident engineer; and Gordon Herreid, geologist; all of Alaska Mines and Minerals, Inc., for data on the Red Devil and DeCoursey Mountain mines. Besides furnishing

[3] Accepted spelling - the mine is called DeCoursey Mountain mine.
[4] Ransome, Alfred L., and Kerns, William H., Names and Definitions of Regions, Districts and Subdistricts in Alaska: Bureau of Mines Inf. Circ. 7679, 1954, 91 pp.

information on the properties owned by Alaska Mines and Minerals, Inc., they contributed a great deal of information on other mercury deposits in the State. The sections on metallurgy and geology were authored by Lyman and Herreid, respectively; the section on mining methods and costs was written from personal contacts and from information contained in an engineering report by Markle.

For a geological background on the Kuskokwim River area, the paper by Cady[5] was freely used. Pennington's[6] mercury study furnished an important source for general information on mercury.

PHYSICAL FEATURES AND CLIMATE

The major mercury occurrences in Alaska lie in or adjacent to the Kuskokwim River region (fig. 1). The region is defined[7] as the area drained by all streams flowing into Baird Inlet, Etolin Strait, and Kuskokwim Bay; Nunivak Island also is included. The Kuskokwim River, With headwaters in the Alaska Range and the Kuskokwim Mountains, flows southwesterly through the region to Kuskokwim Bay on the Bering Sea and is the dominant geographic feature. The river flows through a gorge cut through the Kuskokwim Mountains from Sleetmute to Crooked Creek. Many of the known deposits occur in the rolling foothills of these mountains close to the river (fig. 2). The DeCoursey Mountain mine, just over the boundary line between the Kuskokwim and Yukon River regions, is in the Yukon drainage, about 22 miles by trail from the settlement of Crooked Creek on the Kuskokwim.

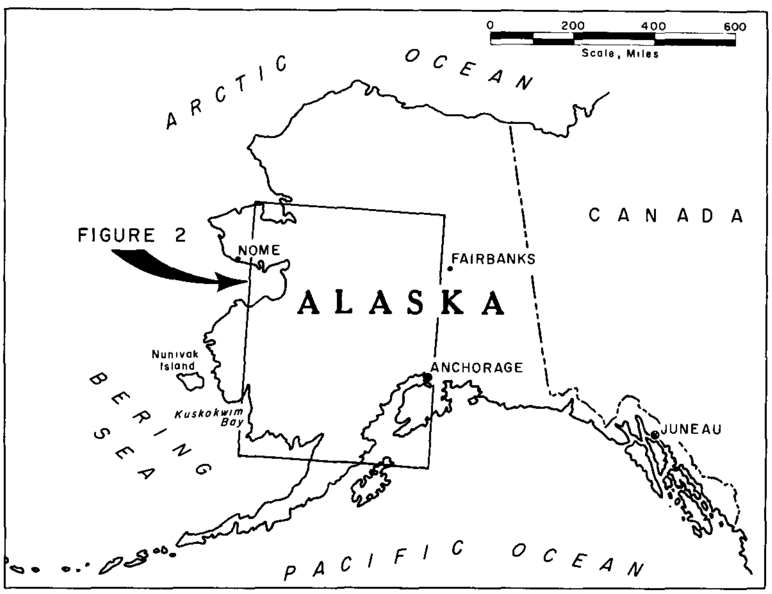

FIGURE 1. - Index Map of Alaska.

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[5] Cady, W. M., Wallace, R. E., Hoare, J. M., and Webber, E. J., The Central Kuskokwim Region, Alaska: Geol. Survey Prof. Paper 268, 1955, 132 pp.

[6] Pennington, James W., Mercury, A Materials Survey: Bureau of Mines Inf. Circ. 7941, 1959, 91 pp.

[7] Work cited in footnote 4, p. 2.

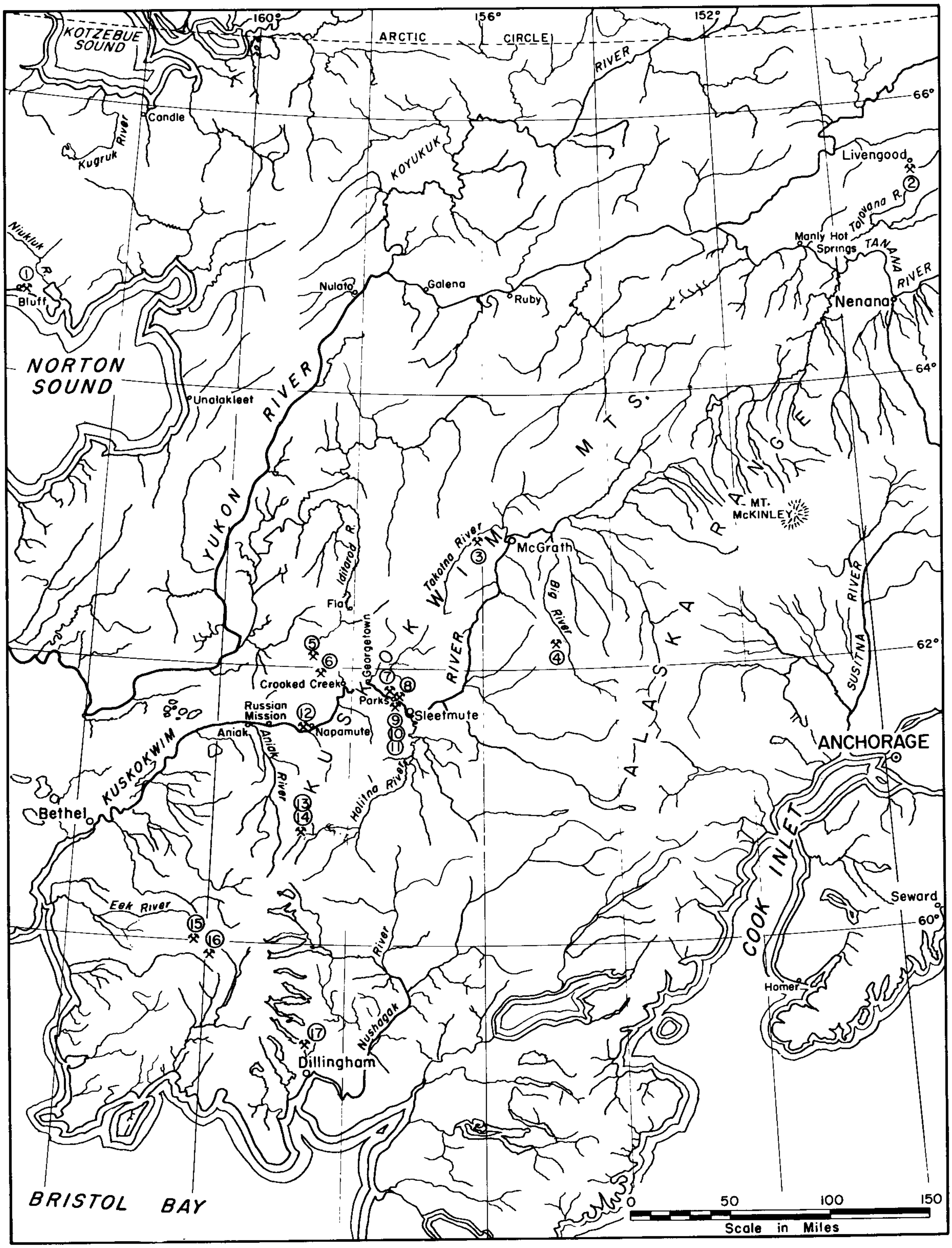

FIGURE 2. - Location Map Showing Mines and Prospects.

The mercury mines and prospects shown in figure 2 are as follows:

Map No.:	Name:
1	Bluff
2	Hudson
3	Mount Joaquin
4	White Mountain
5	DeCoursey Mountain
6	Rhyolite
7	Willis and Fuller
8	Parks (Alice and Bessie)
9	Red Devil
10	Barometer
11	Fairview
12	Kolmakof
13	Lucky Day
14	Broken Shovel
15	Rainy Creek
16	Kagati Lake
17	Marsh Mountain (Red Top)

The climate is subarctic; winters are long, cold, and dry; and summers are short and wet. Winter temperatures are less extreme near the coast than in the interior, but sustained periods to 40° below zero are common throughout the region (table 1). In summer, daylight extends for 20 hours or more; December and early January have only 4 hours of sunlight. The growing season extends from early June to early September; midsummer frosts sometimes cut the season short. Stretches of rainy weather, lasting as much as several days, occur in summer when the wind is from the south or southwest. Records for 1958 at McGrath show a total annual precipitation of 14.26 inches and an annual snowfall of 62.7 inches.

TABLE 1. - Kuskokwim River region temperature data[1]

Station	Month	Temperature °F.					
		Average Maximum	Average minimum	Average	Departure from long-term means	Highest	Lowest
Bethel.....	July 1958	63.0	48.3	55.7	1.2	79	44
Do.......	January 1959	9.7	-3.2	3.3	-3.5	36	-21
Sleetmute..	July 1958	64.7	45.9	55.3	--	80	37
Do.......	January 1959	4.4	-8.7	-2.2	--	23	-34
McGrath....	July 1958	66.9	48.9	57.9	-.8	82	42
Do.......	January 1959	-2.2	-21.7	-12.0	-3.3	19	-41

[1] Source: U.S. Department of Commerce: Climatological Data, Alaska: Weather Bureau, vol. 44, No. 7, p. 103; vol. 45, No. 1, p. 4.

Spruce, to diameters of 20 inches, tamarack, cottonwood, willow, and alder cover the river flood plains. Hill slopes, to an elevation of 1,000 feet, support stands of spruce, birch, and aspen. Brush cover includes alder thickets, dwarf birch, blueberry, and cranberry. The higher slopes and ridges are covered with various lichens and small alpine plants. In the coastal areas and for about 150 miles inland, few trees grow; grass, moss, and stands of small willow and alder form the cover.

There is no transmitted power in the region, and electrical energy is generated in small plants at settlements and mining operations. Oil, delivered by barge on the Kuskokwim River or by ship or barge to coastal points, is the main source of power. The placer-gold operation of New York-Alaska Gold Dredging Corp., at Nyac in the western part of the region, uses hydropower. Domestic and milling water is available throughout the area. There is no connected road system; areas in which mining or other activities are conducted have local roads. Winter sled roads link Bethel with Rex on the Alaska Railroad, but they have not been used in recent years. Foot trails connect the settlements, but travel is chiefly by air or boat.

HISTORY

Mercury occurrences were known in Alaska before 1867, when the territory was sold by the Russians. In discussions with American officials at the time of the transfer, Russian representatives were vague and perhaps deliberately misleading concerning the origin of cinnabar specimens collected by Russian explorers. U.S. officials were told that the fine cinnabar specimens in possession of the Russians were found in the Alexander Archipelago; subsequent investigations have disclosed no mercury mineralization in this region. It is now generally believed that the specimens were from the Kuskokwim River region - an area that the Russians explored as early as 1829.

One of the earliest authentic references to mercury deposits in Alaska was by Petrof,[8] who reported occurrences of cinnabar veins with antimony along the Kuskokwim River and stated, "Assays indicated a very valuable discovery." J. E. Spurr[9] made a reconnaissance survey in the Kuskokwim Valley in 1898 and noted the deposits at Kolmakof which had been under desultory exploration for several years. Spurr reported that an attempt to produce mercury in the early nineties was unsuccessful because the price of mercury was low and shipping the ore to the United States for treatment was expensive. Maddren[10] and Eakin[11] made geological investigations in various parts of the Kuskokwim River region and adjacent area in the early part of this century. Mertie[12] reported small-scale retorting of cinnabar from sluicebox concentrates on Candle Creek in the McGrath area for local gold-placer use. Smith[13] reported on the Parks deposit (Alice and Bessie). The deposit, discovered in 1906, had produced some 700 pounds of mercury by the time of Smith's examination (1914). The metal was sold to placer miners in the Kuskokwim area and on the Seward Peninsula. After Smith's work, little information was published on the region until the Bureau of Mines and the Geological Survey studied the mercury resources of the area at the onset of World War II.

During the many years that placer gold mining was a major industry in Alaska, reports occurred in the literature on cinnabar in the concentrates from many widely scattered mining districts. Numerous placers in the Yukon River region showed appreciable cinnabar in the gravels. Cinnabar was recognized in the beach placers near Bluff on the Seward Peninsula as early as 1900. Boulders of cinnabar as big as a man's fist were reported from sluicebox

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8 Petrof, Ivan, Report on the Population, Industries, and Resources of Alaska: 1884, pp. 13, 77, 90.

9 Spurr, J. E., A Reconnaissance in Southwestern Alaska, in 1898: Geol. Survey 20th Ann. Rept., part 7, 1900, pp. 31-264.

10 Maddren, A. G., Gold Placer Mining Developments in the Innoko-Iditarod Region: Geol. Survey Bull. 480, 1911, pp. 236-270.

11 Eakin, H. M., The Iditarod-Ruby Region, Alaska: Geol. Survey Bull. 578, 1914, 45 pp.

12 Mertie, J. B. Jr., and Harrington, G. L., Mineral Resources of The Ruby-Kuskokwim Region: Geol. Survey Bull. 642-H, 1916, pp. 237-238.

13 Smith, P. S., The Lake Clark-Central Kuskokwim Region, Alaska: Geol. Survey Bull. 655, 1917, pp. 131.

cleanups in the Kuskokwim River region placer districts. There is no record, however, of placer cinnabar being saved, except in the Candle Creek area.

In addition to the Kolmakof and Parks deposits, the Red Devil, DeCoursey Mountain, Marsh Mountain, Fairview, Lucky Day, Rainy Creek, Barometer, Cinnabar Creek, and Willis and Fuller lode deposits in the Kuskokwim River area had been found before World War II. None had had any noteworthy production, although the Red Devil mine had produced about 300 flasks. A lode deposit at Bluff, on the shores of Norton Sound, Seward Peninsula region, was staked in 1922, and some exploratory work was done in subsequent years. Quantities of cinnabar in sluicebox concentrates from placers on Olive Creek, Tolovana district, Yukon River region, led to lode exploration and the discovery of mineral in place on the east fork of Olive Creek in 1917. Some underground exploratory work was done on the deposit, which was abandoned without any recorded production. In the late 1920's James Hudson located the Hudson mine on the west fork of Olive Creek, about one-half mile west of the earlier discovery. Hudson did considerable exploration and development; his efforts were augmented in the early 1940's by those of the Livengood Cinnabar Corp. There is no recorded production for the property.

World War II stimulated the search for mercury. Known deposits were intensively prospected, and the search was pressed in new areas. Some attention was given to prospects outside of the Kuskokwim River region, principally at the Bluff and Olive Creek deposits, but no production from outside areas resulted. In the Kuskokwim region the Red Devil and DeCoursey Mountain mines were opened, and substantial quantities of metal was produced. The Bureau of Mines and the Geological Survey examined mines and prospects starting in 1942. Exploration was done by the Bureau of Mines on the Red Devil, Parks, Barometer, Fairview, Willis and Fuller, DeCoursey Mountain, Lucky Day, Kolmakof, Rainy Creek, and Marsh Mountain deposits between 1942 and 1946. Webber[14] reported on the Bureau's work.

When World War II ended and mercury prices decreased, the DeCoursey Mountain mine became the only producing deposit in Alaska. When this mine closed down in 1949, virtually no more mercury was produced until 1954. Since 1954, under stimulus from the Government's guaranteed price and the DMEA programs, Alaska has contributed substantially to U.S. production totals. With DMEA assistance, work was done on the Red Devil, DeCoursey Mountain, and Marsh Mountain (Red Top) deposits. Recorded production of mercury in Alaska through 1959 was 21,527 flasks. Of the total, the mines of the Kuskokwim River region and the adjacent DeCoursey Mountain mine produced almost 99 percent.

ECONOMIC FACTORS

Mining in Alaska confronts the operator with problems not found in regions of greater development and population. Because the State has one-fifth of the nation's land area and a population (including military personnel) of but 224,000 (1960 preliminary figure by the Bureau of the Census), or less than

[14] Webber, Burr S., Bjorklund, Stuart C., Rutledge, Franklin A., Thomas, Bruce J., and Wright, Wilford S., Mercury Deposits of Southwestern Alaska: Bureau of Mines Rept. of Investigations 4065, 1947, 57 pp.

that of Long Beach, Calif., transportation, communications, service and supply, and other facilities are underdeveloped in the urban areas and primitive or nonexistent in the outlying regions. Along with underdeveloped facilities - or the complete lack of them - in mining areas, the scarcity and high cost of skilled labor, the severity of the climate, and the short surface working season all retard the development of the mining industry.

The supply of skilled labor, except in the more populated areas, is meager; in large areas of the State, no skilled labor is locally available. Anchorage and Fairbanks supply skilled labor for the Kuskokwim River region. Limited semiskilled and common labor is available at the various settlements, but recruitment of labor of any kind for remote mining or exploration projects is difficult and costly. Transportation of labor to the job site is commonly at the mine operator's expense. Living facilities must be provided at high cost, only partly recovered through employee charges. In those instances when workmen arrange for their own board, a cost-of-living allowance generally must be made.

Severe winter weather restricts surface work. Housing and mine plants must be substantially built and well heated to cope with the low temperatures of the region. Pipelines require heavy insulation and sometimes steam lines to prevent freezing. Exploration and work on surface installations is usually restricted to summer, that is, from mid-May or June to mid-September or October. When access to a project is over swampy ground (frequently in interior Alaska), equipment and supplies must be moved while the ground is frozen enough to support tractors or vehicles. Thus, the climate often delays the start of a project or extends the time required for its accomplishment. This long time required to develop a mine and bring it to production is a serious handicap to mining in Alaska.

With a few exceptions, the major mercury occurrences of Alaska lie in the Kuskokwim River region[15] or just over the boundary in the Yukon River region. In this area transportation, except locally, is by air, water, or tractor trail; railroad and road systems do not exist. Freight must be moved from Bethel by riverboat or barge, or by air in the instance of those items urgently needed or which can bear the expense of air freight. Mercury shipped to mainland markets is first sent by air to Anchorage. Waterborne freight moves over the Kuskokwim River and its navigable tributaries; Bethel, about 60 miles above the river's mouth, accommodates shallow draft oceangoing vessels and serves as a port for the region. Scheduled and contract barge service is available on the Kuskokwim. McGrath, a river port 250 airline miles northeast of Bethel and 225 miles northwest of Anchorage, is the distribution hub of the area. The town has a population of 223 persons,[16] several stores and roadhouses, a post office, and a large Federal Aviation Agency station.

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[15] Work cited in footnote 4, p. 2.

[16] Alaska Rural Development Board, Population of Certain Villages in Alaska by Sex and Race, 1958: January 1959, p. 5.

Multiengine aircraft deliver freight and passengers to isolated small settlements. Charter service, by land or float planes, is widely used to reach remote areas. McGrath, served by scheduled airlines, is a staging point for chartered flights in the central Kuskokwim region. Bush flying in Alaska has been developed to a point with few equals in the world. Highly skilled pilots, with an excellent knowledge of the geography, climate, accommodations, and the people in an area, fly anywhere that landing facilities exist. These men are an important asset to the State's transportation system.

Shortwave radio or mail provide communications within the Kuskokwim River region. Alaska Communications System, a unit of the U.S. Army, provides combination shortwave radio, telephone, and telegraph service between the larger settlements in the region and other settlements in the State, and to points outside the State. The Post Office Department often moves mail within the region wholly or partly by air because other means of transport are underdeveloped. Mail deliveries to remote areas may require a month or more in some instances. Private shortwave radio sets are widely used within the region for business and social communications.

Operating conditions in the Kuskokwim River area are difficult and more costly than in the states to the south because of the underdevelopment previously noted, but these difficulties do not present an insurmountable obstacle to establishing a mercury mining industry in the area. Known occurrences of mercury are of higher grade than deposits worked elsewhere in the United States; hence, they can be higher in cost. The expected growth of the State will relieve or eliminate many of the adverse conditions that hamper mining. Further exploration in areas of known mercury occurrences has an excellent chance of disclosing additional mercury resources.

The near-term outlook for mercury production from Alaska is clouded because demand and price are uncertain and because present production comes from one or two operations. Long-term output will probably be obtained from new deposits, and presently known operations will expand.

GEOLOGY[17]

Many of the mercury deposits have marked similarities in geologic features. Most deposits are associated with homoclines in sedimentary rocks into which dikes, or less often sills, have been intruded. The sediments are shales, graywackes, and sandstones. The intrusives are andesite, rhyolite, and biotite basalt. The basalt has been altered to silica-carbonate rock, which is pearl gray on fresh surfaces and weathers to a yellow brown. The weathered version, called yellow rock by prospectors, serves as a guide in prospecting. Disseminated ore and massive kidneys of cinnabar occur in ore shoots, often very short in length of strike, bounded by sills or dikes. The shoots are notably persistent along the dip in some deposits; in others they show tendencies to peter out at depths of 200 feet or less. Stibnite is a common accessory mineral with the cinnabar.

[17] Work cited in footnote 5, p. 3.

Deposition of mercury is believed to have been controlled by breaks and fractures associated with the intrusives and to a lesser extent by bedding planes in the host sedimentary rocks. Brecciated zones, both in the altered intrusives and adjacent sediments, are mineralized to widths of several inches parallel to the contacts. Ore occurs both as veinlets of cinnabar and as disseminations in the altered intrusives and the wall rocks. (The veinlets favor the basalt intrusives.)

Associated minerals are stibnite (Sb_2S_3), realgar (As_2S_3), pyrite (FeS_2), quartz (SiO_2), calcite ($CaCO_3$), and dickite ($H_4Al_2Si_2O_9$). Native mercury has been observed. Stibnite is commonly abundant, but it is not commercially significant; at the Red Devil mine, it has caused considerable difficulty in retorting the ores. More complete and detailed geologic information on the Kuskokwim River region has been given by Cady and others.[18]

MERCURY RESOURCES

Cady, writing in 1951, estimated reserves of 5,000 to 10,000 flasks[19] in the Central Kuskokwim area and the DeCoursey Mountain mine. He did not designate the reserves by class. From 1951 through 1959, the Kuskokwim River region produced 17,109 flasks.

No information is available for estimating measured reserves. Because the ores occur as small, erratic shoots, measured reserves are not significant, and future development of reserves of this class may not be of consequence. Aside from the Red Devil and DeCoursey Mountain mines, work on mercury deposits in the State is largely superficial. Experience in working some of the other deposits indicates they bottom out at shallow depths. Evidence is lacking for estimating the depth of ore at many deposits. From consideration of these factors, indicated reserves appear to be not large and probably never will be. The high exploration costs necessary to establish measured and indicated reserves will likely preclude any appreciable accumulations of such reserves, even aside from the geological limitations that may govern their development.

Inferred reserves, however, are another matter. Consideration of these must take into account the widespread area over which mercury mineralization is known, float and placer cinnabar, the lode sources which have yet to be found, the richness of the few deposits which have been developed, and the impressive production history of the Red Devil and DeCoursey Mountain mines. These factors indicate that the inferred reserves of the region are substantial and that they will make an appreciable contribution to the fulfilling the nation's mercury needs. Price, of course, is the key to any forecast of production and reserves. At prices below $200 per flask, development and production of Alaska mercury deposits probably will not be significant, at least until better operating conditions are effected by the growth of the State. In the $200 to $250 range, a mercury industry can be expected to develop, although growth may be slow. Above a $250 price, and particularly at $300 or more,

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[18] Work cited in footnote 5, p. 3.
[19] Work cited in footnote 5, p. 3.

exploration activity should quicken; resultant work on promising deposits should contribute substantially to the nation's mercury production and reserves.

DESCRIPTION OF DEPOSITS

Kuskokwim River Region

Red Devil Mine

The mine is on the south side of the Kuskokwim River at the mouth of Red Devil Creek, Aniak district, Georgetown subdistrict, at an elevation (shaft collar) of 300 feet. Anchorage is 250 airline miles east; McGrath, a riverport and distribution center for the upper Kuskokwim Basin, is 100 miles northeast. Twice weekly, scheduled airline service is available from Anchorage to the mine; scheduled and charter service is available from McGrath. Freight and fuel oil are hauled from Bethel, a port at the mouth of the Kuskokwim, by company-owned riverboat.

Hans Halverson made the original Red Devil locations in 1933 by tracing float found near the river. A few years later, Nick Mellick joined Halverson as a partner, and additional claims were staked. In early work Halverson and Mellick produced small quantities of mercury from float and residual placer, using Johnson-McKay tubes; installation of two D retorts made possible the production of 162 flasks in 1940.

Harold Schmidt and F. J. Stampe leased the claims in the fall of 1941. The Bureau of Mines examined the deposit the following summer and did considerable surface work. When the surface work exposed commercial deposits on five parallel shoots, the Bureau deepened the main Red Devil shaft, cut a station at the 41-foot level, and drifted on the formation. The work exposed a spectacular showing of cinnabar and stibnite on one of the vein systems (the A series). After the Bureau's work, New Idria Quicksilver Mining Co. subleased the property, forming New Idria-Alaska Quicksilver Co., with Schmidt as manager. New Idria-Alaska opened the deposit for underground mining and installed a 40-ton rotary kiln and condensing system. Under an intensive development program, the mine produced more than 2,000 flasks of metal from 1943 to mid-1945, when lower prices curtailed operations. The Kuskokwim Mining Co., a partnership of Schmidt and Stampe, took a shaft-sinking contract on the Red Devil shaft in early 1945 and later in the year, subleased the mine and reduction works. The partnership did considerable exploration and development in 1945 and 1946; production during the two years was appreciable. Continued low mercury prices - less than $100 per flask - forced the operation to shut down at the end of the 1946 season. Early in 1949 New Idria-Alaska sold all mining and furnacing equipment to Robert F. Lyman.

The mine was then inactive until 1952, when DeCoursey Mountain Mining Co. leased it; various organizational changes in the operating companies have occurred since. The present operating unit is called Alaska Mines and Minerals, Inc. Under this company and its predecessors, the Red Devil has developed into the leading mercury mine in Alaska and is an important producer on the national scene.

Fire destroyed the mine and mill equipment and some of the camp buildings in October 1954. DeCoursey Mountain Mining Co. rebuilt a modern plant, and resumed production in March 1956. The present plant consists of an airfield and a well-equipped camp with bunkhouses, a commissary, a messhall, offices, shops and warehouses, a modern furnacing plant, and diesel-electric power units. Surface and underground mining equipment and installations are efficient and adequate for the operation. Shortwave radio is used for communications with Anchorage, Sleetmute, and McGrath.

The mine consists of nine unpatented mining claims held by location. Five of these are owned by Alaska Mines and Minerals, Inc. (Kusko Nos. 1 to 5), and four by Halverson and Mellick (Red Devil Nos. 1 to 4). The mining company leases the Red Devil group.

The Red Devil is the only mercury-producing property of consequence in Alaska. Production from 1940 through 1959 was 19,530 flasks. Of the total, 15.486 flasks was produced in the 4 years since the plant resumed operations in Marcn 1956.

Descriptive geology[20]

Regional Setting.- The Sleetmute quicksilver district lies in an area of folded Upper Cretaceous geosynclinal sediments consisting of a great thickness of monotonously similar graded graywacke and mudstone. This area includes a Tertiary volcanic province manifested by preorogenic Iditarod basalt, synorogenic albite rhyolite, postorogenic Holokuk basalt, and postorogenic quartz monzonite. The porphyritic Barometer Mountain intrusive 3 miles south of the Red Devil mine may also be postorogenic. During the Pliocene (?) an old-age surface developed, and in late Pliocene or Pleistocent epochs the Kuskokwim Mountains were uplifted. The present topography has developed by erosion of this old surface on the uplifted blocks. The Upper Cretaceous beds have been folded at shallow depth into sharp crested folds of varying trend and plunge, which tend to parallel the margins of the sedimentary basin.

District Setting.- Bedrock geology near the Red Devil mine is largely obscured by a cover of residual mantle, loess, moss, and the Kuskokwim River. The river apparently occupies the crest of the Sleetmute anticline, whose horizontal axis trends northwest. The Red Devil deposit lies on the southwest flank, and the Parks prospect lies on the northeast flank. Altered diabasic (?) dikes and sills occur at the Red Devil mine and at the Barometer, Parks, and Willis prospects. These deposits are the most promising known in the district. The only sulfides found at these deposits are cinnabar, stibnite, and small amounts of orpiment and realgar. Occasional grains and veinlets of authigenic pyrite are present. The richest deposits known in the district, the Red Devil and Barometer, occur along the Red Devil fault zone, a wrench (strike slip) fault with right lateral displacement. To 1959, all the ore shoots in these two deposits have been found along the main Red Devil fault

[20] Written by Gordon Herreid, geologist, Alaska Mines and Minerals, Inc., Red Devil, Alaska.

or along subsidiary slips in its footwall. The Red Devil fault parallels the strike of the sediments and is probably a regional fault, whose orientation has been influenced by the orientation of the Sleetmute anticline.

Geology of the Red Devil Mine

The geological features of the Red Devil mine developed in the following sequence:

1. Beds folded and conjugate joints perpendicular to the beds formed by folding stresses.
2. Red Devil right lateral wrench fault movement began.
3. Dikes intruded parallel to one of the previously formed joints (see No. 1).
4. Further right lateral wrench movement occurred along the Red Devil fault; ore solutions were introduced near the end of the faulting.
5. Postmineral cross faults formed.

The most salient feature of the structure of the Red Devil mine is the series of steplike offsets of the crosscutting dikes along the many right lateral movement planes in and along the Red Devil fault.

Country Rock.

The Red Devil deposits occur in the well-bedded, graded graywacke typical of the Upper Cretaceous Kuskokwim formation. In the mine openings the beds are monoclinal; the average strike is N. 38° W.; dip, 63° S.

The base of each graded graywacke bed is composed of massive dark gray, conchoidally fracturing graywacke. Toward the top the percentage of sand-size grains decreases, and the beds grade into mudstone. In places, several siltstone or mudstone beds, 3 inches to 1 foot thick, occur in succession between the graded graywacke beds. The graywacke beds range in thickness from a few inches to 6 feet but average about 2 feet. Most graywacke beds contain sole markings that preserve the markings in the mud on which the graywacke was deposited. When the beds are rotated around the strike line to the horizontal, the trend of the grooves and flow marks is 150°, southeast or northwest sense unknown.

Joints.

Two sets of joints are present throughout the mine workings. At any one place they are erratic, but the average of many joints taken within a 50-foot radius is close to similar averages taken elsewhere in the mine. The joints are oriented an average of N. 37° E., 63° SE. (J-1) and N. 69° E., 60° NW. (J-2). Both sets are perpendicular to the bedding, and the acute bisector of the two is parallel to the dip of the beds. During folding, in which the bedding plane slip is active, the direction of maximum stress lies along the bedding in a plane perpendicular to the fold axis. At Red Devil the direction of maximum stress is parallel to the dip of the beds. The joints at Red Devil lie symmetrically on either side of the maximum stress direction and must have been formed during the folding of the Sleetmute anticline.

Dikes.

Three dikes, exposed in the mine workings, have been identified as altered biotite basalt and as andesite.[21] The less altered dikes in the district show a diabasic texture under the microscope. Andesite is the local term. The dikes are altered to quartz, chalcedony, carbonate, and sericite.[22] At depths greater than 100 feet, the dike rock consists of an aphanitic, cream to light-gray matrix with medium-gray specks, which may be altered phenocrysts. It also contains patches and tiny veinlets of quartz. In places, slickensided greenish patches occur; these have been identified as dickite. The dike rock is strikingly different from the graywacke-mudstone country rock. In the zone of surface alteration, the dike rock is reddish or yellowish tan, but it may have residual light-colored patches of unlimonitized rock. On the surface the dike is generally distinguishable from limonitized graywacke, particularly in exposures large enough to show the well-bedded character of the sediments compared with the massive dike. Megascopically the dikes appear to be approximately the same in all the exposures at Red Devil and at the Barometer, Parks, and Willis prospects. It is unknown whether the alteration of the dikes is regional or a large halo around the ore shoots. Dike contacts are generally sharp, but in places they are brecciated to an approximately 1-inch aggregate of mixed dike and country rock. Often the adjacent graywacke is argillized, but contacts with shale or mudstone are sharp and may form deep reentrants into the dike. Dike contacts are irregular in places, but over any distance they parallel the J-1 joint direction (N. 37° E., 63° SE.), and in many places the contact follows a joint plane for several feet. The dikes do not carry megascopic disseminated cinnabar, except locally within a few feet of the ore shoots.

The dikes present are the Dolly dike, with which the Dolly and Rice series ore shoots are associated; the Red Devil dike, with which the A, B, Girlie, and C series are associated; and the F dike, with which the D, E, and F ore shoots are associated.

Wrench Faults.

Red Devil Fault.- The movement direction of the Red Devil fault zone parallels the strike of the bedding and is within 10° to 15° of horizontal. The fault is a compromise between the tendency of strike slip faults to be vertical and the tendency for movement to occur along the planes of easiest slip, which are the bedding planes. Consequently, the fault follows bedding

21 Work cited in footnote 14, p. 8.

22 Cady, W. M., and Others, The Central Kuskokwim Region, Alaska: Geol. Survey Prof. Paper 268, 1955, p. 107.

for the most part, but in many places it laces from one bedding plane to another along steep slip surfaces, forming nearly horizontal noses that are typical of the fault zone. Also, in many places minor flat dipping faults lace between bedding plane faults. The zone is complex, and ore shoots in it are difficult to follow.

Crosscutting dikes have been cut into segments, which almost invariably indicate that movement on the faults was in a right lateral direction. The Red Devil fault zone is a rather elusive thing in narrow workings due to the large horses of undeformed country rock which occur in it. It can be recognized by the presence of steep lacing faults and horizontal noses. In all probability the faults of similar appearance, which occur within 50 feet in the hanging walls and footwalls, connect with the main Red Devil fault up or down dip.

Accurate projections of the Red Devil fault zone up and down dip are impossible. Between the 450 and 300 levels the dip is about 85° SW, between the 300 and 150 levels about 66° SW., and above the 150 level the fault is apparently about vertical, although it partly feathers out along the bedding.

Wrench Faults Subsidiary to the Red Devil Fault Zone.- Exposures are limited in the hanging wall of the Red Devil fault, but in the footwall subsidiary, right-lateral strike slip movements occur for a width of at least 300 feet on the 300 level. Right-lateral faulting is visible at the surface over a width of 650 feet. The total right-lateral strike slip movement between the known dike segments is about 800 feet; half or less is in the Red Devil fault, and the rest is taken up by the subsidiary movements in the footwall. All the subsidiary faults are bedding-plane faults. These faults occur because of the strong preferred orientation of slip planes along the shaley bedding planes. Therefore, subsidiary faults are not parallel to the parent fault, although the movement directions of the two are parallel.

In places, bedding plane faults, which are probably wrench faults, are cut off by dikes; elsewhere unfaulted dikes are on strike with badly faulted ground. This predike faulting is probably an early phase of the Red Devil wrench faulting.

Geometry of the Deposit

The pattern of the dike segments and ore shoots is approximately the same at each level, and the projection from one level to the next is fairly constant. This structural uniformity has greatly facilitated mining. The dike pattern is the result of the interaction of most of the elements of the structure. The primary structure, the Sleetmute anticline, determines orientation of the joints, along which the dikes have been intruded, and also probably the direction of the Red Devil wrench fault zone. In the footwall of the Red Devil fault, drag movement has caused slippage along bedding planes between lamellae of differing thicknesses. The crosscutting dikes are cut into segments that form half of an S-curve. The other half presumably is present in the hanging wall of the Red Devil fault. The inclinations of the dikes (N. 37° E., 63° SE.) and the bedding plane faults (N. 40° W., 60° SW.), which cut the dikes into segments, are responsible for the direction and plunge of the dike segments (39° plunge on a S. 10° E. bearing). The B-type ore shoots described later follow the truncated ends of the dike segments and have the same plunge as the dike segments. A complication is introduced by the intersection of the plunging dikes and ore shoots with the steep slip planes of the Red Devil fault zone. Along the Red Devil dike this intersection occurs just below the adit level in the C-zone and to the southeast at greater depths than yet attained in the B and Girlie workings. The steep lacing faults of the Red Devil fault zone displace the dike segments northwest below the faults so that the dike-ore zone as a whole is steepened (fig. 3).

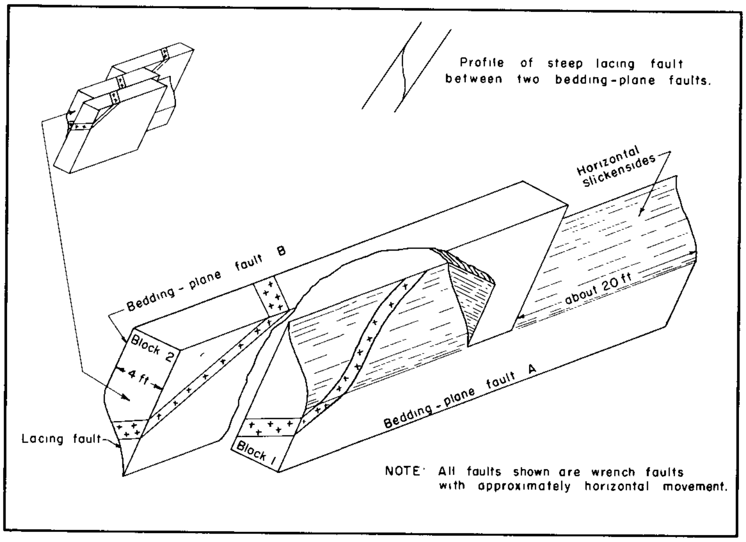


FIGURE 3. - Schematic Diagram of a Steep Lacing Fault, Red Devil Mine.

Ore Deposits

Structure of the Ore Shoots.

B-Type Ore Shoots.- Ore production has come mostly from the footwall of the Red Devil fault zone, where ore shoots are localized at the intersections of bedding-plane wrench faults with crosscutting dikes. At these intersections, the rolls in the fault may be likened to large-scale chattermarks. These rolls are often occupied by plunging pencils of ore, which have a lenticular cross section and which may overlap one another. En echelon movements along joints in the graywacke beds in the immediate hanging walls of the intersections show that the bedrock was compressed around the dike segments. One dike segment (footwall of the A-6 stope) has cracked across from corner to corner; the cracks maintain the same position in the segment up and down plunge. Structures formed at an intersection tend to continue all along the intersection. These open spaces have acted as channels for the ore solutions. These effects at the dike-fault intersections are apparently due to the smaller tendency of the dikes to give or to flow relative to the country rock. The regular shape and plunge of these ore shoots greatly facilitates mining.

C-Type Ore Shoots.- Ore shoots that occur along and around steep pre-ore lacing faults along the Red Devil fault zone are called C-type ore shoots. Below the adit level the C-zone ore shoots intersect the Red Devil fault with its lacing faults. These lacing faults were preceded by bedding plane faults and were formed mainly before and during ore deposition; however, some post-ore movement has taken place. They have both cut off the plunging dike segments and provided dams for the ore solutions. Between the lacers, the ore follows the dikes in B-type shoots and is often of marginal grade or lower. Along the lacers the ore forms flat plunging ore shoots; the richest ore is along the lacer, becoming leaner away from it (fig. 3). The ore is concentrated along the lacers, but at the expense of diverting it away from the more regular B-type ore along the dikes. This ore, oddly enough, forms both immediately under and immediately over the lacers.

Mineralogy of the Ore.- The only sulfides found throughout the deposit at Red Devil are stibnite and cinnabar; small amounts of orpiment and realgar are present locally. All ores are composed of volatile elements. Rare, local pyrite films on joints are probably due to migration and redeposition of authigenic pyrite during ore deposition. The principal gangue minerals are quartz and white clay. In the B-type ore the shoots are composed of stibnite-cinnabar-quartz. The stibnite is euhedral and may form laths as large as 1/4 by 3 inches, which tend to be oriented parallel to the vein and normal to the plunge. Cinnabar and quartz are interstitial within the stibnite, but in vuggy areas they are euhedral. The cinnabar and quartz often occur in streaks in the ore parallel to the vein along the walls or out in the stibnite. All the ore minerals were deposited at about the same time. The stibnite-cinnabar-quartz shoots range in width from 1 or 2 inches to about 1 foot and in strike length from 6 to 30 feet. Cinnabar may constitute from 0 to 40 percent of the ore shoot; quartz, from 1 to 10 percent; and stibnite, the remainder. The stibnite to cinnabar ratio tends to be higher in the wider shoots and to increase with depth. Peripherally to these ore shoots, the cracks in the graywacke and dike rock carry vuggy veinlets 1/16- to 1/4-inch wide, of quartz-white clay-cinnabar, in which the quartz and cinnabar are often euhedral. The transition from the central stibnite-cinnabar-quartz ore shoot to the quartz-white clay-cinnabar halo usually occurs within a few inches, and the halo may extend for 2 to 50 feet awav from the ore shoot before the cinnabar disappears. The quartz-white clay veinlets continue to a greater distance. These halos are ubiquitous and furnish a short-range guide to ore. Their mineralogy is invariable, and no crosscutting relationships exist between the central ore shoots and the halos. The halos are contemporaneous with ore shoots and are not due to a separate period of mineralization. Where the halos occur in graywacke, they tend to remain in the same horizon and seem to be equally developed above and below the ore shoot. The ore shoots were clearly the channels where ore fluids rose from greater depths.

C-type ore occurs along the Red Devil fault in the C-zone. The lacing faults and fractures in horses of graywacke-shale contain veins of stibnite-cinnabar-quartz, indicating that the main ore solution channels were diverted by these structures. Much of the C-type ore consists of a halo of quartz-white clay-cinnabar expanded due to the diversion of the ore solutions by lacing faults. Brecciated silicified shale is often cemented by quartz-white clay-cinnabar.

At various places, especially in the C-zone, orpiment and realgar are present in the ore. Realgar is mainly confined to the main ore shoots, whereas orpiment occurs in the main ore shoots and the halos.

Cross Faults.- The ore shoots have been cut by two major cross faults, which postdate both wrench faulting and ore deposition. Both faults are marked by gray, rubbery gouge a few inches thick. The best understood is the 411 B-1 fault; it cuts off the B, Girlie, and A series ore shoots below the 300 level (fig. 4). This fault has been intersected in four places where it cuts off dike segments. It is a wrench fault with a normal-throw component. Its orientation varies, but averages N. 76° W., 74° S., and dike segments have been displaced 65 feet horizontally in a left lateral sense with about 30-foot vertical movement, hanging wall down. The other post-ore cross fault, the 388 fault, is exposed in the Dolly area, where it cuts off the ore shoots about 190 feet (vertically) below the collar of the Dolly shaft. This fault strikes about N. 72° W. and dips from 57° to 72° N. Drag on ore and dike along this fault indicates that it also moved in a left lateral sense. Probably other steep, crosscutting left lateral faults of similar orientation will be found along the Red Devil fault.

Age and Depth of the Red Devil Deposit.- The only age during Tertiary times that can be estimated with any degree of accuracy is that of the Georgetown summit level surface. This old-age surface represents the surface that the Kuskokwim River flowed on before uplift of the Kuskokwim Mountains. It formed no earlier than late-Miocene and was destroyed on the Kuskokwim Mountain block by uplift in late-Pliocene or early Pleistocene time.[23] The Georgetown surface is probably represented near Red Devil by the local ridge tops, which are at about a 1,500-foot elevation. The Kuskokwim has followed its same course through the Kuskokwim hills since before the uplift and was probably at or near its present location when the Red Devil deposit was formed. The ground surface at the time of uplift is estimated to have been about 1,100 feet above the present shaft collar (elevation 308 feet) and 1,640 feet above the deepest workings.

The known depth of quicksilver deposits at New Almaden ranges from the surface to 2,450 feet. Thus, the oldest probable date of mineralization at Red Devil is contemporary with the Georgetown erosion surface, or late Miocene. The deposit could be much younger than that. Barometer Mountain rises above the Georgetown surface about 1,000 feet and is therefore considerably older.

Relation of the Red Devil Deposit to Igneous Intrusion.- Intrusion of the dikes at Red Devil occurred during the period of strike slip movement on the Red Devil fault. Directed stress was necessary to selectively open up the J-1 joint direction, and not the J-2 or the bedding planes, to the intruding magma. The necessary stress direction would be parallel to the J-1 joint direction. If any stress parallel to J-1 could also produce the observed movement on the Red Devil fault, then probably the interaction of the fault with a shallow intrusive could account directly for the intrusion of dikes during the wrench faulting.

[23] Cady, W. M., and others, The Central Kuskokwim Region, Alaska: Geol. Survey Prof. Paper 268, 1955, p. 95.

The direction of stress responsible for the movement on the Red Devil fault can be ascertained by assuming that its tendency to be vertical, despite the greater ease of slippage along the inclined bedding planes, indicates that the stress field is the kind that would produce a vertical wrench fault in an isotropic medium. If so, the direction of stress would be along a horizontal N. 08° W. line, 30° away from the strike.

This direction lies 45° away from the J-1 joint plane and clearly was not responsible for causing a highly selective dike intrusion along this plane. Therefore, change of orientation of externally applied stress is necessary if the dikes were to intrude along the J-1. This change of stress must have been of short duration and was probably local. That is was also accompanied by intrusion of dikes makes a nearby intrusive a most reasonable source of the magma as well as the source of compressive forces. Thus, dike intrusion, wrench faulting, and ore deposition were part of a sequence of events which were related closely in time. It seems likely that they were also genetically related. Figures 4 and 5 are a geological plan of the Red Devil.

Mining Methods and Costs[24]

The mine originally was opened with adits at the 1311- and 1325-foot elevations; the portals of these are 70 feet apart in plan. Later the Red Devil incline was sunk with stations at the 33, 73, 150, 300, and 450 levels. The 1311 adit is at approximately the same elevation as the shaft collar; the 1325 is 25 feet higher. The Dolly shaft, in the hanging wall of the Red Devil shaft, is collared above the Red Devil and is connected with the Red Devil on the 300 level. Figure 6 is a plan of the mine workings.

As has been noted, ore shoots at the Red Devil are extremely short in strike length but may persist along the plunge for several hundred feet. Strike lengths range from 6 to 30 feet and vein widths from 3 to 10 inches. The ore shoots plunge at an average of 39°. The combination of short strike length, narrow width, and flat plunge results in excessively high mining costs.

After a level has been opened for mining, raises are driven on the ore shoots. Stoping proceeds from the top down; the stope width is controlled by the closest convenient hanging wall that will stand until it can be supported. Stope widths range from 3 to 6 feet. Stulls, obtained locally at about 10 cents per linear foot, and headboards are used for support. Timbering labor cost is high, 25 percent of direct stoping costs. Muck from the stopes will not run by gravity, and the relatively small tonnage from a stope does not warrant installing slusher setups. Hence, mucking to the level is by hand, with an assist from water run-in from above. Mucking is a large item in stoping costs.

Where ore cannot be moved economically by raises, slusher crosscuts are used to transfer muck to shafts, winzes, or ore passes. The scraper dumps directly into skips or into ore passes to the haulage level. On the 358

[24] Material from this section is taken from an engineering report by Roger A. Markle, resident engineer, Red Devil mine.

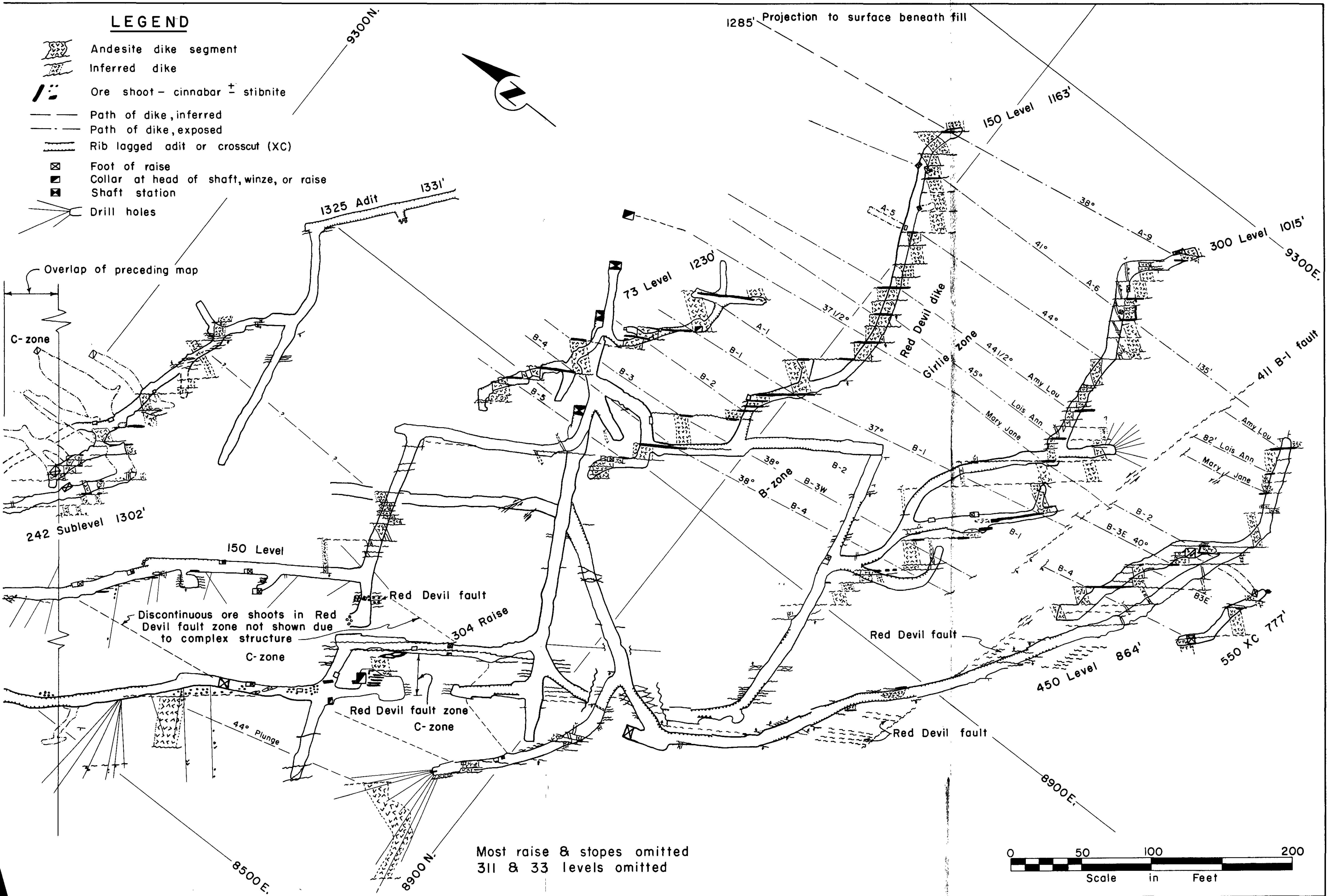


FIGURE 4. - Geologic Map of Southeast Half of Red Devil Mine.

(Faces p. 20)

crosscut, 100 feet were driven using a slusher to draw muck to a mucking machine for loading into mine cars; the crosscut, 3 by 4 feet in cross section, was driven at a faster rate and at slightlv more than one-half the cost of a conventional 5- by 7-foot crosscut.

Drifts and crosscuts are 5 by 7 feet in the clear. Most of the ground requires timbering; some sections of the mine stand well enough to need only an occasional set of timbers. Mining is on a one-shift, 6-day-week basis; however, at times some development headings are double shifted. All development work - drifting, raising, crosscutting, shaft sinking, and winzing - is on a contract basis; the company furnishes all equipment and supplies. Miners are paid an agreed amount per foot of work done and a guaranteed minimum if unusual conditions reduce contract earnings below normal wages. Rates are so set that competent men have an opportunity to earn more than wages in normal going. Contract stoping has been tried at Red Devil, but widely changing conditions in different stopes of the mine forced abandonment of contract work. The company now pays a production bonus, based on flasks produced per month, to all underground crews not on contract work. A "cave bonus", in addition to the production bonus is also paid to any crew working a stope which has caved in any way that was not the fault of the miners.

Tramming is by an air trammer on the 450 level and by a battery-driven electric unit on the 300. Hand tramming is used on the 150. Muck is trammed to pockets in the Red Devil shaft. At present a 20-hp. hoist serves the Red Devil shaft. A 100-hp. hoist on the property was scheduled for installation in the summer of 1960. The new hoist will haul twice the load at roughly twice the speed of the hoist previously used, thus increasing shaft capacity perhaps two or three times. A 4-inch air line provides adequate compressed air for drilling.

Recent exploration and development has centered on the Girlie and B series below the 450 level, the Dolly series below the 388 fault, and the Rice series from the surface down. The rake of the ore shoots in the Girlie and B series has carried them well away from the Red Devil shaft on and below the 450 level. To avoid a long drive from the shaft, deeper work on this series is by winzing from the 450. The winze has been sunk 115 feet along the plunge of the ore shoot, and a station has been cut at this level. Slusher crosscuts are planned to the other shoots of the Girlie and B series. There is some question whether all of the Girlie shoots will be minable at this depth.

Longholing for the Dolly series on the 300 level has not picked up the downward extension of the ore below the Dolly 388 fault. The 358 slusher crosscut has been driven 100 feet into the footwall, and a new longhole station is planned to allow deeper exploration into the footwall. Picking up the Dolly series on the 300 will add substantially to the ore reserves at Red Devil if the ore shoots below the 388 fault compare with those above it. About 3,600 tons, averaging 51 pounds, was mined from this series above the fault.

The Rice series is being explored by a shaft sunk along the plunge of the strongest surface showing. The shaft is now 84 feet deep on the plunge of the shoot. Plans are to sink to 100 feet vertically below the collar and to explore the remaining shoots of the Rice series with slusher crosscuts. Ore found in the Rice shaft so far has been erratic; some very high-grade ore has occurred, the average ore over the entire face gives 10 to 15 pounds per ton.

Table 2 contains a breakdown of mining costs for the company's 1959 fiscal year. In discussing Red Devil operations, Robert Lyman, manager, stresses that the high unit costs result more from the nature of the deposit than its isolated Alaska location. During an 18-month period 5,860 feet of raise (3 by 4 feet in cross section) were driven, and 8,782 tons of ore was stoped; thus, 1.5 tons was stoped per foot of raise driven. During the same period development ore from all work (drifting, raising, and sinking) was 5,813 tons. Therefore, 14,595 tons was obtained from stopes and development work. The figures show the reasons for high underground costs at Red Devil. Mucking costs for drifting and crosscutting include tramming to the station; for stoping, no tramming is included. The supervision cost is the salary of the mine foreman. The salaries of the engineering and geology staffs are included with administrative expense.

TABLE 2. - Mining costs, Alaska Mines and Minerals, Inc., Red Devil mine, fiscal year 1959

	Stoping, per ton	Raising, per foot	X-cutting and drifting, 5 by 7 feet, per foot	Sumps and pockets, per cubic foot	Long-holing, per foot
Labor:					
Drilling	$3.46	$6.70	$ 6.13	$1.25	$0.75
Mucking	4.72	4.35	12.07	2.65	--
Timbering	3.51	2.78	4.26	1.48	--
Pipe, track, and miscellaneous items	.58	1.12	2.84	.38	--
Supervision	.84	.86	1.69	.35	.06
Material:					
Timber	.34	.23	.43	.07	--
Powder	.32	1.43	3.10	.31	--
Caps	.58	.61	1.10	.22	--
Rail	--	--	2.00	--	--
Pipe	--	--	1.18	--	--
Steel, bits, and machine parts	--	--	--	--	.21
Total	$14.35	$18.08	$34.80	$6.71	$1.02

Table 3 contains mining costs for 7 months in 1959. Winzing costs from the 450 level are relatively high. The erratic plunge of the ore body in this section has made sinking slow and expensive; at one point it was necessary to go back and take up bottom to maintain hoisting arrangements. Table 4 is a comparison of mining costs for fiscal 1959 and the last 7 months of calendar 1959.

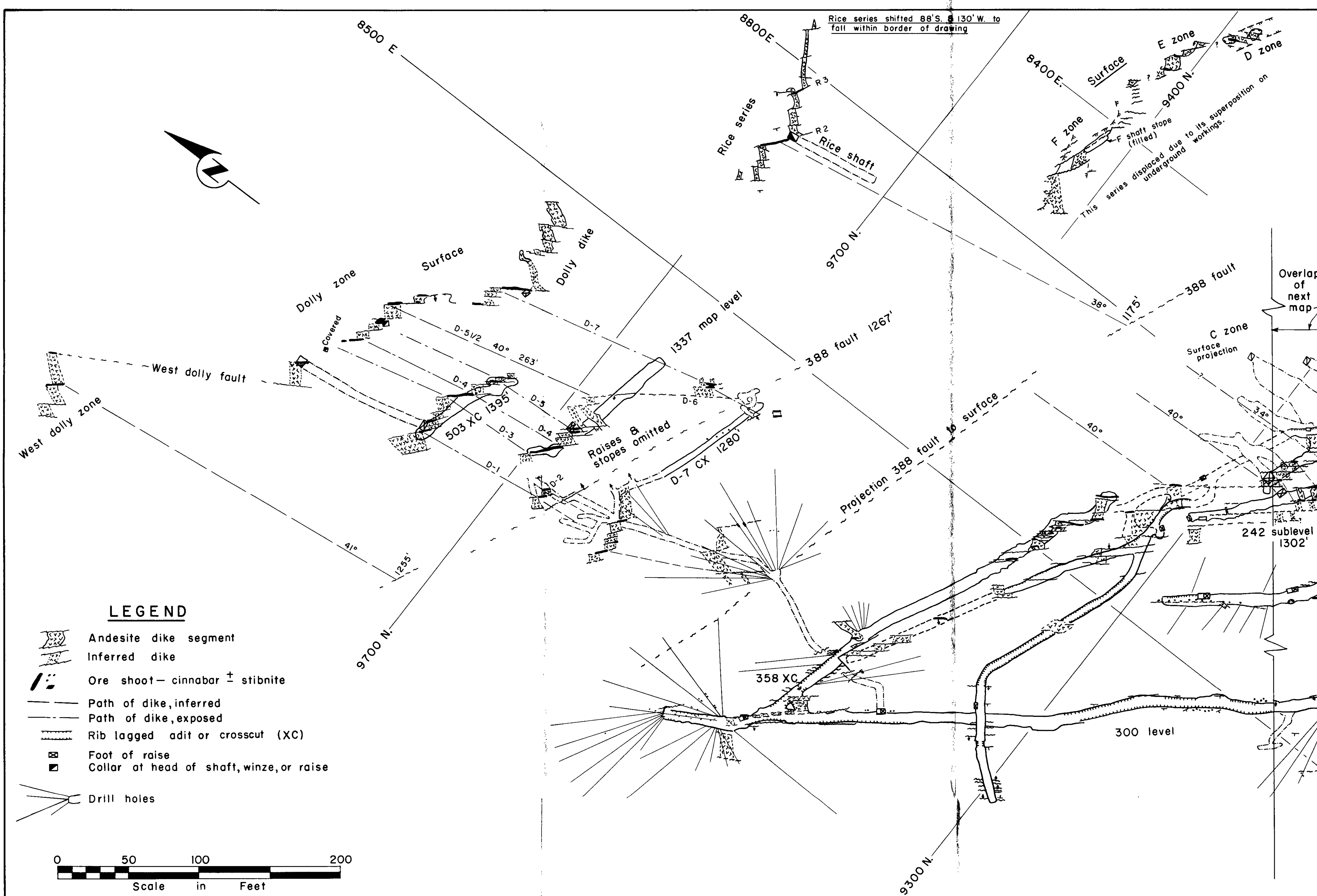


FIGURE 5. - Geologic Map of Northwest Half of Red Devil Mine.

(Faces p. 22)

TABLE 3. - Mining costs, Alaska Mines and Minerals, Inc., Red Devil mine, June 1, 1959 through December 31, 1959

	Stoping, per ton	Raising, per foot	Slusher Cross X cuts, per foot	450 Winze, per foot	Rice shaft, per foot	Long-holing, per foot
Labor:						
Drilling.............	$3.16	$8.72	$5.54	$23.14	$8.35	$0.78
Mucking.............	4.20	4.16	6.73	42.65	26.18	--
Timbering............	2.94	2.09	1.65	29.91	8.18	--
Pipe, track, and miscellaneous items...............	.29	.66	1.95	5.36	.38	--
Supervision..........	.56	.75	.79	4.95	2.40	.04
Material:						
Timber...............	.62	.17	.07	9.44	2.39	--
Powder...............	.38	1.73	1.40	3.04	2.29	--
Caps.................	.50	.75	.59	2.71	1.54	--
Pipe.................	--	--	--	1.56	--	--
Steel, bits, and machine parts[1]......	--	--	--	--	--	.25
Total..............	$12.65	$19.03	$18.72	$122.76	$51.71	$1.07

1 Estimated cost.

TABLE 4. - Comparative mining costs, Alaska Mines and Minerals, Inc., Red Devil mine, fiscal year 1959 and June through December 1959

	Fiscal Year 1959	June-December 1959
Stoping................................	$14.35 per ton	$12.65 per ton
Raising................................	18.08 per ft.	19.23 per ft.
Drifts, crosscuts......................	34.80 per ft.	
Slusher crosscuts......................		18.72 per ft.
Pockets, sumps.........................	6.71 per cu. ft.	
450 winze..............................		122.76 per ft.
Rice shaft.............................		51.71 per ft.
Longholing.............................	1.02 per ft.	1.07 per ft.
Mine maintenance.......................	1.37 per ton	.66 per ton
Hoist and truck to mill................	1.95 per ton	1.61 per ton
Tramming...............................	1.99 per ton	1.89 per ton
Skiptender and pumpman.................	1.88 per ton	.90 per ton
Mechanic and electrician...............	1.31 per ton	1.25 per ton
Repair parts...........................	1.89 per ton	1.68 per ton
Heat, light, power, and compressed air..	4.00 per ton	3.24 per ton
Total tons mined....................	8,215.5	6,379
Direct cost per ton mined............	$34.35	$28.68

Table 5 gives all costs for fiscal 1958 and 1959. The figures for fiscal 1959 apply to 8,215.5 tons of ore mined. Wage rates are shown in table 6.

TABLE 5. - Comparative costs, Alaska Mines and Minerals, Inc., Red Devil mine, fiscal years 1958 and 1959

	June 1957-May 1958		June 1958-May 1959	
	per ton	per flask	per ton	per flask
Direct labor, material, and expense:				
Mining	$53.62	$130.73	$34.35	$70.95
Milling	9.60	23.42	13.74	28.25
Other direct charges:				
Freight out	3.01	7.34	3.13	6.46
Royalty	10.33	25.16	9.48	19.58
Payroll taxes	1.99	4.86	1.73	3.58
Workmens Compensation Insurance	3.16	7.72	4.25	8.78
Shop and equipment	2.55	6.22	2.98	6.16
Rebottling expense	.06	.15	.24	.49
Campsite expense:				
Cookery and commissary (net)	1.23	3.01	1.56	3.22
Labor	6.69	16.32	1.75	3.62
Heat, light, and power	1.64	4.00	4.00	8.26
Maintenance and warehouse	.73	1.79	6.41	13.24
Sales and administrative expense:				
Marketing	3.54	8.64	2.53	5.23
Office salaries and expense	3.52	8.57	5.97	12.34
Audit and legal expense	1.08	2.64	.85	1.75
Travel and entertainment	2.30	5.62	.56	1.16
Professional services	.57	1.39	--	--
Telephone and telegraph	.12	.30	.10	.21
Taxes and licenses	.44	1.07	--	--
Workmens Compensation Insurance	.01	.02	.01	.01
Fire and other insurance	1.32	3.23	1.02	2.11
Uncollectible accounts	.15	.36	--	--
Memberships	.12	.29	.24	.49
Other expenses	.24	.57	.08	.18
Interest on loans	1.07	2.62	3.30	6.82
Total direct production costs	$109.09	$266.04	$98.28	$202.89
Depreciation	11.45	27.93	11.56	23.89
Amortization of deferred exploration and development costs	18.80	45.86	21.26	42.91
Loss on sale of fixed assets	--	--	.06	.12
Outside exploration written off	--	--	4.75	9.81
Cost of registration, SEC	--	--	2.33	4.82
Grand total	$139.43	$339.83	$138.24	$284.44

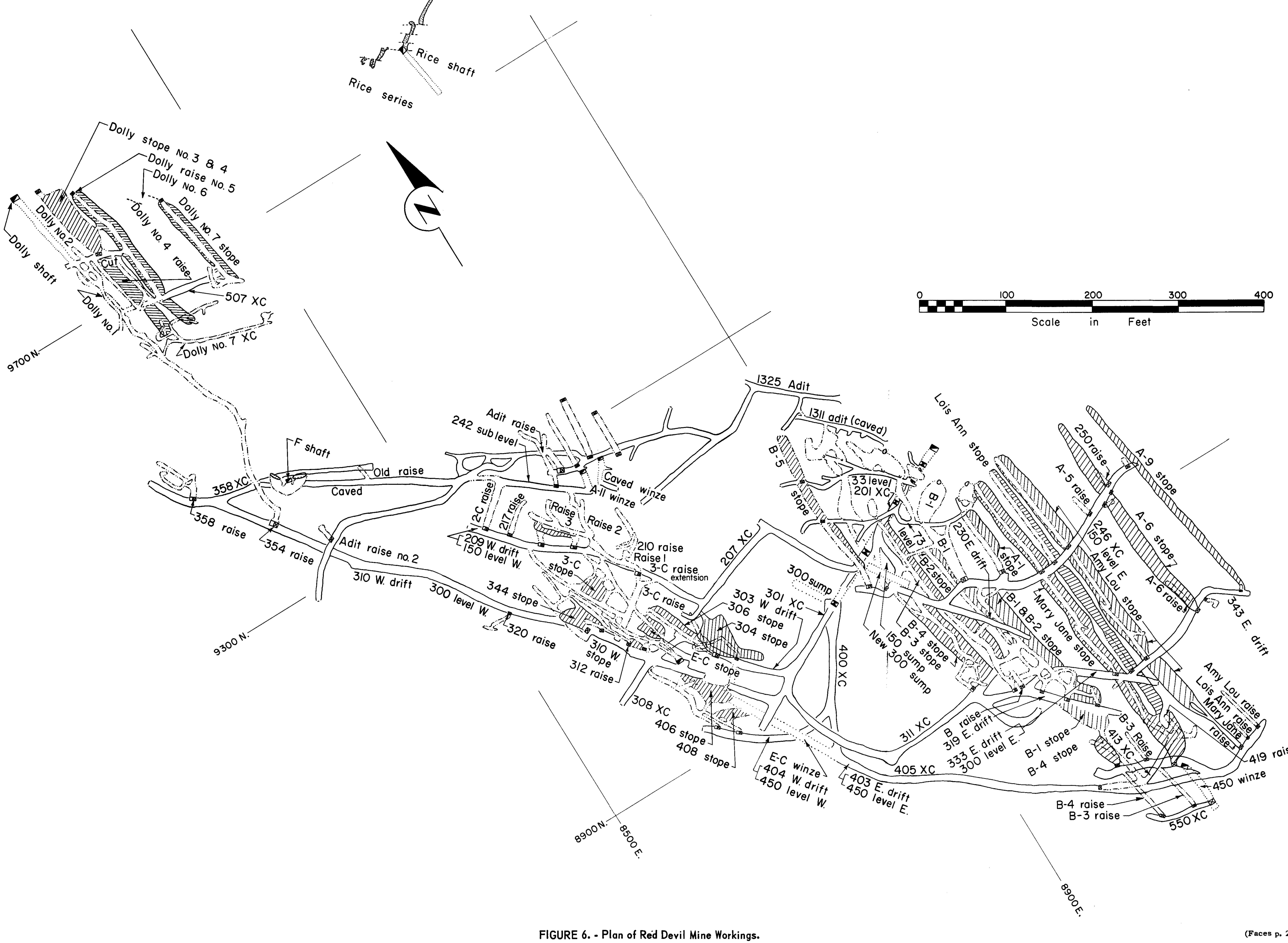


FIGURE 6. - Plan of Red Devil Mine Workings.

(Faces p. 24)

TABLE 6. - Wage rates

	Rate per hour
Miners and timbermen............	$3.00
Trammers and skiptenders........	2.50
Hoistmen........................	2.50
Mill operators..................	2.60
Mechanics.......................	3.00
Electricians....................	3.00
Surface labor...................	2.00-3.00

When the mine was reopened in 1952, the operators applied for a DMEA loan for exploration. After various modifications and amendments, a program calling for expenditure of $288,000 for surface and underground exploration was authorized. Actual expense of the program was $213,000; the Government's contribution was $160,000. When the exploration was discontinued in 1959, the entire Government outlay had been returned by the operator from royalty payments on ore found.

Metallurgy[25]

Reduction of mercury ores by fire methods is about the simplest and most efficient method of treating any metalliferous ore known, with the possible exception of free milling gold ore. Certainly, this is true of all sulfide base ores, for cinnabar in the presence of air breaks down into mercury and combustible sulfur at the comparatively low temperature of about 500° F. In practice, minimum temperatures of 1,000° F. are required to carry the reaction along at a rapid rate. Actually the required temperature for reduction is a function of the size of the ore being treated; the porosity, thermal characteristics, and wetness of the ore; the availability of free oxygen; and the time of exposure to these conditions. In practice, good balance of these variables in a rotary furnace is a calcine discharge temperature of 1,400° F. for ore crushed to 2 inches, with a 45-minute retention time within the furnace. At Red Devil a Herreshoff[26] furnace is used; common practice is to maintain a calcine discharge temperature around 1,200° to 1,300° F. for ore crushed to 1 inch, with 1½ to 2 hours retention time.

The occurrence of antimony in the Red Devil mercury ores greatly increases the furnacing problems. The antimony content on occasion runs to many times that of mercury and averages more than double the mercury content. Various remedies,[27] most of them aimed at eliminating the antimony before furnacing,

[25] This section was written by Robert F. Lyman, manager, Red Devil mine.
[26] Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement of such devices by the Bureau of Mines.
[27] Wells, R. R., Johnson, M. M., and Sterling, F. T., Recovery of Mercury From Cinnabar-Stibnite Ore by Flotation and Fluidized-Bed Roasting: Bureau of Mines Rept. of Investigations 5433, 1958, 19 pp.

have been proposed, but none as yet has appeared sufficiently promising to justify installing the special equipment needed to remove the antimony.

Like cinnabar, stibnite breaks down at a relatively low temperature. Its speed of reaction closely parallels cinnabar in the operational temperature range of furnace practice. There are, however, two significant differences in the way stibnite and cinnabar react. First, stibnite has a liquid state through which it passes and second, during the reaction the antimony combines with oxygen to form oxides of antimony, specifically the trioxide in the temperature range of mercury furnacing.

These differences permit more separation of the mercury from stibnite ore than would be expected because they tend to slow down the rate of burning of the antimony, especially on the heavy mixed stibnite-cinnabar pieces within the ore wherein lie most of the mine's value. The sticky molten stibnite picks up dust and fine ore, effectively sealing some of the sulfide from contact with the air, thus slowing down the burning rate. More effective, however, is the fact that in burning, the antimony goes over to the finely divided oxide in a solid state; this represents a much lesser expansion than takes place within the cinnabar when it burns, as both the sulfur and mercury go into a gaseous state and quickly are released from the rock under pressure. Therefore, given the same roasting period at a minimum furnace roasting temperature for cinnabar, a piece of mixed sulfide will give up all of its mercury while only about a quarter of the stibnite is decomposed.

If these conditions were obtainable in a furnace, it would be possible to extract the mercury from the ore while leaving up to 75 percent of the stibnite in the calcine as waste for disposal or further treatment. Attempts have been made to achieve this extraction by temperature control, but results are far from satisfactory because of the size range of the feed.

Nearly all the stibnite in the fines, probably up to 2-mesh, burns completely at the temperature and time needed to release the mercury from the plus 2-mesh material. That this condition is achieved in the coarser pieces can readily be seen from visual examination of the calcine. The vesicles in specimens show what portion of the ore was originally cinnabar. For a quick and accurate check on tailing losses, a visual inspection of picked pieces from the calcine is more satisfactory than assays on quenched calcine directly out of the furnace discharge, because the larger pure stibnite-cinnabar pieces are the slowest burning part of the ore. In checking the tailings, therefore, the larger pieces, which were originally all sulfide, are cracked open and examined for any red in the center. These pieces generally make up 5 to 10 percent of the feed. Consequently, if the calcine will stand visual inspection, the tailings are acceptable. Even with a small showing in the center of these pieces, the calcine may assay from 0 to 0.03 percent, which is satisfactory.

From the instant the stibnite burns in the furnace, it causes trouble all along the process. Antimony trioxide has a melting point of about 1,200° F. Although the lowest and hottest hearth is carried at 1,100° F., the temperature near the burners on the lower four hearths of our six-hearth furnace is high enough to fuse some of the oxide. The oxide is carried along by the gas flow and rabble arms, slagging with the dust and adhering to the inside of the furnace. The burner blocks and drop holes must be constantly cleaned to keep them from plugging up entirely with antimony glass. Periodic shutdowns are required to clean the entire inside of the furnace. The rest of the oxide passes into the condensing system with the mercury-laden gases. As is standard practice in quicksilver plants, the gases pass through a cyclone dust collector. A cyclone, however, is ineffective on most of the antimony oxides and on arsenic trioxide. However, within the furnace itself, the arsenic fumes are mostly vapor. The size range of these oxides upon leaving the furnace is mostly in the minus 10 micron range, which is well below the capabilities of cyclone operation. The heavy concentration of these oxides in the cyclone ducts and within the entire cyclone itself except for the cone rapidly coats all surfaces. Daily blowing with compressed air and hammering with a rubber mallet are required to keep these openings clean.

When the furnace gases reach the condensers, the gas velocity is slowed considerably, and the oxides begin to drop immediately. Also, the particle size increases as the gases are cooled. Much of the oxide is so finely divided that it never settles, and it goes through the condenser and out the stack. Enough oxide, however, settles into the launders, where the mercury also accumulates to greatly dilute the condenser mud, or soot as it is commonly called. This makes the process of removing the mercury from the soot a much greater problem than in most other quicksilver mines. Most mines obtain up to 80 percent free mercury out of the soot by merely settling and pouring off the quicksilver from under the soot. The remainder is usually dumped on an inclined metal hoe table and worked over by hand. At the Red Devil, the soot shows no visible mercury as it comes from the condenser launders, and free metal will not separate from the mud without treatment. It is worked both wet and dry by hoeing, paddling, pushing, agitating, stirring, scraping, vibrating, rolling, pressing, raking, and jiggling, with or without various additives. Despite this treatment the residue must be returned to the furnace or retorted.

Formerly the impoverished soot from the hoeing table was returned to the furnace. Considerable recycling of the antimony and arsenic oxides resulted, plus an aggravation of the conditions these oxides create throughout the process. Retorting the worked-over soot would appear to be better practice, thus finally disposing of the residue as tailing. Actually, however, retorting was found to be not only unsatisfactory but expensive and hazardous. Unless a large amount of lime is added to the soot before retorting, the charge fuses into an antimonial-arsenical glass, which boils and froths in the retort. This sticks to the charging pans and in general makes a mess. This antimonial-arsenical glass also vaporizes and condenses in the head of the retort and in the condenser pipes, sealing them up completely. When this happens, mercury vapors under high pressure build up in the retort, and leakage occurs. High labor costs, health hazards, virtual disintegration of the pans and retorts after only a few weeks' operation, and poor recovery all dictated abandonment of retorting after a short trial at Red Devil.

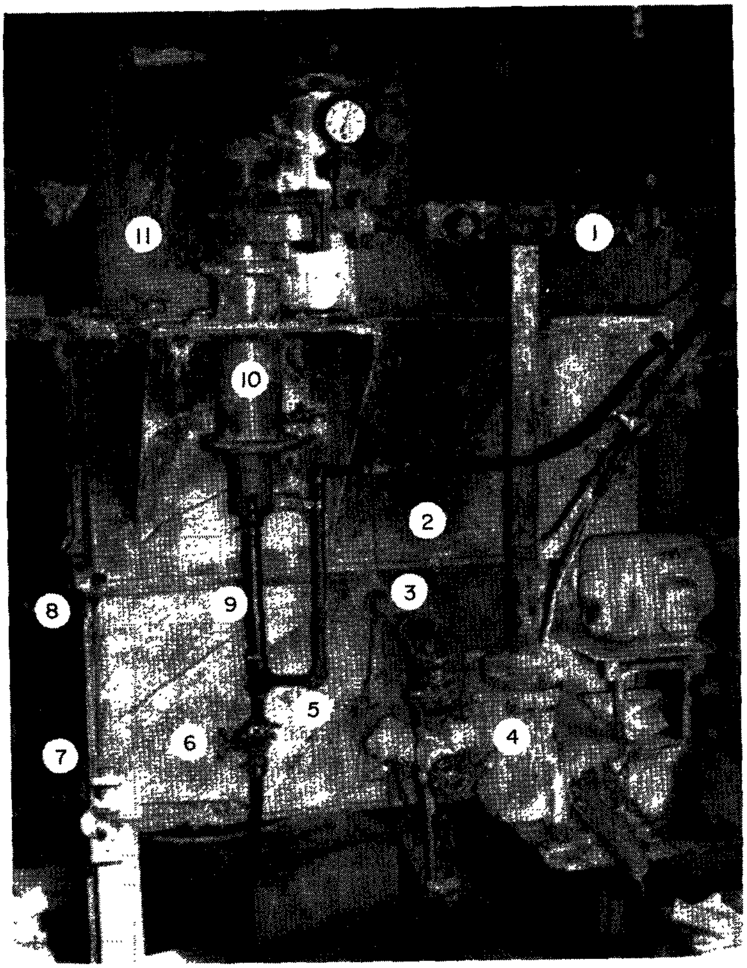
The standard practice of hoeing the mud in a mechanical hoeing machine with quicklime was used until the later part of 1959. The hoed-out mud was returned to the furnace on the No. 5 hearth through a self-sealing screw feeder. This product, containing about 35 percent mercury, amounted to about a ton a day. Failure of mechanical hoeing to do a better job on the soot is attributed mainly to the strong adhering action of the dust toward the mercury. This prevents the globules from coalescing.

In November 1959, equipment was installed to treat the condenser mud by a wet method. Mercury was separated from the mud by this method in two ways: (1) agitating and aerating the heated mud and (2) centrifuging with a wet cyclone. The mud is pumped from an agitator through a wet cyclone and back into the agitator. A modified 4- by 4-foot Denver Super Agitator with conical bottom, a 2-inch SRL pump, and a 4-inch Krebs wet cyclone are used. The agitator is made of 304 stainless steel and is mounted in an insulated square "water jacket" tank. Four 3,000-watt emersion heaters are capable of holding the water at temperatures up to the boiling point. The bottom of the agitator cone is tapped and piped through a gooseneck to the mercury pot to hold the mercury level about 5 inches deep in the cone. About a quarter of the contained mercury in the soot separates in the agitator and discharges automatically through this arrangement. Figure 7 shows the cyclone and auxiliary equipment.

The pump intake is about 4 inches above the mercury pool in the agitator cone. The cyclone is mounted above the pump and to one side. An operating pressure of about 40 pounds per square inch is maintained. The pulp density does not materially affect recovery. Operation is satisfactory through a range of 25 to 70 percent total solids. The temperature of the pulp is not critical, but it should be above 80° F. for satisfactory operation.

The cyclone is used to make the liquid separation of mercury from a liquid-solid fluid pulp. Therefore, its operation is different from the usual practice in that the apex valve must be capable of complete closure. In operation the proper setting of the apex valve is an opening just large enough to permit free mercury to escape at the same rate it is released in the cyclone. This setting is not critical, but it must be small enough to maintain a seal of mercury in the bottom of the cyclone.

This seal of mercury is kept by visual control. The following modification was made to accomplish this control: The standard, lever-operated apex valve was removed from the cyclone. A 12-inch piece of 1-inch transparent plastic tubing was attached to the apex. The lower end of this tube was attached to a plastic T, through which water may be injected if and when required. Beyond the T and straight below the tube a full-flow pinch-valve is attached. In operation the valve is adjusted so that the entire tube remains full of mercury, and a noticeable rotation of this mercury column is evident. At the start of a run, the discharge is at a rate of about four flasks per minute, so that the cyclone tends to fill up with free mercury if the valve is not opened sufficiently. This causes a chatter and "bumping" in the pump. As the run progresses, the valve is gradually closed. The usual



LEGEND

1. Discharge line - used when pumping out a batch.
2. Insulated water tank.
3. Decanter outlet.
4. 2-inch SRL pump.
5. Waterline.
6. Pinch valve.
7. Mercury outlet for agitator.
8. Air line for blowing out mercury outlet in case of plugging.
9. M-34 plastic tubing.
10. 4-inch Krebs cyclone.
11. Agitator tank.

FIGURE 7. - View of Krebs Cyclone.

batch contains from 250 to 300 gallons of pulp and requires about 2 hours to run. Toward the end of the run, water is injected intermittently to help recycle the heavier sand that accumulates on top of the mercury in the cyclone. This water injection is also necessary to clean the inner surface of the plastic tube in case the mud level descends into the plastic tube, thus obscuring vision.

This process does not make tailings that can be discarded, although tailings of less than 2 percent have been achieved, and treatment time has been reduced to about 5 percent of that formerly needed with the hoeing machine. At present the tailings are dried and fluxed with lime for refurnacing. Installation of a filter and mixer for this final stage is planned. If the impoverished soot did not contain such a high percentage of antimony and arsenic oxides (which require fluxing), it could probably be pumped as a slurry directly back into the furnace.

The mill flowsheet is shown in figure 8. The capacity of 6-hearth Herreshoff furnace is 30 to 40 tons per day, depending on the quantity of moisture in the ore. Since the original installation in March 1956, this furnace has handled 34,700 tons, with no maintenance required on the brick lining. The condenser tubes were replaced in June 1958. Adding a dryer to the mill circuit would increase capacity an estimated 50 percent. At present the richest ore usually is the wettest, so that furnace capacity is reduced on high-grade ore, and daily production increases only slightly, if at all, when the feed is high grade.

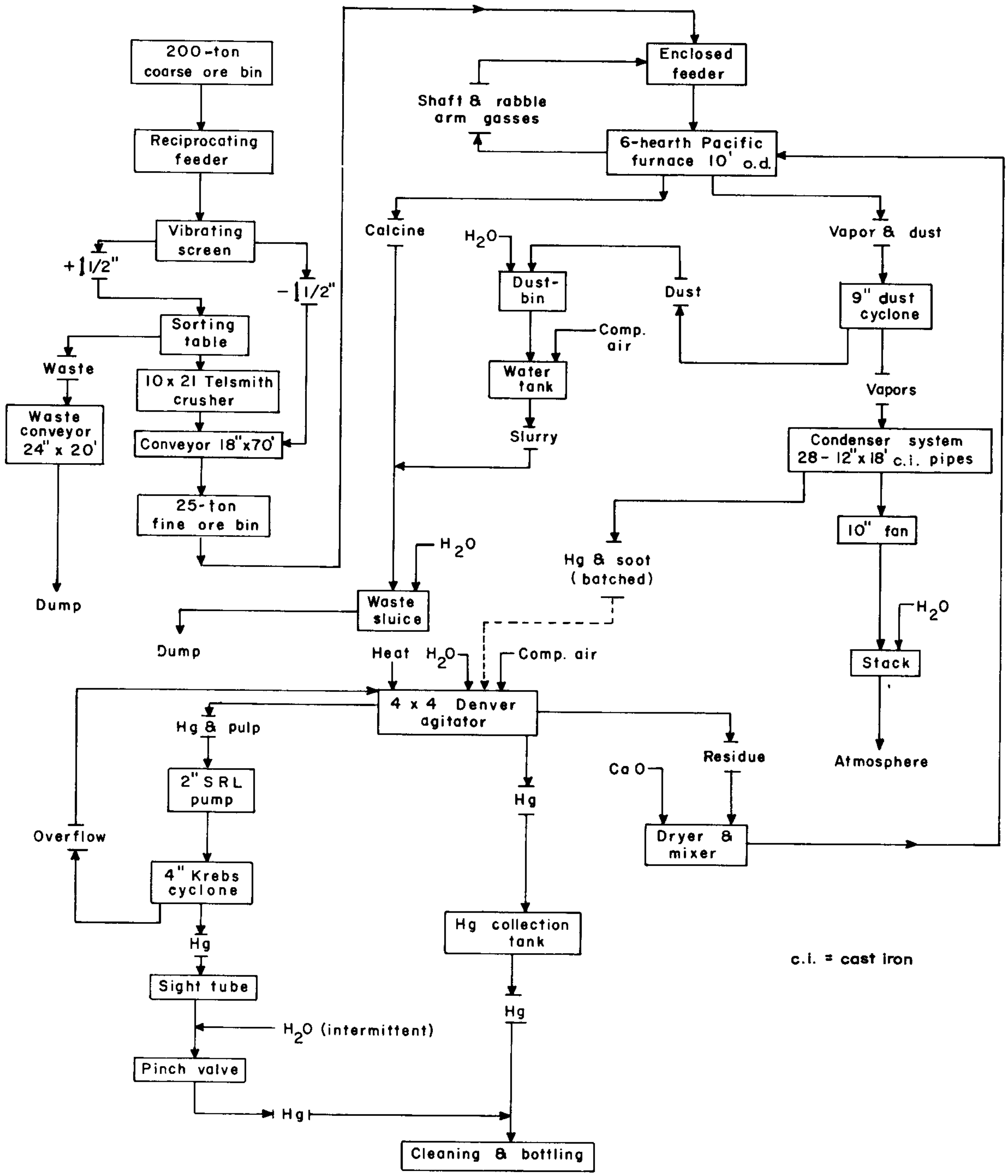


FIGURE 8. - Flowsheet, Red Devil Mill.

The Red Devil mill is primarily a standardized Pacific Foundry installation. No special engineering went into its design except to fit it onto the topography and house it for Alaska's year-round conditions. Certain changes and additions have been made. Others are greatly to be desired, but the original layout makes these too expensive, if not entirely impossible.

The fact that the entire plant, including bins, conveyors, condensers, and so forth, had to be housed, created a problem in ventilation on the one hand and condenser cooling in the summer on the other. Also, for 6 months of the year, two large hot-air furnaces must be used to keep the buildings warm enough for operations. These two furnaces use about the same amount of fuel as the reduction furnace.

Mine-run ore is almost always saturated, as it is necessary to use water to move the ore out of the stopes. Often the ore is very sticky. Feed rate is slowed greatly by this condition, owing to bridging the feed hole in the top of the furnace. Automatic signal lights and buzzers were installed throughout the plant to warn the operator whenever the feed hole bridged. Also, the space between the fine-ore bin and top hearth was enclosed, and the cooling air from the main shaft and rabble arms is exhausted directly into this enclosure. This partially dries the ore before it enters the furnace.

Calcine disposal is by sluicing and bulldozing. A 7- by 10-inch sluicebox, at a slope of 2 inches per foot, extends from under the burned-ore bin to the waste dump 100 feet away. From here the calcine is bulldozed away every second day. When road-surfacing material is needed, it is sometimes loaded directly into a truck spotted under the sluiceway. The calcine feeds directly from the burned-ore bin into one side of the sluicebox through a 12- by 5-inch slot (fig. 9).

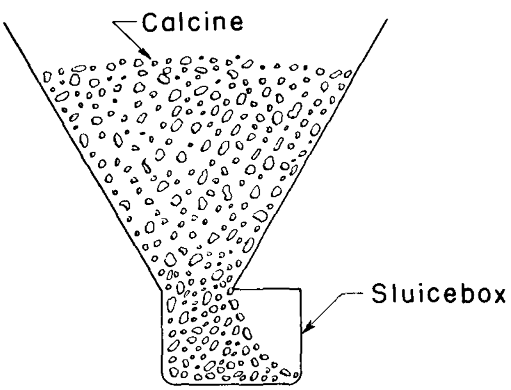


FIGURE 9. - Cross Section of Calcine Feeder.

This feed end of the sluicebox is covered for about 6 feet. Sluice water is admitted through two 2-inch pipes, one directly behind the calcine and one directly in front. Control of the water at the rear adjusts the flow of calcine; the water at the front is for added sluicing and flushing. This arrangement is self-sealing, as a plug of calcine is always left in the throat of the burned-rock bin. The burned rock is sluiced out of the bin at about 45-minute intervals. Sluicing time is about 5 minutes. During sluicing the water requirement is about 150 gallons per minute.

The draft fan speed on the original installation was increased from 1,900 to 2,250 r.p.m. This increase gives a water-gage reading of about 12 inches (between the high and low side on the U-tube), increases the efficiency of the cyclone, and keeps the fan cleaner. The fan requires daily washing. The condensers are washed at least once each shift. The cyclone and ducts require constant beating and blowing to keep them clean. All this work is caused by the large amounts of antimony and arsenic oxides in the gas stream. These finely divided particles adhere like glue to everything. Even the stack requires occasional washing. A washing sprayer has been permanently installed at the top of the stack. Failure to keep the entire gas-stream system clean results in loss of draft within a matter of hours. Fan blades usually fail after about 6 months of operation, probably because unbalance builds up that causes vibration. Fan impellers are rebuilt and balanced at the mine shop.

Temperatures are as follows: Furnace gas outlet, 650° F.; bottom hearth (calcine), 1,050° F.; and end condenser, 90° to 115° F. (average, 105° F.). The reason for the unusual temperatures is covered in the discussion of the relative volatilities of mercury and antimony. The top temperature is kept as high as possible without throwing the end condenser temperature out of good operating range; the bottom temperature is kept as low as possible to minimize the antimony difficulties and still recover the mercury.

Dust from the cyclone-dust bin is discharged with the aid of several water jets built into the bin. The dust is not free flowing when it is dry. The discharge pipe enters an open tank through a water seal. This tank is air-agitated and discharges automatically to the tailing sluicebox. Occasional samples of this dust have been assayed, but as would be expected, only traces of mercury have been found, as the cyclone is operated about 100° hotter than common practice.

Condenser-tube life is 18 months to 2 years for centrifugal cast iron. A changeover to reinforced plastic, as used by some plants, is under consideration. Used flasks are reconditioned and cleaned with jig shot, wire-brushing, and painting. Table 7 summarizes milling costs for fiscal year 1959 and the last 7 months of calendar year 1959.

TABLE 7. - Comparative milling costs, Alaska Mines and Minerals, Inc., Red Devil mine, fiscal year 1958-59 and June through December 1959

	Fiscal year 1958-59[1]		June-December 1959[2]	
	per ton	per flask	per ton	per flask
Operating labor................	$3.53	$7.26	$2.58	$7.91
Repair and maintenance labor...	.81	1.67	1.22	3.75
Crushing and picking labor.....	.84	1.74	1.00	3.05
Calcine removal labor..........	.10	.20	.09	.27
Mill supervision...............	1.22	2.52	1.09	3.33
Repair parts...................	.66	1.35	.73	2.24
Flasks.........................	1.22	2.50	.69	2.11
Heat, light, and power.........	5.36	11.01	4.95	15.16
Total......................	$13.74	$28.25	$12.35	$37.82

[1] Tons milled, 8,175.5; flasks produced, 3,977.
[2] Tons milled, 6,104; tons of waste picked, 569; flasks produced, 1,992.

An interesting sidelight to the operation of the Red Devil plant is the fact that it has produced at a rate of 30 flasks per day during a week period. The highest single day's production is 43 flasks. This figure is an "honest" day's run, as it was preceded by a 41-flask production the day before.

Kolmakof Deposit

The Kolmakof deposit is in the Aniak district, Georgetown subdistrict, on the north bank of the Kuskokwim River, 18 miles upstream from Aniak. It is probably the first mercury discovery in Alaska. Spurr[28] reported unsuccessful attempts to exploit the deposit in the early 1890's. The high cost of shipping ore to San Francisco for reduction is given as the reason for the failure.

Willie Rabidoux of Aniak holds the Jaufok Nos. 1 and 2 lode claims. Western Alaska Mining Co. holds the Wamco Nos. 1 to 6. Both groups of claims are unpatented and held by location.

According to Smith and Maddren,[29] the north bank of the Kuskokwim River near Kolmakof is made up of bluffs, 100 to 400 feet high, composed of sedimentary rocks intruded by dikes and sills. The intrusions may be related to large masses of igneous rocks, which occur in the nearby Russian Mountains. Folded sandstones and shales, striking N. 60° to 70° E. and dipping 40° to 45° NW., are exposed in a 200-foot bluff at the Kolmakof prospect. Two andesite sills, 200 feet apart, appear to control mineralization, with the one at the eastern end the more important. Smith reports that no cinnabar occurs in the eastern sill itself but that appreciable quantities occur in lenses and stringers of quartz near the sill and extend along joint and bedding planes into the sediments. Maximum width of mineralization is about 4 feet. The quartz lenses carrying the cinnabar are short, narrow, and discontinuous.

The Bureau of Mines explored the deposit[30] as part of the mercury investigation program of World War II and the post-war period. Twenty-nine trenches, aggregating 600 feet in length, were spaced irregularly along a strike length of 350 feet. Figure 10 is a plan of the Bureau's work. The trenches exposed mineralization associated with a prominent rhyolite sill. Three modes of occurrence were found:

1. A narrow, persistent stringer, averaging one-half inch in width in the sill itself, was traced 250 feet along the strike and through a vertical depth of 100 feet. Locally it swells to 3 inches in width. A Composite sample from this stringer contained 20.2 percent mercury.

2. A narrow shear zone, roughly paralleling the sill on the hanging wall side, was found along the eastern two-thirds of the exposed strike length.

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[28] Work cited in footnote 9, p. 7.

[29] Smith, P. S., and Maddren, A. G., Quicksilver Deposits of the Kuskokwim Region in Mineral Resources of Alaska: Geol. Survey Bull. 622, 1914, pp. 272-291.

[30] Work cited in footnote 14, p. 8.

Intermittent cinnabar mineralization as small pods occurs within or adjacent to the shear zone. One pod, 6 feet by 6 feet and with a maximum thickness of 5 inches, contained 9.58 percent mercury.

3. Thin films of cinnabar were found in cross fractures extending from the shear zone to the hanging wall of the sill.

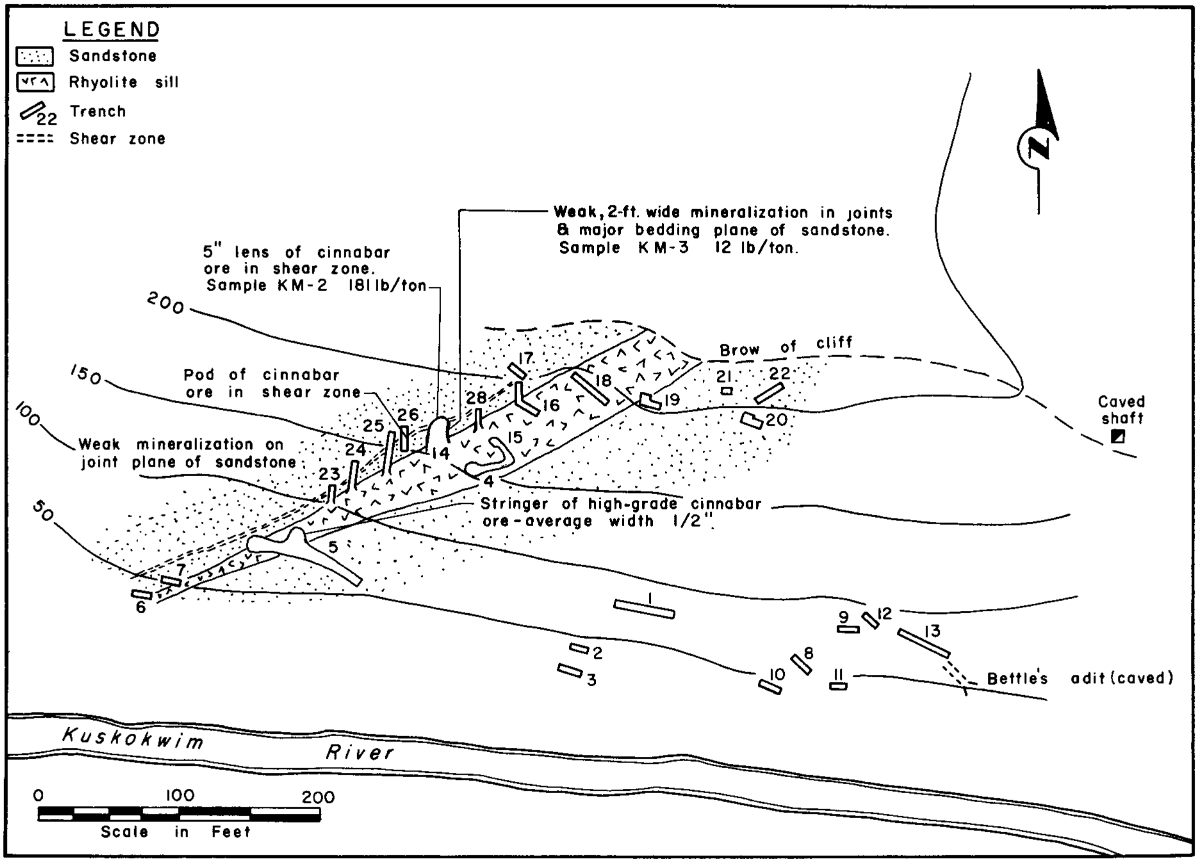


FIGURE 10. - Kolmakof Mercury Deposit.

In 1958, a Bureau of Mines engineer sampled the trenches, using a 3-inch posthole auger. A total of 145 samples was taken on bedrock at 5-foot intervals. The Bureau's work was not conclusive but did indicate the possibility of mineralization away from the crest of the river bluff.

The deposit has no recorded production. An engineer of one of the major domestic mercury producers examined the property in 1959. No reports on the examination have been released.

Parks Deposit (Alice and Bessie)

This deposit, on the north bank of the Kuskokwim River, 8 miles downstream from Sleetmute, was discovered by E. W. Parks in 1906. It is in the Aniak district, Georgetown subdistrict. Believed to be the first mercury discovery in the Sleetmute area and second only to the Kolmakof deposit in Alaska, it is credited with most of the small Alaskan mercury production up to the early 1920's. Parks, a trader on the Kuskokwim, prospected the deposit and produced mercury for sale to placer miners in the Iditarod and Flat areas. Total production to the end of 1959 is estimated at 130 flasks. George Willis, R. F. Lyman, and Nick Mellick own the deposit. Eight claims are held by location.

Parks obtained the early production largely from surface pits and shallow workings. An early crosscut adit, driven 200 feet by Parks, was extended in 1936 by W. E. Dunkle (lessee) to cut the ore zone at 450 feet from the collar and some 160 feet below the outcrops. However, only a small output resulted from this work.

Graywackes and shales make up the country rock on the property. Cinnabar mineralization is found associated with altered andesite sills and dikes. The altered andesite is a light-colored rock readily distinguishable from the unaltered dark biotite rock from which it is derived; it is a valuable guide in prospecting. Three ore zones occur: The upper zone, on which Parks did much of his work; an intermediate zone, cropping out some 50 feet lower; and a zone cropping out in the riverbed. The Bureau of Mines trenched and sampled the upper zone in conjunction with the World War II mercury program. Figure 11, a plan of part of the property, shows the Bureau's work. Trenches 1 to 10 and 14 and 15 assayed from 2.2 to 39.0 pounds of mercury per ton of ore (arithmetic average 16.1 pounds per ton). Mineralization was found chiefly in the andesite, but extended in places into the wall rock.

Willis and Fuller Group

This deposit is 1 mile north of the Kuskokwim River, 12 miles downstream from Sleetmute; it is above timberline at an elevation of 700 feet. The group consists of the Buck, Headache, Jack, Nick, Relief, and Sam Lodes. Alaska Mines and Minerals, Inc., leases the property under option. Access from the mouth of Willis Creek on the Kuskokwim is by foot trail; a tractor road connects the property with the Parks deposit about 2 miles east. Willis and Fuller made the original locations in 1909. Development work consists of shallow pits and adits, largely caved, and six trenches cut by the Bureau of Mines in its 1942 exploration program.

Andesite dikes, subsequently altered by hydrothermal action, intrude graywackes, sandstones, and shales. Four roughly parallel dikes containing mineralized zones are known. Bureau personnel explored a 30-foot dike striking N. 30° W. and dipping steeply southwest. Mineral deposition is concentrated in a brecciated zone on the hanging wall side of the dike and extends into the dike along fractures. Stibnite occurs with the cinnabar. Webber[31] reports that the entire dike in one trench averaged 1.6 pounds of mercury per ton of ore and that a second trench averaged 3.7 pounds per ton over a 30-foot width. Recorded output for the Willis group is two flasks, produced during World War I.

[31] Work cited in footnote 14, p. 8.

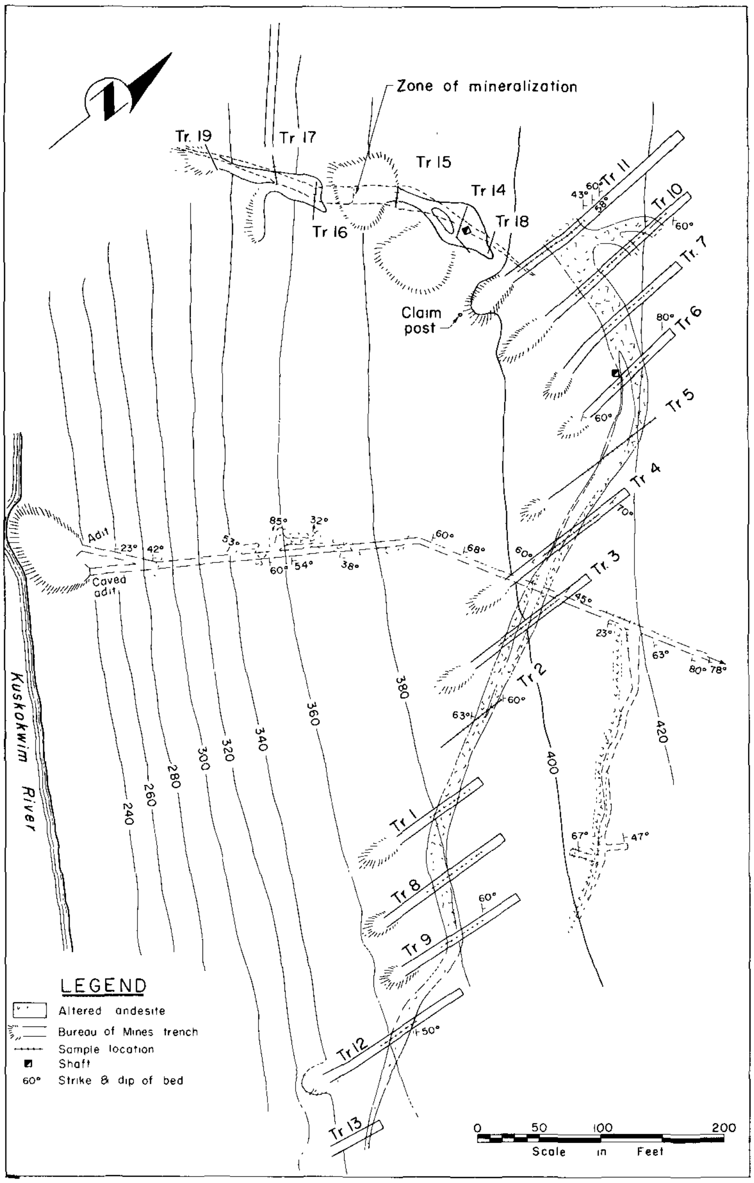


FIGURE 11. - Alice and Bessie Mine.

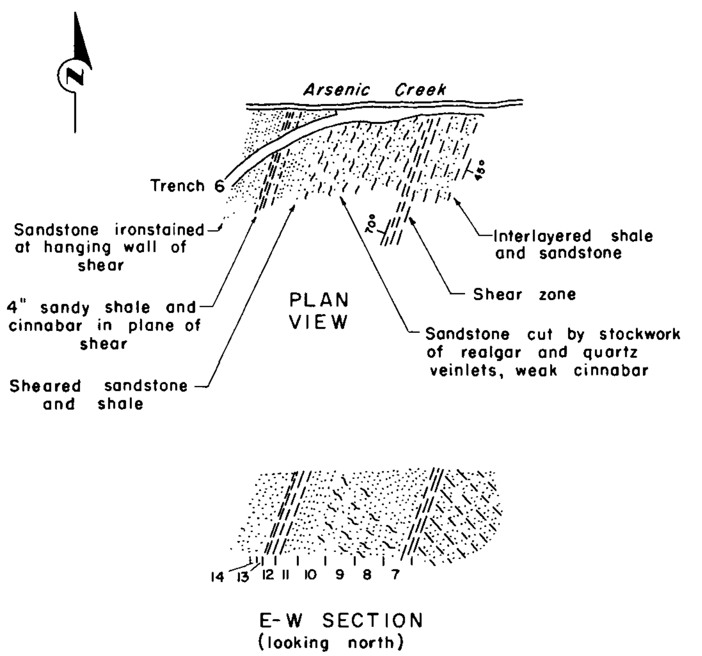
Rainy Creek Deposit

The deposit is at the western base of the Kilbuck Mountains on the headwaters of the Eek River, a tributary of the Kuskokwim. It is in the Bethel district, Bethel subdistrict. Kagati Lake is 7 miles south, Mount Oratia, 7 miles southeast; and Bethel, 80 miles northwest. There is a winter tractor trail 120 miles in length between Bethel and Rainy Creek. Present ownership of the deposit could not be determined.

Ed McCann of Bethel is credited with the original discovery sometime between 1910 and 1920. Neal Corrigal, also of Bethel, staked the ground in the twenties and did some exploratory work before allowing his locations to lapse. Before World War II, Al Jones is reported to have produced 2,000 pounds of high-grade cinnabar from gold placering on Rainy Creek. Recorded production is six flasks, obtained in the 1941 season.

Country rock in the area is composed of sandstones and shales striking N. 20° to 30° E. and dipping 70° SE. Mineralization occurs along the bedding planes and is associated with fault planes paralleling the bedding planes but dipping northwest. The igneous intrusives usually found associated with mercury deposits in the Kuskokwim region are absent. Realgar accompanies cinnabar in a quartz gangue.

The Bureau of Mines explored the property by trenching in 1947. Rutledge[32] has reported on the Bureau's work. In the most prominent showing, cinnabar occurs within and between two shear zones separated by 16 feet of fractured sandstone. To the southwest the showing is masked by the overlying sediments; to the northeast trenching failed to reveal the shear zones or mineralization. Figure 12 indicates a plan and the elevation of the showing with assays.



Sample number	Width sampled	Lb. Hg/ton
7	4.4′	3.6
8	4.4′	1.6
9	4.4′	1.2
10	4.4′	.6
11	4.0′	9.4
12	2.0′	1.4
13	.33′	35.4
14	.7′	1.6

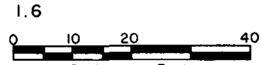


FIGURE 12. - Deposit No. 1, Rainy Creek Area.

Barometer Prospect

The mine lies on the south side of the Kuskokwim River, about 7 miles northwest of Sleetmute, at an elevation of 400 feet. It is in the Aniak district, Georgetown subdistrict, approximately three claim lengths northwest of the Red Devil deposit. Hans Halverson made the discovery in 1921, locating the Barometers Nos. 1 to 6; the deposit was sold to E. W. Parks in 1923. Various lessees worked the property during the ensuing years. A. G. Skidmore did some work in 1938, producing 8 flasks from 25 tons of ore. Small quantities of mercury were later produced in connection with annual assessment work. Alaska Mines and Minerals, Inc., successor to DeCoursey Mountain Mining Co., leases the deposit. The property now consists of the Barometer Nos. 1 to 10. The claims are unpatented.

The country rock at the Barometer is largely shale. To the west, graywacke and sandstone begin to appear. Two deposits, known as the upper and lower, have been prospected. At the upper deposit, where most of the work has been done, the strike of the sediments varies between N. 20° and 60° W. The sediments strike consistently N. 10° W. at the lower deposit. Hydrothermally altered igneous intrusives are

[32] Rutledge, F. A., Investigation of the Rainy Creek Mercury Prospect, Bethel District, Kuskokwim Region, Southwestern Alaska: Bureau of Mines Rept. of Investigations 4361, 1948, 7 pp.

associated with the mineralization. Cinnabar occurs along bedding joints and in openings along fault and fracture zones, particularly in the vicinity of the altered intrusives. Deposition is irregular; realgar and stibnite accompany the cinnabar.

Halverson drove a 122-foot adit, exposing the upper deposit 46 feet below the surface in 1922. In 1931, Otto Rhophs, lessee, crosscut and drifted on the deposit from the Halverson adit. These workings, totaling 200 feet, comprise the underground exploration on the property. The Bureau of Mines trenched and sampled the deposit in connection with its World War II mercury program. Five trenches across the mineralized zone and an underground crosscut were sampled on the upper deposit; figure 13 is a plan of the work. Sample results will be found in Report of Investigations 4065.[33] Visible cinnabar was observed over a strike length of 165 feet in the segment, including trenches 2 and 3 and the surface exposures lying over the underground workings. Assays proved the zone to be low grade. Underground samples (Nos. 241 to 247) represent the most consistent mineralization found on the deposit. The Bureau's work on the lower deposit did not disclose the structural relationship of the andesite and the ore. However, samples 261 and 268 show interesting quantities of mercury. All samples were 5 feet in length.

Under the DMEA program, at the Red Devil mine 1,000 feet of trenching on the north side of the Red Devil fault was done on Barometer No. 3 and No. 5 claims. The work was done in 1957 and involved stripping 5,400 cubic yards of overburden from bedrock. The work showed no andesite dikes, as expected, and no cinnabar mineralization. Excavation of 2,200 cubic yards of trenching on the south side of the Red Devil fault in 1958 also failed to show cinnabar mineralization.

Fairview Group

The deposit is 1 mile southwest of the Red Devil mine near the mouth of McCally Creek at an elevation of 900 feet, Aniak district, Georgetown subdistrict. There is no trail to the property. The first locations were made in the mid-thirties; the deposit is not held by Alaska Mines and Minerals, Inc., successor to DeCoursey Mountain Mining Co. Graywackes and shales of the Kuskokwim group have been intruded by a massive rhyolite dike at least 1,000 feet long and 120 feet wide; it strikes N. 60° W. and dips northeast. Mercury occurs in a fractured zone cutting across the dike at an acute angle. Stibnite accompanies cinnabar.

The Bureau of Mines examined the deposit by trenching in 1942. Figure 14 is a plan and assay map of the Bureau's work. Trench No. 2 shows a 25-foot zone at the north end, assaying 2.6 pounds of mercury a ton, and a second 25-foot zone, 10 feet south, assaying 3.5 pounds. Mineralization is weaker in trench No. 1. No visable cinnabar occurred in trench No. 3; the trench was not sampled.

There is no recorded production from the property.

[33] Work cited in footnote 14, p. 8.

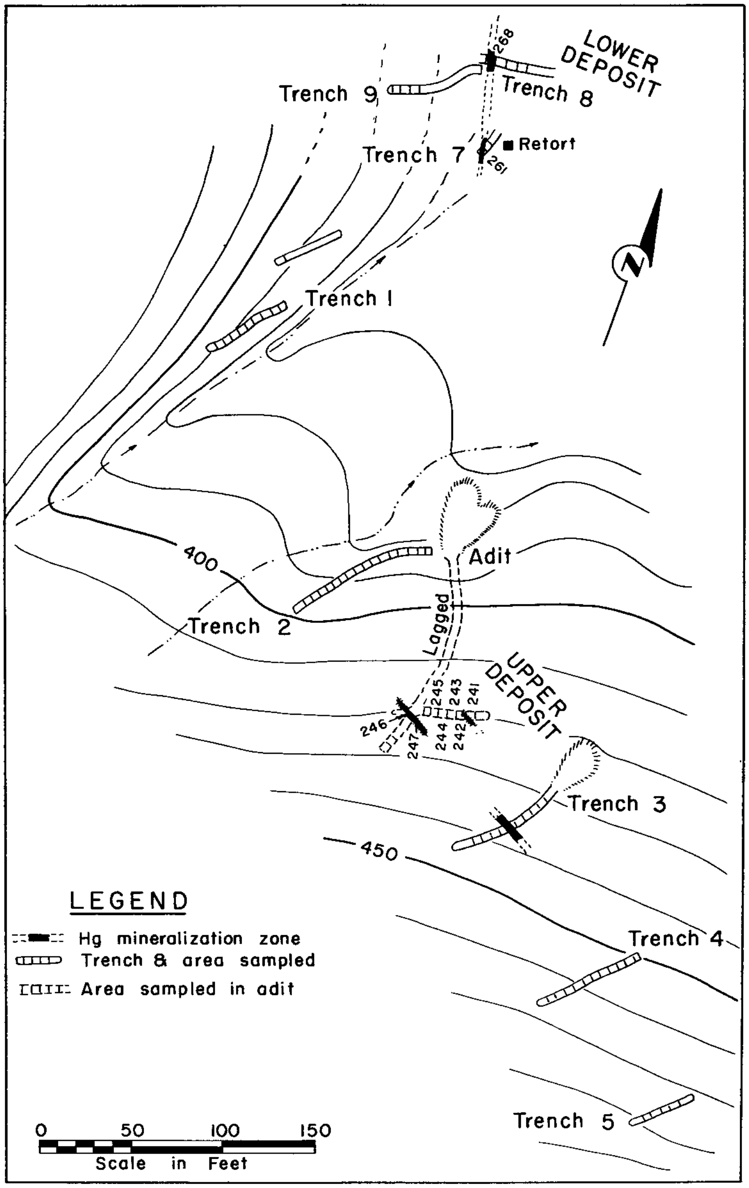


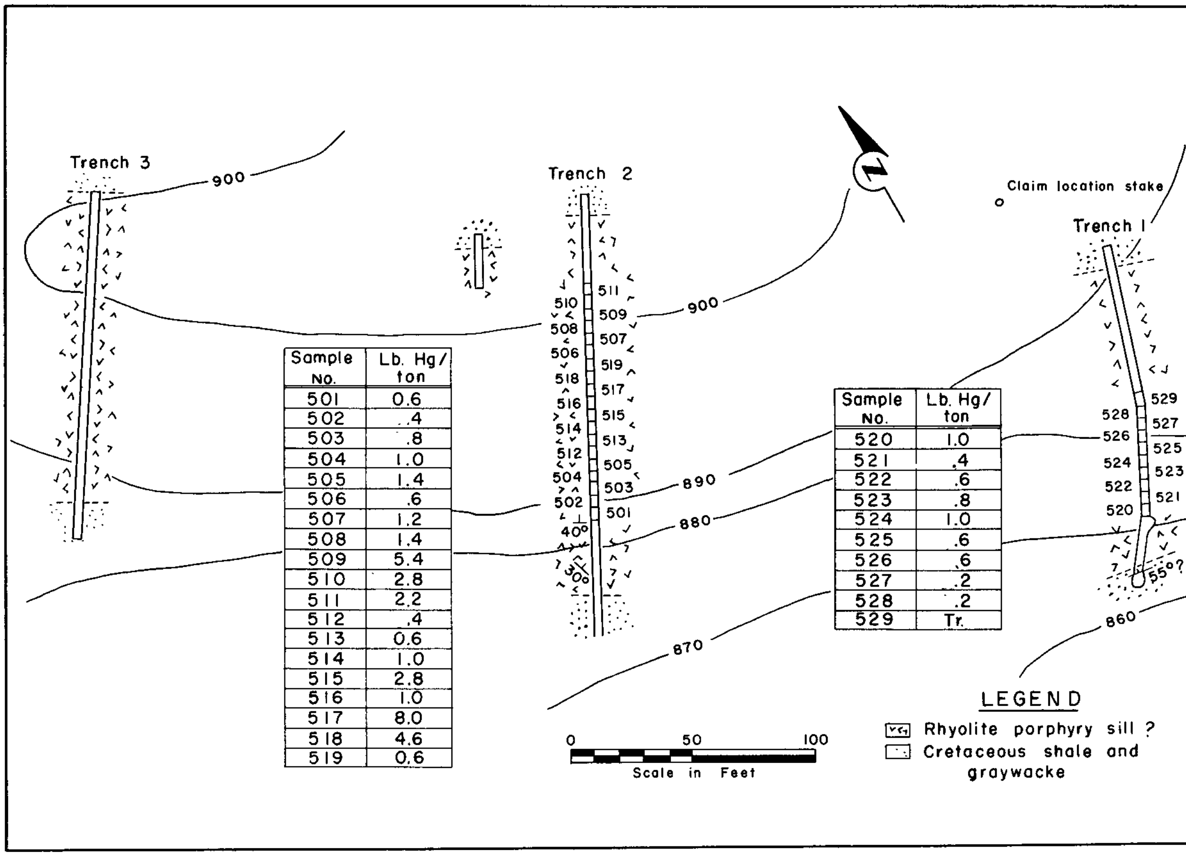
FIGURE 13. - The Barometer Mine.

Lucky Day Group

The Lucky Day deposits are in the Aniak district, Georgetown subdistrict, on the Holitna side of the divide between the Holitna and Aniak Rivers. They are on Beaver and Cinnabar Creeks, 85 miles southwest of Sleetmute, at an elevation of 1,400 feet. Access is by boat up the Holitna, Chukowan, and Gemuk Rivers or in winter by sled trail from Nyac, 42 airline miles to the northwest. Nyac, the base of operations for New York-Alaska Gold Dredging Corp., receives supplies by riverboat on the Tuluksak followed by a 10- to 30-mile tractor haul from the river. The Lucky Day deposit is reported as 76 miles by tractor trail from Nyac.

Russell Schaefer and Harvey Winchell located the Lucky Day lode deposit in Canary Gulch in the summer of 1941 and also placer ground in Cinnabar Gulch and Cinnabar Run in the same year. The original holdings comprised three lode claims, the Lucky Day, Lucky Day No. 1, and the Redskin, and six placer claims, Discovery and Nos. 1 to 5 below Discovery. Schaefer later acquired sole ownership of the deposit.

In 1942 and 1943, Schaefer retorted 26 flasks from 3,600 pounds of high-grade float gathered on the property. Schaefer has maintained a small but consistent output of mercury for several years from the Lucky Day group and the nearby Broken Shovel deposit.



Sample No.	Lb. Hg/ ton
501	0.6
502	.4
503	.8
504	1.0
505	1.4
506	.6
507	1.2
508	1.4
509	5.4
510	2.8
511	2.2
512	.4
513	0.6
514	1.0
515	2.8
516	1.0
517	8.0
518	4.6
519	0.6

Sample No.	Lb. Hg/ ton
520	1.0
521	.4
522	.6
523	.8
524	1.0
525	.6
526	.6
527	.2
528	.2
529	Tr.

FIGURE 14. - Sample Locations and Analyses, Fairview Prospect.

Cady[34] states that the country rock is made up of typical graywacke and shales of the Kuskokwim group. The sediments are intruded by large sills of coarse-grained basalt and quartz diabase and by small sills of biotite basalt; some of the biotite basalt is altered to silica-carbonate rock. Alteration extends into the sediments in places. The formations are in a homocline that dips southwest.

The lode as exposed over a vertical extent of 130 feet consists of a low-grade mineralized zone at least 900 feet long and 50 feet or more wide, striking a little east of north, and dipping steeply west. Within the zone several narrow high-grade stringers, averaging 1 inch in width, lie in the bedding-plane fractures in the upper section. Fine-grained dense cinnabar occurs with stibnite and native quicksilver; dickite is localized along and near the hanging walls of the sills. In the lower section of the lode there are more cross joints and breccia openings, and the mixed cinnabar and quartz gangue is coarsely crystalline. The high-grade veins in the lode are wider but leaner where exposed in the lower section than they are in the upper section.

According to Cady,[35] the operator, Russell R. Schaefer, believes that all the high-grade ore in the Lucky Day lode has already been mined. Hand-selected

[34] Work cited in footnote 5, p. 3.
[35] Work cited in footnote 5, p. 3.

high-grade ore from the upper section yielded 55 percent mercury, but similarly selected ore from 100 feet lower on the deposit is estimated at 5 percent.

The Bureau of Mines made a limited examination of the Lucky Day lode and the Cinnabar Creek placers as part of the World War II mercury program. Two types of mineralization were recognized. Along Canary Gulch the quicksilver occurs as thin, sparse films of cinnabar ("paint") associated with quartz and stibnite along bedding-plane faults, cross joints, and zones of brecciation in the graywacke and shale. Some native mercury was observed. The second type is directly associated with the sill-like intrusives of basalt in the graywacke near the head of Canary Gulch (fig. 15). These occurrences consist of lenticular pods of nearly massive cinnabar paralleling the intrusives and narrow offshoots of lower grade cinnabar mineralization along bedding-plane faults between the high-grade pods and the intrusives.

Channel sampling of the first type of mineralization by the Bureau failed to reveal significant mercury values. Under an examination by Webber,[36] mercury values from less than 1 pound per ton to 16.8 pounds per ton were found over widths ranging from 1 to 7 feet. The weighted average of nine samples was 10.5 pounds per ton over a 3.2-foot width. The samples were taken at either end of an indicated strike length of 632 feet; the intervening length of 450 feet was not sampled. Rutledge,[37] sampling at three locations, obtained values from 1.4 to 6.2 pounds per ton over widths ranging from 1.1 to 1.7 feet. Samples taken by Schaefer are in general agreement with the Bureau's assays.

Figure 16 gives results of the Bureau's sampling of the second type of deposit. All of the early production from the deposit came from float of this type of mineralization. The showings are especially high grade, but the evidence points to shallow, superficial deposition.

New York-Alaska Gold Dredging Corp. sampled the Lucky Day placer in the spring of 1943. The deposits, in Cinnabar Gulch and Cinnabar Run, are 5 to 10 feet in depth and range in width from 74 feet at the lower end to 10 feet at the upper end, and are 2,100 feet in length (fig. 17). Results of New York-Alaska's prospecting will be found in Report of Investigations 4065.[38] The corporation did not work the deposit.

Broken Shovel Group

The Broken Shovel claims are on the north bank of Cinnabar Creek, 4 miles north of the Lucky Day group, at an elevation of 1,400 feet. Sleetmute is 85 miles to the northeast. Herschel Landau made the first locations in 1941, shortly after Schaefer and Winchell staked the Lucky Day group. It appears from the latest available records that Schaefer now holds the claims, which are in the Aniak district.

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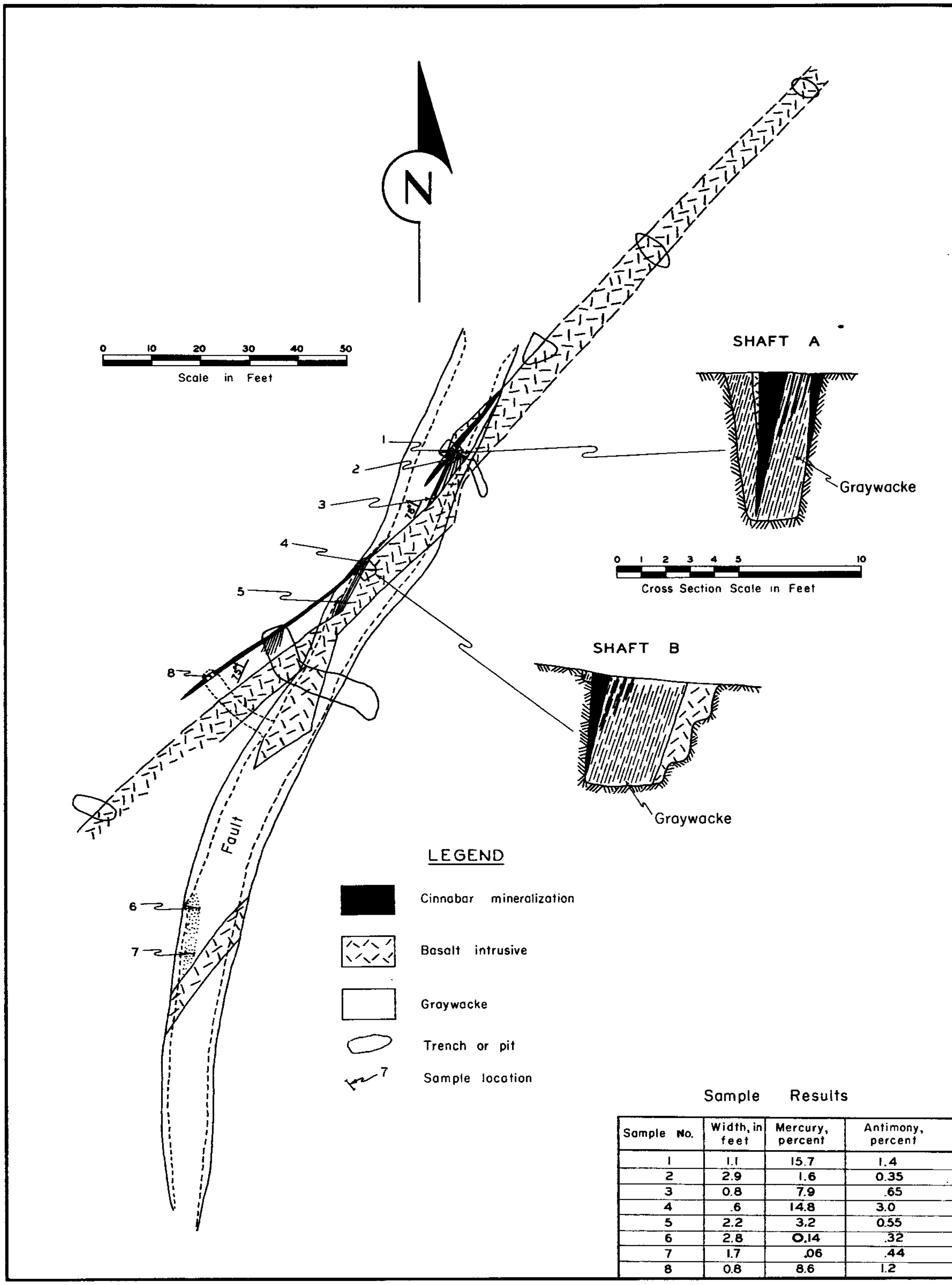
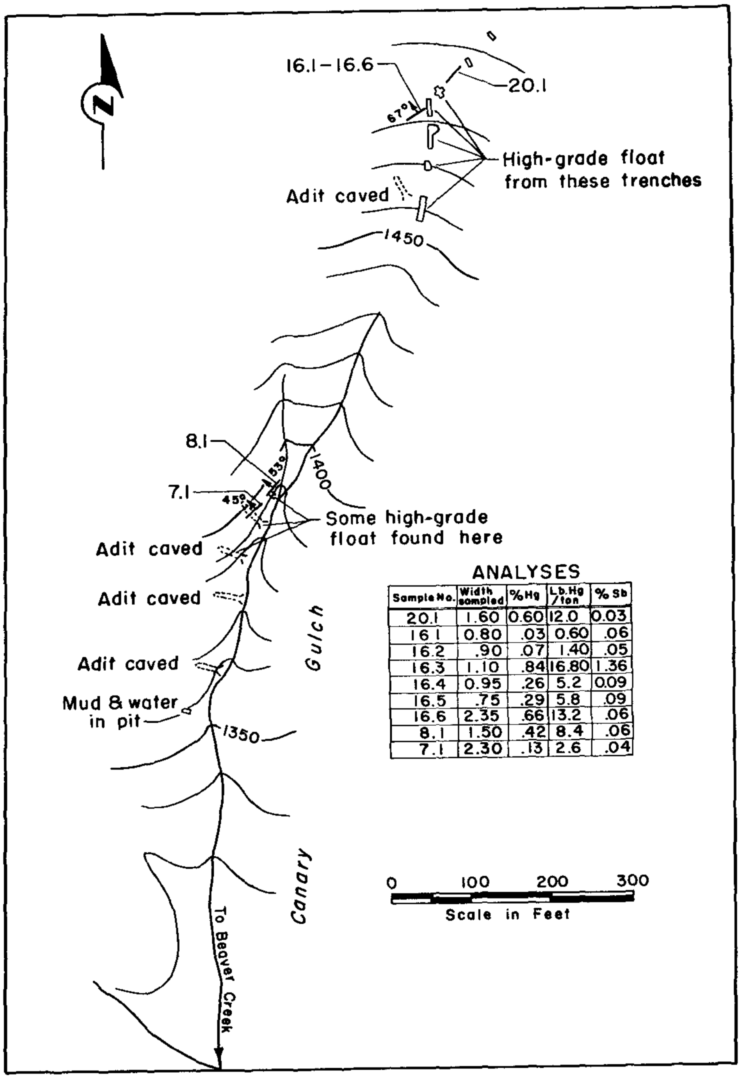
[36] Work cited in footnote 14, p. 8.
[37] Rutledge, F. A., Investigation of Mercury Deposits, Cinnabar Creek Area, Georgetown and Aniak Districts, Kuskokwim Region, Southwestern Alaska: Bureau of Mines Rept. of Investigations 4719, 1950, 9 pp.
[38] Work cited in footnote 14, p. 8.



Sample Results

Sample No.	Width, in feet	Mercury, percent	Antimony, percent
1	1.1	15.7	1.4
2	2.9	1.6	0.35
3	0.8	7.9	.65
4	.6	14.8	3.0
5	2.2	3.2	0.55
6	2.8	0.14	.32
7	1.7	.06	.44
8	0.8	8.6	1.2

FIGURE 15. - Lucky Day Lode.



ANALYSES

Sample No.	Width sampled	%Hg	Lb.Hg /ton	% Sb
20.1	1.60	0.60	12.0	0.03
16 1	0.80	.03	0.60	.06
16.2	.90	.07	1.40	.05
16.3	1.10	.84	16.80	1.36
16.4	0.95	.26	5.2	0.09
16.5	.75	.29	5.8	.09
16.6	2.35	.66	13.2	.06
8.1	1.50	.42	8.4	.06
7.1	2.30	.13	2.6	.04

FIGURE 16. - Schaefer-Winchell Property, Lucky Day Lode.

Mineralization occurs in sedimentary formations intruded by sills. The intrusives have been altered to silica-carbonate rock. The lode, striking slightly west of north, is a narrow, irregular quartz vein, containing small lenses of cinnabar and stibnite. Some native mercury is reported.

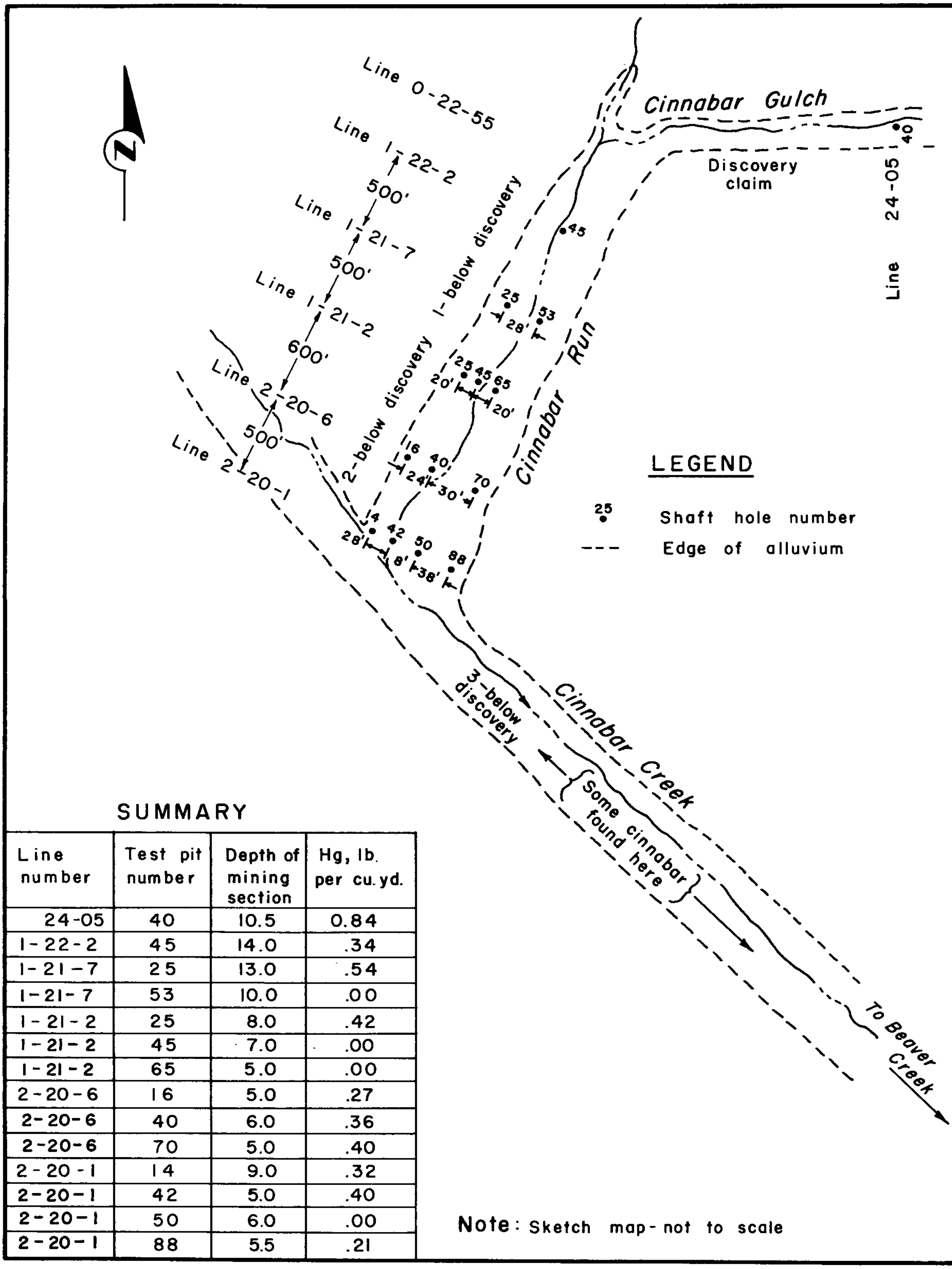
Landau prospected the placer deposits in Broken Shovel Gulch and traced float to the outcrop of the lode. There is some doubt, however, whether the vein uncovered is the source of all the float found in the gulch. Cady[39] compares the mineralization with that of the Lucky Day group. Figure 18 shows the location of the Broken Shovel in relation to the Lucky Day.

Rhyolite Deposit

The deposit is near the base of the southwest end of Juninggulra Mountain, 12 miles northwest of Crooked Creek and 300 miles northwest of Anchorage. Crooked Creek, an Eskimo village on the north bank of the Kuskokwim River, has a population of 50, a small trading post, and a post office. The deposit, discovered by Joe Stuver in 1957, is at an elevation of 500 feet; it is in Aniak district, Georgetown subdistrict.

Sedimentary rocks, chiefly shales and graywackes of late Cretaceous age, form the country rock of the area. Rhyolite extrusives, of which Juninggulra Mountain, at an elevation of 1,200 feet, is one of the more prominent, outcrop in the area. Mineralization occurs near the rhyolite-shale contacts as stringers

[39] Cady, W. M., and Others, The Central Kuskokwim Region, Alaska: Geological Survey Prof. Paper 268, p. 70.



SUMMARY

Line number	Test pit number	Depth of mining section	Hg, lb. per cu. yd.
24-05	40	10.5	0.84
1-22-2	45	14.0	.34
1-21-7	25	13.0	.54
1-21-7	53	10.0	.00
1-21-2	25	8.0	.42
1-21-2	45	7.0	.00
1-21-2	65	5.0	.00
2-20-6	16	5.0	.27
2-20-6	40	6.0	.36
2-20-6	70	5.0	.40
2-20-1	14	9.0	.32
2-20-1	42	5.0	.40
2-20-1	50	6.0	.00
2-20-1	88	5.5	.21

FIGURE 17. - Cinnabar Creek Placer Area.

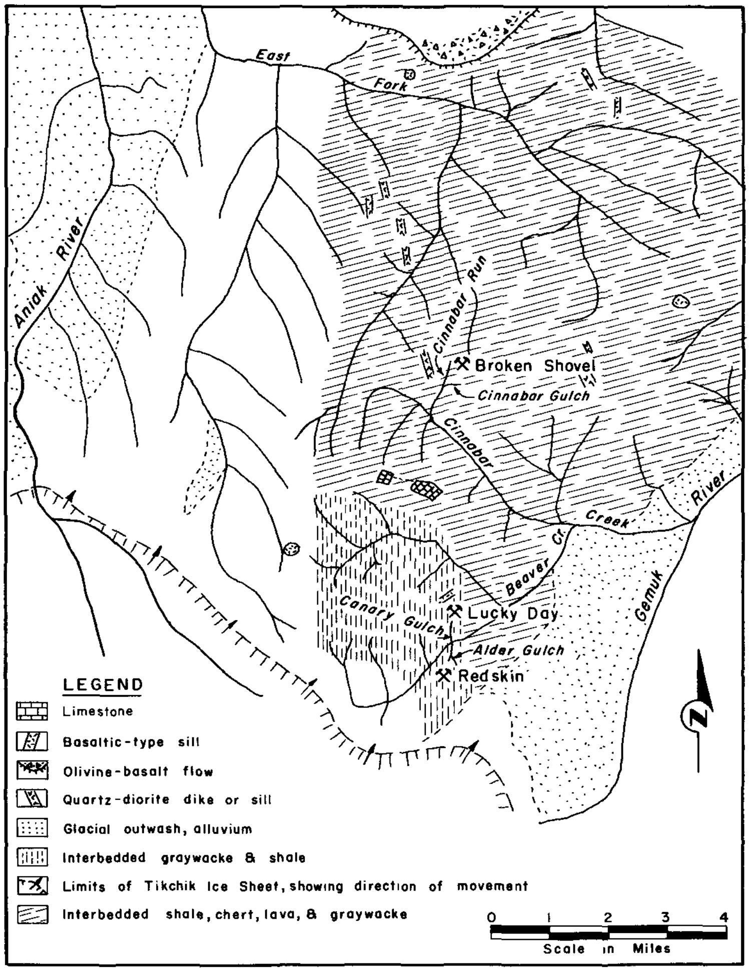


FIGURE 18. - Mercury Deposits, Cinnabar Creek Area.

and lenses of cinnabar associated with stibnite. Moss and brush obscure bedrock except high on the rhyolite ridges. The few exposures available indicate a north-south strike to the mineral zones and a vertical dip; maximum width of the mineralized zones observed was 2 feet. In some instances cinnabar stringers and lenses have a maximum width of 6 inches; these assayed as much as 42 percent mercury, but they appeared to be short, erratic, and discontinuous. At one place a silica-carbonate sill 8 to 10 feet thick has irregularly disseminated mercury mineralization over a section 70 feet long by 20 to 30 feet wide. The section averages 0.1 percent mercury.

No mineralization was found in the rhyolite mass comprising Juninggulra Mountain, but several small cinnabar stringers were found in this formation about 3 miles to the southwest. The DeCoursey Mountain mine, a well-mineralized deposit with a notable mercury production record, is 8 miles to the north. Several intervening creeks have strong placer cinnabar showings. The area, like many in Alaska, warrants additional prospecting.

The deposit has no record of production.

White Mountain Deposit

The deposit is between the headwaters of Tatlawiksuk River and Chunitna Creek some 60 miles southeast of McGrath, in the McGrath district, McGrath subdistrict, Kuskokwim River region. The area is uninhabited and is without roads or trails; elevation is approximately 2,500 feet.

Jack Egnaty of Sleetmute discovered the deposit in 1958. Seven claims, located and subsequently leased to Cordero Mining Co. of Palo Alto, Calif., are the White Mountain Mercury Lode, Mary Margie, Mary Margie No. 1, Peggy Barbara, and the White Mountain Mercury Nos. 1 to 3.

The area is composed of massive dolomitic limestones, dolomites, shales, and conglomerates. A highly faulted section of dolomitic limestone and shale about 2,000 feet wide strikes N. 30° E. and is exposed for 20,000 feet. The known mineralization occurs in the northern part of this faulted zone. Cinnabar has been found in place at both ends and in the center of a strike length of 10,000 feet. On the west side of the faulted zone the mineralization is in fractured dolomite, adjacent to a dolomite-shale contact; on the east side it occurs in limestone, adjacent to the conglomerates. Most of the creeks draining the eastern side of the 10,000-foot faulted zone carry placer cinnabar; those on the west do not. Massive cinnabar up to 6-inches thick occurs in well-fractured dolomite in almost horizontal zones at the northern end of the area. Near the center of the mineralized zone, cinnabar occurs as disseminations and irregular masses in fractured yellow dolomite. At the south end, cinnabar occurs in dolomite as several narrow stringers, striking north-south and dipping 90°. No cinnabar was found in the shale. The property is in the exploratory stage and has no production record.

Mount Joaquin Prospect

The prospect is on the east flank of Mount Joaquin at the head of O.K. Creek (tributary to the Tatalina River), McGrath district, at an elevation of 2,500 feet. Knute P. Lind located the O.K. and Joaquin lode claims in 1957 and has done some prospecting. Cinnabar occurs in a limestone inclusion within a large monzonite mass. The deposit is in the prospecting stage. There is no record of production.

Yukon River Region

DeCoursey Mountain Mine

The mine is north of the Kuskokwim River on Return Creek, a tributary of the Iditarod River, in the Iditarod mining district. The settlement of Crooked Creek, on the Kuskokwim River, is 18 miles south; Flat, on Otter Creek, is 35 miles northeast. The property can be reached by trail from either Flat or Crooked Creeks. The trails are barely passable in summer, but they are suitable for tractor hauling after the freezeup. A small landing strip at the mine allows access by aircraft. The property comprises 14 unpatented claims, Last Chance Nos. 1 to 3, Snowbird Nos. 1 to 5, Tunnel lode, Swexde, Swextu, Nextu, Nexto, and Swexa. Elevation is about 900 feet.

The first locations in the area were made in 1919 by a prospector named DeCourcy.[40] From 1921 to 1924 the property was operated by Thrift Mining Co., a small production was obtained. Incomplete records show 45 flasks produced from 14 tons of hand-sorted ore. C. F. Lindfors and associates held the property from 1924 to 1926. Records show 38 flasks produced from 45 tons in 1925. The mine was called the Corona during this period. When Lindfors died in 1926

[40] Accepted spelling.

or 1927, the deposit reverted to open ground; John and Harry Brink relocated the claims in 1927. From 1927 to 1940 some prospecting was done. There is no record of production during this time.[41]

In 1942, R. F. Lyman, K. M. Johnston, and F. C. Rocheleau formed the DeCoursey Mountain Mining Co., a partnership, and took a lease with a 4-year option to purchase (later exercised). Lyman bought out the interests of his two partners and in 1951 sold the holdings to DeCoursey Mountain Mining Co., a corporation. Alaska Mines and Minerals, Inc., a successor to DeCoursey Mountain Mining Co. (through DeCoursey-Brewis Minerals, Ltd.), now holds the property. From 1942 to 1949 Lyman produced approximately 1,200 flasks. No production has been obtained from the property since 1949. After taking over in 1951, DeCoursey Mountain Mining Co. explored the deposit under a DMEA loan. The work indicated that the ore shoots probably continue in depth. However, the company has made no attempt to put the mine into production.

Graywacke and shale of the Kuskokwim group, intruded by sill-like bodies of basalt and diabase, form the bedrock at the mine. Both the sedimentary and intrusive formations have been extensively altered to silica-carbonate rock. Alluvium covers the bedrock and masks the geologic features. The deposits appear to be associated with a homocline striking northeast and dipping northwest.

Cinnabar occurs in the silica-carbonate rocks and in unaltered formations immediately adjacent. The silica-carbonate rock is more highly silicified at the DeCoursey deposit than at other deposits of the Kuskokwim River region. The resulting brittleness of relatively large masses of wall rock accounts for the wide breccia zones that may dip across the strata but are generally parallel to the strike. Mineralization along bedding-plane joints, as occurs where alteration is confined largely to the intrusives, is less common. Apparent offsets of the large veins are thought to be a result of an irregular fracture pattern rather than of post-ore faulting. Associated minerals are cervantite, arsenopyrite, stibnite, chalcedony, and kaolin. The DeCoursey deposits contain very little stibnite.

The ore bodies are exposed for short distances over a slightly curved belt about 2,000 feet long, 250 feet wide, and through a vertical range of 360 feet. Cinnabar occurs over an area 2,600 feet by 2,000 feet and over a vertical extent of 420 feet.

Two vein systems exist. The upper system, exposed from elevations of 760 to 1,020 feet, includes the Top, Retort, Tunnel, and DeCoursey veins. The lower system, 1,000 feet southwest of the upper system and exposed from elevations of 640 to 740 feet, has the A vein and some unnamed veinlets.

The Tunnel vein has been the most productive. It is opened by adits at 820-, 871-, and 910-foot elevations. About 750 feet of drifting and crosscutting in the ore zone have been done. The sediments here strike N. 5° E. and dip 65° W. The vein strikes N. 10° to 15° E. and dips 65° E. across the strata. The continuity of the vein is broken by barren cross fractures; postmineral movement seems to be limited to an inch or less. The Tunnel vein has been worked or prospected over a strike length of 200 feet and through a vertical

[41] R. F. Lyman estimates the DeCoursey Mountain mine output at 100 to 300 flasks to 1941.

range of 130 feet. The mineralized section averages 3.2 feet in width. Production from the vein has been about 800 flasks.

The Retort and Top veins are in the hanging wall of the Tunnel vein, outcropping 125 feet to the east and somewhat higher up the hill. The veins strike N. 30° E. and dip 50° to 75° W., or back toward the Tunnel vein. Most of the early production from the deposit came from these two veins. The 820 adit on the Tunnel vein was extended about 500 feet to the northeast in a sort of combination crosscut and drift. An extensive fracture, striking N. 54° E. and dipping 79° NW., was followed for 150 feet in this heading; no production resulted from this work. On the surface the Top and Retort veins have been exposed over a strike length of 300 feet. Cinnabar occurs in discontinuous bedding-plane joints and in fractures (Top vein). Production from the two veins has been about 300 flasks, largely from float and residual placer.

The DeCoursey and associated veins, striking northeast and dipping steeply east at some places and west at others, have been exposed for 300 feet on the surface. The DeCoursey, enclosed in a large body of silica-carbonate rock, has abrupt changes in width and shape. The blocky fracturing of the brecciated silica-carbonate rock gives the vein segments the appearance of postmineral offsets, but no evidence of faulting was found. One cross fracture contained an unbroken continuation of the ore. The DeCoursey vein has produced a few flasks from the vein and from float. Surface exposures have been found over elevations from 770 to 840 feet.

The A vein is a mineralized zone 500 feet long at elevations of 660 to 740 feet. The vein occupies a continuous fissure striking north with the sedimentary beds but dipping 75° E. across the strata. It is along the contact of the sediments and a diabase porphyry locally altered to silica-carbonate rock. Some evidence of faulting and postmineral movement is seen here, including slickensides on the walls and a polished, greasy-appearing gouge. Production from the A vein has been small.

Mine workings include the Lyman tunnel (820 adit), the New Adit (910 adit), and 871 Adit, and an adit on the A vein.

DeCoursey Mountain Mining Co. drilled 2,614 feet of diamond-drill hole in 1953 and 1954 under a DMEA contract. Twenty-five horizontal holes to explore for downward extensions of the Top and Retort mineralization, and parallel leads, were drilled from the northeast section of the Lyman tunnel. The drilling indicated that mineralization extends at least to the elevation of the Lyman tunnel. No attempt was made by the DeCoursey Co. to follow up the diamind-drill findings with exploratory workings. The company has concentrated on opening its Red Devil property in the past few years. Figure 19 is a plan of the deposit; figure 20 shows the Lyman Adit with diamond-drill holes.

Hudson Mine (Livengood Cinnabar Corp.)

The mine is in the Tolovana district at the head of the west fork of Olive Creek, a Tolovana River tributary, at a 1,500-foot elevation. Livengood, a gold-placer camp, is 2 miles north. Mertie[42] states that cinnabar in place was first noted after a small landslide on the east fork of Olive Creek exposed

[42] Mertie, J. B., and Harrington, G. L., Mineral Resources of the Ruby-Kuskokwim Region: Geol. Survey Bull. 642-H, 1916, pp. 237-238.

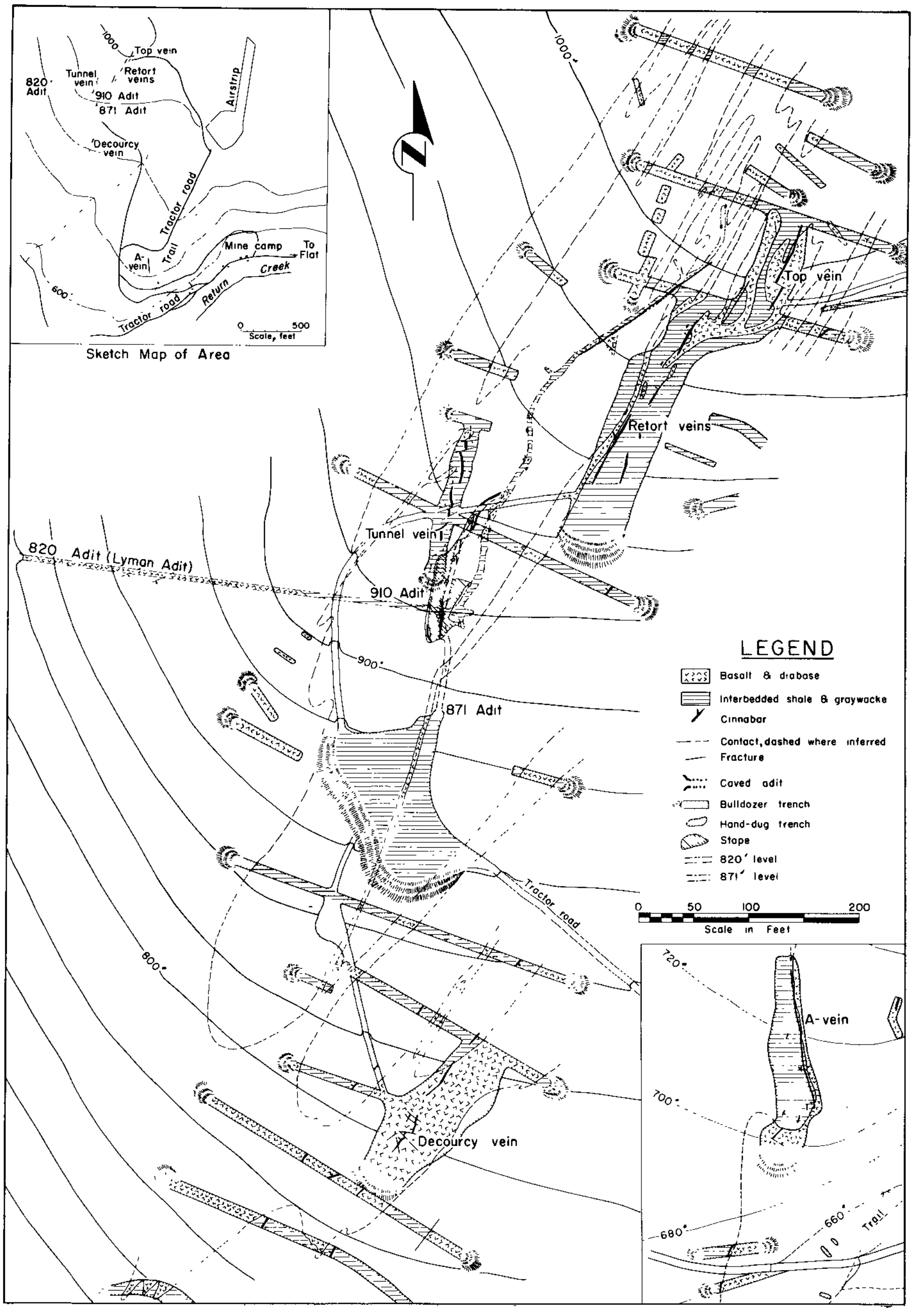


FIGURE 19. - Surface and Underground Geologic Map of the DeCoursey Mountain Mine.

bedrock in 1916. Some exploratory work was done on the showing, but nothing considered as potential ore was found. James Hudson prospected the area in the late 1920's and discovered cinnabar in place on the west fork of Olive Creek about one-half mile from the earlier discovery.

According to reports, sedimentary slates and sandstones of Silurian and Permian age make up the country rock. At the mine, a highly altered granitic rock, decomposed as to resemble talc or a soft white impure sandstone, is associated with cinnabar. The ferromagnesian minerals of the original rock show as small black specks in the white groundmass. Cinnabar is evenly disseminated

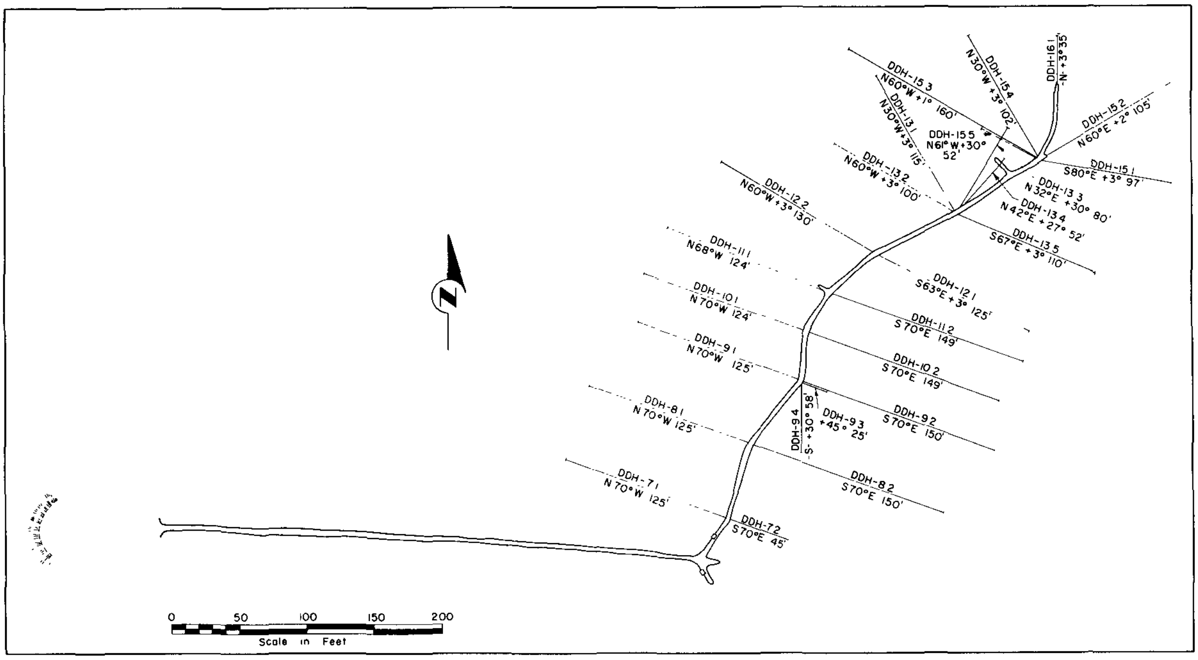


FIGURE 20. - Diamond-Drill Holes in Lyman Adit, DeCoursey Mountain Mine.

through the altered rock as small specks and grains; as the degree of alteration lessens, the rock becomes leaner in cinnabar.

Hudson drove a 134-foot adit (N. 30° W.) into the hill on the deposit. Strong alteration and mercury mineralization are reported for 120 feet along the adit from the portal; alteration and mineralization decrease rapidly in the last 14 feet. A tunnel runs from the end of the adit S. 60° W. for 50 feet in rather weakly mineralized rock much like that at the adit face. Ten feet back from the latter point a winze was collared in the floor of the adit. At 104 feet from the portal, a tunnel runs approximately due north for 85 feet. Mineralization in the stub tunnel is good to about on line with the winze; from that point to the tunnel face, alteration and mineralization rapidly diminish. From the reports available it is difficult to determine whether the Hudson adit crosscuts the mineralized zone, drifts along it, or cuts it obliquely. Several areas containing 20 to 30 pounds of mercury per ton are reported between the portal and the winze.

Canyon Creek

Canyon Creek, some 20 airline miles northeast of Eagle, was the scene of one of the earliest attempts to find the lode source of placer cinnabar. James Hudson, working with Bert Bryant on the gold placer of the area, noted cinnabar in sluicebox concentrates and made a competent and intelligent search for the mineral in place as early as 1907. The cinnabar noted by Hudson was washed from the gravels near the mouth of the creek. Hudson was not able to find the mineral in place, nor did he find any cinnabar in the upper reaches of the creek.

The country rock from the mouth of the creek to 1,500 feet upstream is schist. Tertiary conglomerates and sandstones form the bedrock for the next

6,000 feet, and they are succeeded by metamorphosed sedimentaries, including greenstone, to the head of the valley.

The Geological Survey examined the area in 1942. A rather extensive program of trenching and test pitting failed to show cinnabar in place. In most of the prospect cuts, the gravel contained little or no cinnabar.

Other Lode Occurrences

Mertie[43] reports a 30-inch vein of stibnite, cinnabar, and quartz at the head of Wyoming Creek in the Cripple Creek Mountains. The vein occurs at the contact of a monzonite intrusive with sedimentaries; a specimen showed quartz and cinnabar along the walls, with stibnite at the center of the vein. Mertie also reports stibnite and cinnabar lodes on the border of the quartz monzonite area at the heads of Flat, Chicken, and Happy Creeks, in the Iditarod district. Again, the stibnite is at the center of the vein, with quartz and cinnabar along the walls.

Smith[44] reports several small veins containing cinnabar, stibnite, and quartz at the head of Glen Gulch, in the Iditarod district. Mercury mineralization occurs in quartz stringers both in granite and in sedimentaries. One zone, several feet wide but not persistent along the strike, occurs in slates along the granite contact. Some work was done on the showing, but it was abandoned as unpromising. Small veins of cinnabar associated with gold-bearing quartz stringers are reported in the face of a 70-foot caved adit about 400 feet west of the mouth of Malemute Gulch in the Flat-Iditarod area. The adit is thought to have been driven for the gold prospect. Moffit[45] reports cinnabar occurring with stibnite on the Merinser claim at the head of Slippery Creek, Kantishna district.

The Bureau of Mines, in 1956, prospected for the lode sources of cinnabar found in Flat and Otter Creeks. Over 10,000 lineal feet of bedrock were exposed in bulldozer trenches in the Glen and Black Gulch areas; 83 channel samples were taken from the trenches. In addition, 279 soil samples were taken from the upper Chicken Creek area. The primary source of the cinnabar placer material appears to be a large monzonitic intrusive in contact with argillite and quartzite. The last two are metamorphic products from the local shales and sandstones. Numerous veins and veinlets, some showing fair gold values, were uncovered. No significant cinnabar mineralization was found in place.

Marsh Mountain (Red Top Mine)

The Marsh Mountain deposit, in the Bristol Bay region (Tikchik district), is on Marsh Mountain, 3 miles east of the settlement of Aleknagik and 17 miles north of Dillingham. It is at an elevation of 1,000 feet. Red Top Mercury Mine, Inc., holds the Red Top, Red Top Nos. 1 and 2, the East Extension Red Top, and the East Extension Red Top Nos. 1 and 2 by location. DeCoursey Mountain Mining Co. and Moneta Porcupine Mines, Ltd., are reported to hold the property under lease. There is a 2-mile tractor road from Wood River to the mine.

43 Work cited in footnote 42.

44 Smith, P. S., The Lake Clark-Central Kuskokwim Region, Alaska: Geol. Survey Bull. 655, 1917, p. 145.

45 Moffit, F. H., The Kantishna District: Geol. Survey Bull. 836-d, 1933, p. 321.

Frank H. Waskey discovered placer cinnabar on Arcana Creek in 1941 while prospecting for gold. On the strength of Waskey's placer showings, Charles Wolfe and Clarence Wren prospected the area and traced float up Feeder Creek to mineral in place. Ore occurs in a brecciated zone 100 feet or more in width in graywacke. Within the zone one series of high-grade stringers lies parallel to the walls on the footwall side; a second series, also parallel, lies 50 feet from the first A transverse series cuts across the zone between the first two series. Cinnabar occurs as nearly pure mineral in the stringers; there is little or no dissemination into surrounding rock. The Bureau of Mines examined the property in 1943 and 1953. The 1953 examination was made in connection with a DMEA loan. Surface prospecting under the DMEA program was sufficiently promising to warrant underground exploration work. The underground work, comprising 550 feet of drifts and crosscuts, showed that the surface mineralization extends downward, but without improvement in grade to the depth explored. Figure 21 is a plan of the Red Top area; figure 22 shows underground work and assay results. The property has produced a few flasks of mercury.

Occurrences in Other Regions

Some work has been done on a lode prospect near Mount Oratia in the Togiak district, Bristol Bay region, 8 miles northeast of Kagati Lake. The prospect, known as the Kagati Lake mercury deposit, is 80 miles southeast of Bethel, at an elevation of 2,600 feet. Atayak Mountain is 3 miles south; Mount Oratia is 4 miles west.

There are no roads or trails in the area; access is by foot, float plane, or by tractor train in winter. The first location was made in 1927 by a man named Gieger, who drove an adit on a shear zone at the south end of the deposit. The adit has since caved, leaving only a dump as evidence of the early work. Gieger allowed his locations to lapse. In 1956, a Bethel group called the Bethel Exploration Co. staked the property. Sunshine Mining Co. optioned the property the same year and prospected from 1956 to 1958.

Mineralization occurs in two shear zones, 200 feet apart, in granite. The larger zone is well defined, 50 to 100 feet wide, and 1,400 feet in length. The smaller zone, 6 feet wide and 200 feet long, is poorly defined and obscured by moss and debris. The main shear strikes N. 15° W. and dips 90°. It is cut off at the south end by a vertical fault, resulting in a cliff 100 feet or more in height; overburden conceals the extension to the north. Little mineralization occurs in either shear zone. A few small pieces of cinnabar with quartz and realgar were found in both zones; several pieces of stibnite float up to 8 inches were found at the north end of the larger shear zone. The deposit has no recorded production.

At Bluff, on the Seward Peninsula about 50 miles east of Nome, a lode prospect in a 100-foot, nearly vertical bluff on the shore of Norton Sound has been prospected by two adits and a 55-foot test shaft. The deposit is at the mouth of Swede Creek, 2 miles east of Bluff. A landing strip suitable for light aircraft lies about a mile northeast of the settlement. Weather at

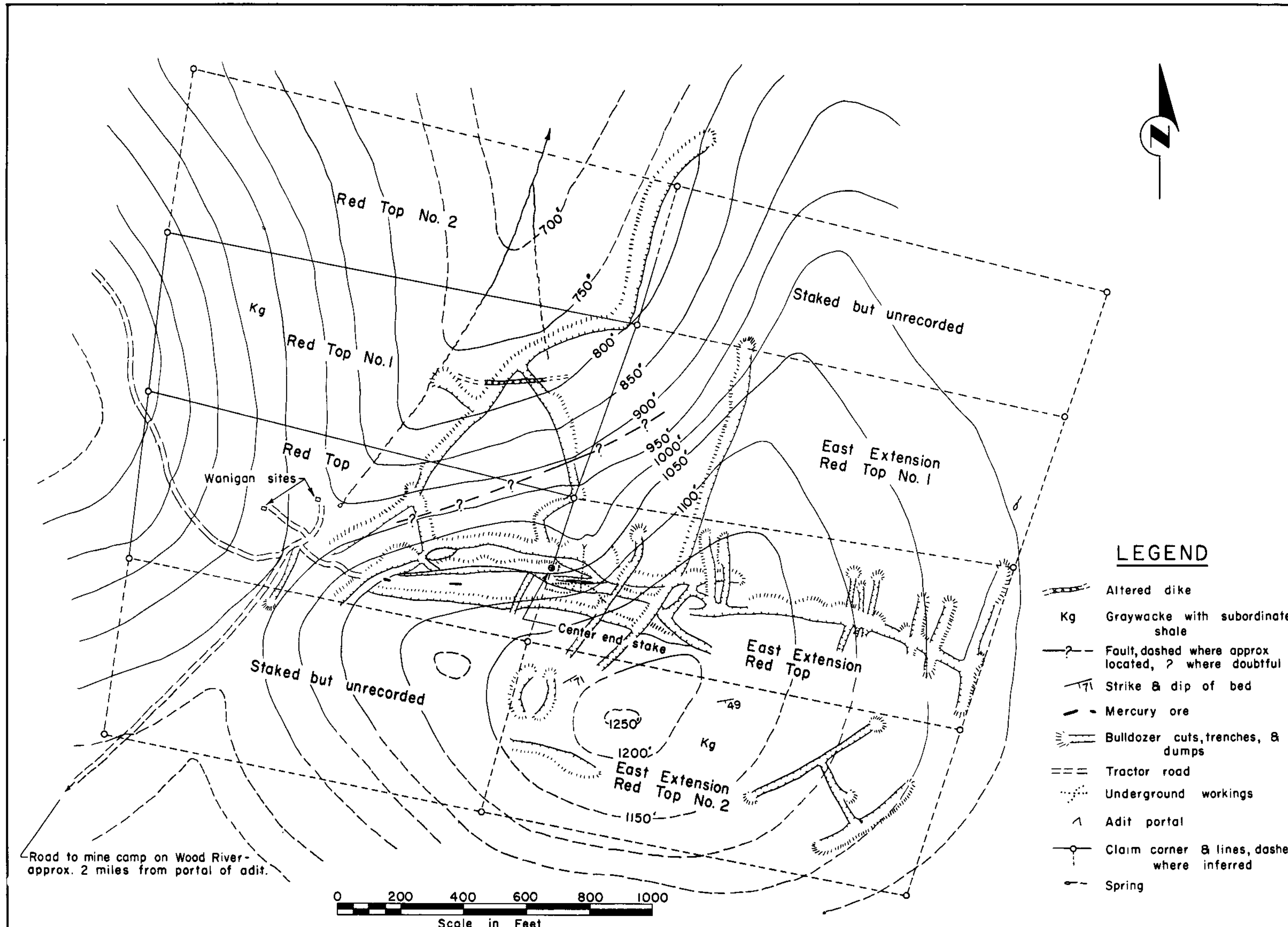


FIGURE 21. - Plan of the Red Top Mine Area.

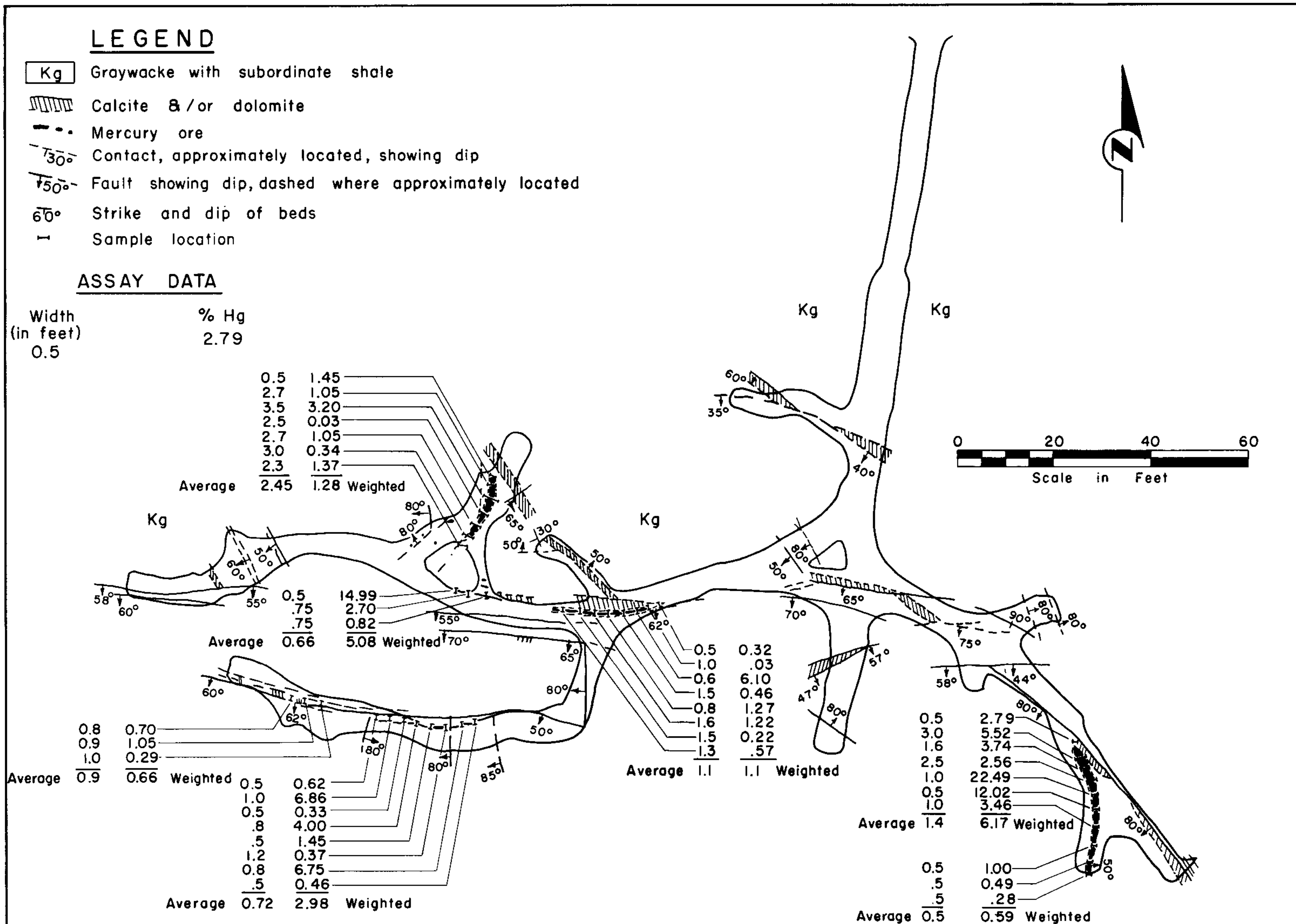


FIGURE 22. - Underground Works and Assay Results of the Red Top Mine.

Bluff is much the same as at Nome. Average yearly temperature at Nome for 1958 was 26.3° F., with a daily maximum high of 55.4° in June and a low of 2.2° F. below in February. The lowest temperature recorded in the past 10 years was 42° below in 1949. Normal annual precipitation is about 18 inches.

The deposit was located by Sam Tucker in 1922. J. J. Keenan explored the property under a lease basis and is credited with most of the exploration done. Jerry Galvin of Nome obtained a lease in 1942 and moved furnacing equipment to Bluff for use at the deposit. However, the equipment was never set up.

W. S. Wright examined the property in 1946. He states that limestone, shale, and schist are the principal rock types in the Bluff area. The mercury deposits, however, occur in quartzite formations striking N. 60° E. and dipping 15° NW. Two parallel seams, 35 feet apart vertically, show mineralization. The lower seam is weakly mineralized and has not been prospected. The upper seam, 70 feet above the beach, has been explored by 2 adits, one 70 feet and one 20 feet in length. The shaft east of the face of Adit No. 1 is vertical and 55 feet deep. It was not safe to enter at the time of Wright's examination. The deposit has no recorded production.

Placer Occurrences

Placer cinnabar has been found in many widely scattered mining districts in Alaska. On the Seward Peninsula it occurs in the gravels of Koyana, Swede, and Deniels Creeks and in the beach placers, all near Bluff. Brooks[46], in describing the beach placers at the mouth of Daniels Creek, states, "The heavy minerals associated with the gold are magnetite, nodules of limonite, small pieces of ilmenite, and bits of cinnabar. Cinnabar is fairly abundant in the tailings, ranging from specks to rounded pebbles the size of marbles, but it has not been found in place." Cinnabar has also been recognized in the gravels of Budd Creek, 30 miles northeast of Teller, and by a Bureau of Mines engineer in the Timber Creek area. Two selected specimens from the Timber Creek area contained 0.19 and 0.17 percent mercury.

In the Yukon River region, the mercury mineral occurs in appreciable quantities in the gravels of the Iditarod, Innoko, and Tolovana districts and to a lesser extent in the Marshall, Kantishna, Bonnifield, Rampart, Hot Springs, Circle, Eagle, and Fortymile districts. Joesting[47] lists the following occurrences:

[46] Brooks, A. H., The Gold Placers of Parts of Seward Peninsula, Alaska: Geol. Survey Bull. 328, 1908, p. 289.

[47] Joesting, H. R., Strategic Mineral Occurrences in Interior Alaska, Territory of Alaska: Dept. of Mines Pamphlet No. 1, 1942, 46 pp.

District	Location	Relative abundance	Reference
Innoko.........	Boob Creek.......	Scarce....	Geol. Survey Bull. 754, p. 106
Marshall.......	Bobtail Creek, tributary of Kako Creek......	Rare......	T.A.[1] Dept. of Mines
Do..........	Flat Creek, tributary of Stuyahok River.......	Scarce....	Do.
Bonnifield.....	Moose Creek......	Common....	Do.
Do..........	Grubstake Creek..	Scarce....	Do.
Do..........	California Creek...........	Do......	Do.
Rampart........	Hunter Creek.....	Do......	Geol. Survey Bull. 844-7, p. 232
Do..........	Little Minook Creek...........	Rare......	Geol. Survey Bull. 844-7, p. 233
Do..........	Hoosier Creek....	Do......	Geol. Survey Bull. 844-7, p. 234
Do..........	Quail Creek......	Do......	Geol. Survey Bull. 844-7, p. 235
Do..........	Troublesome Creek...........	Scarce....	Geol. Survey Bull. 844-7, p. 236
Hot Springs (Eureka area)..	Pioneer Creek....	Rare......	Geol. Survey Bull. 844-7, p. 237
Do..........	McKaskey Bar.....	Do......	Geol. Survey Bull. 844-7, p. 238
Do..........	Shirley Bar......	Common....	Geol. Survey Bull. 844-7, p. 238
Do..........	Omega Creek......	Rare......	Geol. Survey Bull. 844-7, p. 238
Eagle..........	Seventymile River below the falls...........	Scarce....	Geol. Survey Bull. 872, p. 192
Do..........	Canyon Creek.....	Do......	Geol. Survey Bull. 872, p. 245
Do..........	Mogul Creek......	Do......	T.A. Dept. of Mines
Circle.........	Deadwood Creek...	Do......	Do.
Fortymile......	Wade Creek.......	Do......	Geol. Survey Bull. 897, p. 166
Iditarod.......	Glen Gulch.......	Common....	Geol. Survey Bull. 655, p. 145
Do..........	Happy Creek......	Abundant..	Geol. Survey Bull. 864, p. 212
Do..........	Black Creek......	Do......	Geol. Survey Bull. 655, p. 145
Do..........	Flat Creek.......	Common....	T.A. Dept. of Mines
Do..........	Otter Creek......	Abundant..	Geol. Survey Bull. 739, p. 157

[1] Territory of Alaska.

The following occurrences can be added to Joesting's listing:

District	Location	Reference
Iditarod.......	Moore Creek................	Geol. Survey Bull. 864-c, p. 224
Do..........	Anvil Creek................	Geol. Survey Bull. 864-c, p. 190
Do..........	Victor Gulch...............	Geol. Survey Bull. 864-c, p. 191
Fortymile......	Stonehouse Creek...........	Geol. Survey Bull. 813, p. 135

Additions to Joesting's Listing (Con.):

District	Location	Reference
Fortymile......	Franklin Creek.............	Geol. Survey Bull. 813, p. 183
Do..........	Dome Creek.................	Geol. Survey Bull. 813, p. 190
Casadepega.....	Auburn Creek...............	Geol. Survey Bull. 433, p. 206
Kougarok.......	Dome Creek.................	Geol. Survey Bull. 379, p. 326
Chisana........	Bonanza Creek..............	Geol. Survey Bull. 933-b, p. 174
Tolovana.......	Ester Creek................	Geol. Survey Bull. 662, p. 270
Do..........	Lillian Creek..............	Geol. Survey Bull. 662, p. 270
Do..........	Olive Creek................	Geol. Survey Bull. 662, p. 271
Hot Springs....	Rhode Island Creek.........	Geol. Survey Bull. 844-d, p. 204
Do..........	Eureka Creek...............	Geol. Survey Bull. 844-d, p. 204

The occurrences on Candle Creek near McGrath, Kuskokwim River region, have already been noted. Rainy Creek, in the western Kuskokwim region, carries cinnabar in its gravels; reported production, as a byproduct of gold placering, is 6 flasks produced in 1941. The Cinnabar Creek placers have been noted under the Lucky Day lode deposit.

Moffit[48] reports cinnabar in the creek gravels of the Nizina district, Copper River region. Wood River, in the area above Dillingham, is reported as carrying cinnabar in its gravels. Occurrences have been reported in the Canning River area north of the Brooks Range, Northern Alaska region.

48 Moffit, F. H., Geology of the Chitina Valley and Adjacent Area, Alaska: Geol. Survey Bull. 894, 1938, 137 pp. (p. 128).

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