Geology of the Sumdum Copper-Zinc Prospect Southeastern Alaska

By E. M. MACKEVETT, JR., and M. C. BLAKE, JR.

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Recently discovered copper-zinc deposits near western margin of Coast Range batholith

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[Plate is in pocket]

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By E. M. MacKevett, Jr., and M. C. Blake, Jr.

ABSTRACT

The Sumdum copper-zinc prospect is in an alpine region on the mainland of southeastern Alaska, about 50 miles southeast of Juneau and about 25 miles west of the Canadian boundary. The ore-bearing outcrops at the prospect were discovered by the Alaska Helicopter Syndicate during the summer of 1958. The prospect is within a few thousand feet of the western margin of the Coast Range batholith in regionally metamorphosed rocks that locally have been contact metamorphosed. Most of the known ore deposits are in the intermediate unit of three metamorphic-rock units that were mapped. This unit consists mainly of interlayered light and dark gneiss. The intermediate unit is largely bounded on the east by a unit that contains abundant calc-silicate rocks and on the west by a unit that consists of schist. A few dikes and sills of lamprophyre and of pegmatite and apophyses of quartz diorite cut the metamorphic rocks. The metamorphic rocks are separated from the dominant quartz diorite of the batholith by a steep northwest-striking fault. Several other northwest-striking faults and a few northeast-striking faults are at the prospect. The metamorphic rocks have been folded into a series of isoclinal folds characterized by numerous minor folds on the limbs of larger folds. Typically, the folds are overturned to the southwest and plunge southeastward at low angles.

The ore occurs in northwest-trending zones that are generally not traceable for more than a few hundred feet because of snow or glacial cover. However, diamond-drilling data indicate that at least two of these zones are continuous for several thousand feet along strike. The ore zones are commonly between 1 and 50 feet thick. They are partly masked by secondary iron minerals and consist of sulfide minerals that form masses or disseminations or that are irregularly distributed in veins or breccia. Pyrite and pyrrhotite are the dominant sulfide minerals; chalcopyrite and sphalerite—along with very minor amounts of bornite, chalcocite, malachite, azurite, and galena—constitute the ore minerals. Some of the deposits are localized along minor folds; others are in brecciated fault zones or are disseminated in favorable host rock. They were formed by replacement and by open-space filling. Although at present (1962) it is not economically feasible to mine the ore, economic conditions in the future may warrant additional exploration of the prospect.

INTRODUCTION

The Sumdum copper-zinc prospect is on the mainland of southeastern Alaska about 50 miles southeast of Juneau, 75 miles northwest of Petersburg and 25 miles west of the international boundary (fig. 1). The prospect is in rugged terrain that ranges in altitude from about 2,000 to 6,666 feet, the summit of Mount Sumdum. The timberline in the region is between 2,000 and 2,500 feet; glaciers, snow, and bare precipitous slopes are the dominant surficial features throughout much of the prospect area (fig. 2). The prospect is in a region that contains two fiords, Tracy Arm and Endicott Arm (fig. 3), and abrupt transitions from the littoral domain and low-altitude forests to the alpine environment.

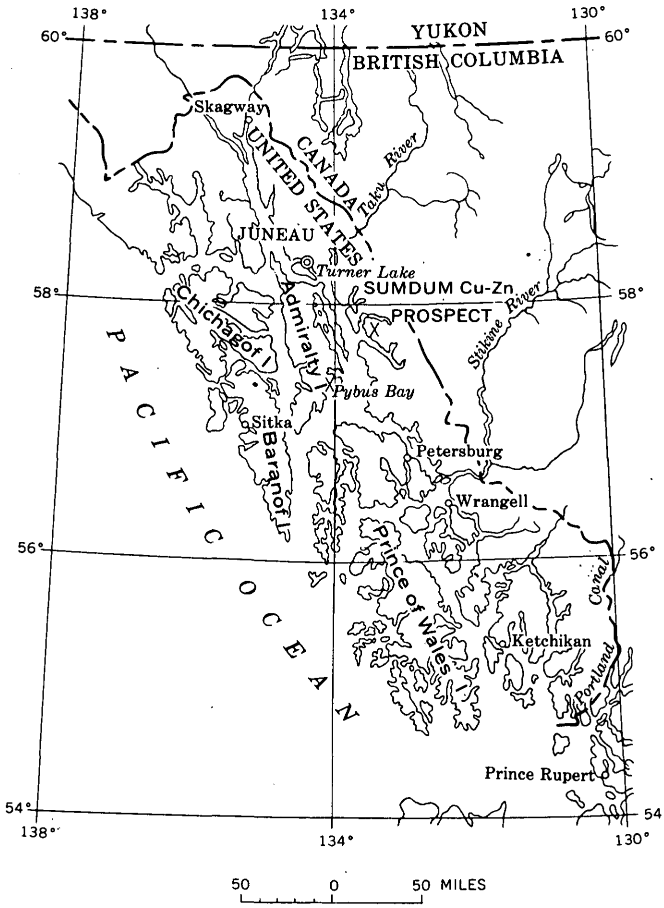


FIGURE 1.—Index map of southeastern Alaska showing the location of the Sumdum copper-zinc prospect.

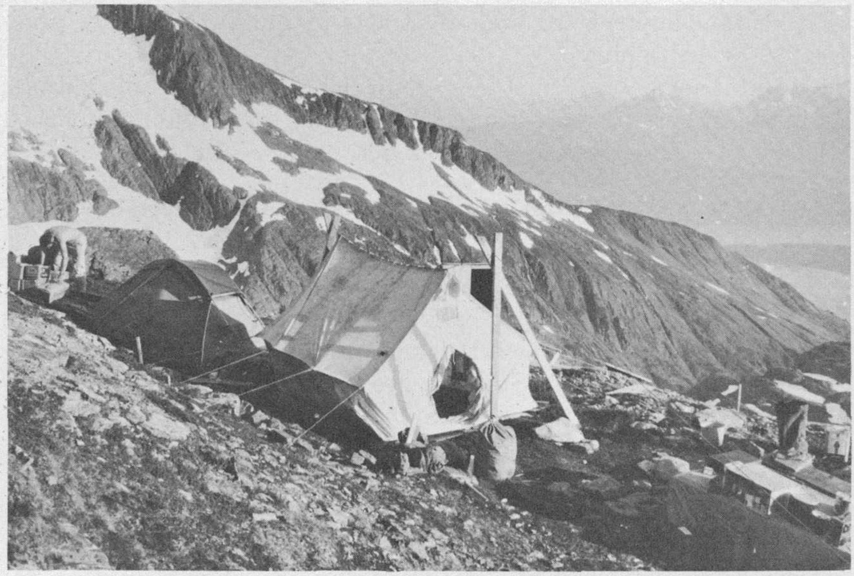


FIGURE 2.—Typical terrain at the Sumdum prospect. View is to the southwest from camp in area 4.

High winds, fog, and heavy precipitation are common deterrents to fieldwork, and geologic mapping at the prospect is feasible only during July and August when the ground is relatively free from snow cover.

The main objectives of our investigations were to evaluate the economic potential of the prospect, to determine its geologic setting, and to contribute to an understanding of the regional geology. Our field studies consisted of geologically mapping an irregularly shaped tract of about 7 square miles at a scale of 1:20,000, of examining the known ore deposits, and of collecting numerous rock and ore specimens. Fieldwork was done between August 11 and August 26, 1960. We were transported to the prospect by helicopter from the U.S. Geological Survey MV *Stephen R. Capps*, which was anchored in Holkham Bay, and were picked up on the shore of Endicott Arm when snow made it necessary to end the fieldwork. The fieldwork was supplemented by a variety of laboratory investigations, including thin-section and polished-section studies, X-ray diffraction and X-ray fluorescent spectroscopy determinations, semiquantitative spectrographic analyses, and mineral determinations by oil-immersion methods.

The prospect is accessible by hiking from the shore of Endicott Arm for a distance of about 2½ miles over forested and brushy slopes that contain interspersed swampy tracts of muskeg or, more practically, by helicopter.

Grateful acknowledgment is made to the Moneta Porcupine Mines, Ltd., the owners of the prospect, for making available unpublished data by one of their geologists, R. H. Seraphim.

HISTORICAL SKETCH OF MINING NEAR THE SUMDUM PROSPECT

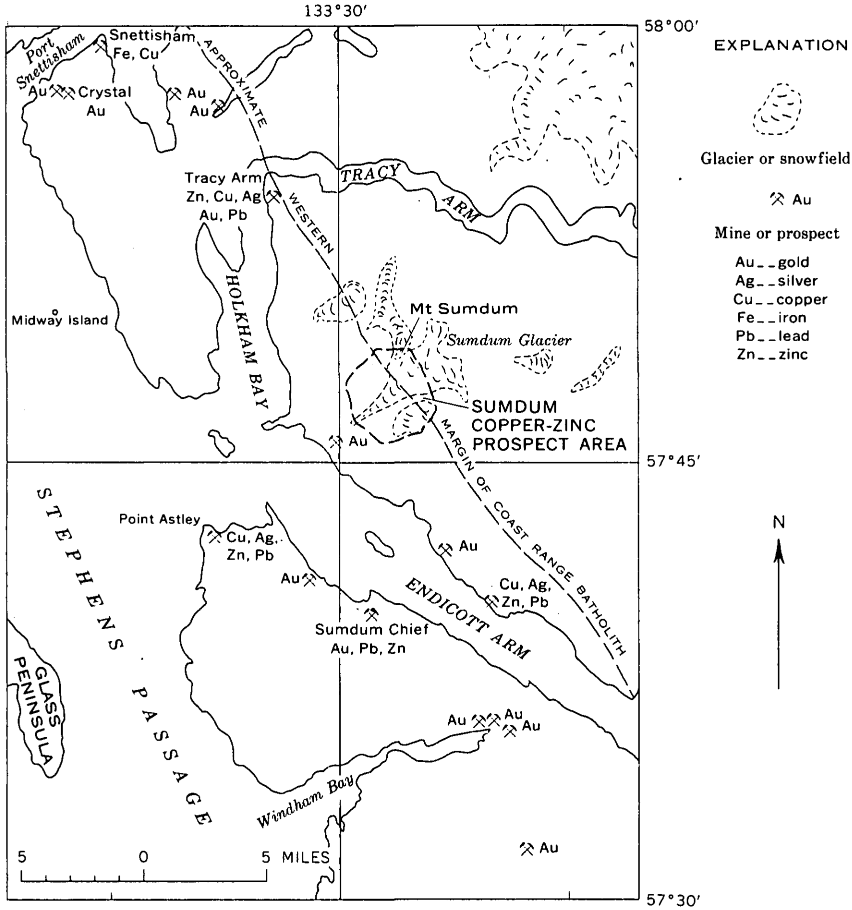
The Sumdum copper-zinc prospect is in a northwest-trending belt of mineralized metamorphic rocks that borders the Coast Range batholith on the west. The better known mines and prospects within this belt in the vicinity of Sumdum are shown on figure 3, which also shows the detailed location of the Sumdum prospect.

Gold was the principal commodity sought by the early prospectors. Most of the gold mines and prospects that are shown on figure 3 were developed around 1900 or shortly thereafter. The gold mines and prospects were best described by Spencer (1906, p. 38–47). Many references to published reports describing the known mineral deposits near the Sumdum prospect are listed by Cobb and Kachadoorian (1961, p. 294–296). Most of the gold mines yielded significant quantities of silver as a byproduct.

Probably the earliest known deposits of base metals in the vicinity of Sumdum are those near Point Astley, which were first described by Spencer (1906, p. 45) and subsequently by other U.S. Geological Survey geologists (Cobb and Kachadoorian, 1961, p. 295).

Following the heyday of gold mining in the early 1900's, there was little mining activity in the area. The titaniferous magnetite deposit at Port Snettisham has been known at least since 1918 (Thorne and Wells, 1956, p. 6). This deposit differs from the others in the Sumdum region because it occurs in pyroxenite within a pluton that cuts the metamorphic belt. Gault and Fellows (1953, p. 8) report that the Tracy Arm zinc-copper prospect was discovered in 1916.

The ore-bearing outcrops at the Sumdum copper-zinc prospect were discovered in August 1958 by the Alaska Helicopter Syndicate prospectors under the direction of L. M. Anthony and were explored mainly during the summer of 1959. The company-sponsored exploration consisted chiefly of diamond drilling, but it included excavating several shallow trenches and collecting numerous channel samples (Seraphim, unpub. data, 1960).



Base from U.S. Geological Survey 1:250 000 series quadrangle: Sumdum, 1952

Locations of mines and prospects from Buddington and Chapin (1929) and Cobb and Kachadoorian (1961)

FIGURE 3.—Map showing locations of mines and prospects near the Sumdum copper-zinc prospect.

GEOLOGY

PHYSIOGRAPHY

The environment at the Sumdum prospect is alpine, and glaciation was the dominant process in sculpturing the topography. Snow and ice persist in the higher parts of the prospect area, where the outcrops are largely confined to narrow ridges or steep hillsides (fig. 4). Most of the rock exposures have been glacially striated and scoured. The precipitous topography is characterized by sharp, narrow ridges and deeply incised valleys. The southwestern part of the prospect area locally contains hummocky terrain that sustains a few ponds.

FIGURE 4.—Alpine topography at the Sumdum prospect. View is to the southwest from area 5. Fog enshrouds Endicott Arm and other waterways in the background.

The prospect area is roughly bisected by the Sumdum Glacier, which accumulates in the snow and ice fields contiguous to Mount Sumdum and forms an icefall which drops about 1,500 feet to the lobar extremities of the glacier in the Sumdum Creek valley (pl. 1). The glacier terminates at an altitude of about 1,100 feet in the valley. The upper part of the glacier is almost free of crevasses and is largely mantled by dimpled surfaces caused by melting action of the sun. The icefall is characterized by abundant crevasses and seracs (fig. 5), and the lower lobar part of the glacier is characterized by ogives.

The other glaciers in the area are unnamed and less spectacular than the Sumdum Glacier. A well-formed cirque has been carved in the dioritic rocks near the northern part of the prospect, and the valley that drains the cirque is U-shaped, fairly broad, and partly filled with glacial deposits (pl. 1).

GEOLOGIC SETTING

The Sumdum copper-zinc prospect is in a northwest-trending belt of metamorphic rocks that forms the western margin of the Coast Range batholith throughout most of southeastern Alaska (Buddington and Chapin, 1929, pl. 1). The prospect is in the eastern part of the metamorphic belt within a mile of the contact with the batholith.

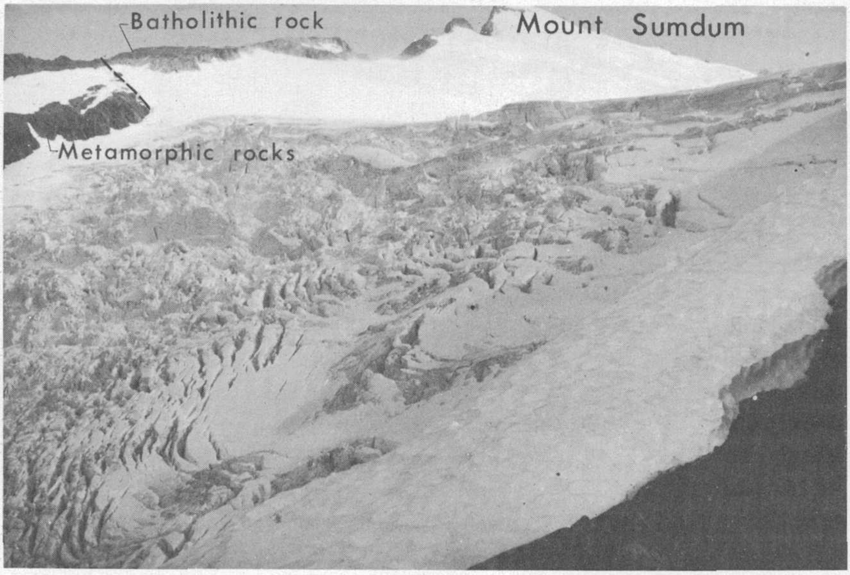


FIGURE 5.—View to the north near the brink of the Sumdum Glacier icefall showing abundant crevasses and seracs. Mount Sumdum and the contact between the metamorphic and batholithic rocks are on the ridge in the background. The glacier is about 1¼ miles wide at the brink of the icefall.

At the prospect the metamorphic rocks are folded into a series of isoclinal folds whose axial planes strike northwestward and dip steeply northeastward parallel to the conspicuous foliation. These rocks are separated from the foliated dioritic rocks of the batholith by a fault that is almost parallel to the foliation. They are cut by a few apophyses of quartz diorite and by dikes or sills of pegmatite or lamprophyre, and they are locally overlain by surficial deposits. The main faults at the prospect are parallel or subparallel to the northwest-striking foliation.

The rocks of the metamorphic belt, particularly those in its eastern part, are strongly foliated. These rocks have been most extensively studied in the Juneau district (fig. 1), where they have been interpreted as being strongly folded and are characterized by tight, asymmetrical folds and foliation, both of which strike northwestward and dip northeastward (Sainsbury, 1953, p. 16, 17; Forbes, 1959, p. 50–64; and G. D. Eberlein, oral commun., 1962. Gault and Fellows (1953, p. 6 and pls. 2 and 3) noted the isoclinal folds and dominantly vertical foliation that strike northwestward at the Tracy Arm zinc-copper prospect (fig. 3); Gault (1953, p. 18, 19) described the dominant foliation at the Groundhog zinc prospect in the Wrangell District (fig. 1) as striking northwestward and dipping steeply northeastward.

The western contact of the Coast Range batholith is commonly gradational and is marked by a transition zone of gneiss. The grade of regional metamorphism within the belt of metamorphic rocks decreases from east to west, as indicated by the general transition from gneiss and crystalline schist, through slate and phyllite, to slate, greenstone, and argillite. Near the latitude of Sumdum this transition is exemplified by the progressive change from gneiss and schist in the almandine amphibolite facies near the batholithic rocks, through rocks representative of the greenschist facies, to the diverse assemblage containing greenschist facies and relatively unmetamorphosed rocks that were mapped by Loney (1961) on Admiralty Island near Pybus Bay (fig. 1). The effects of contact metamorphism locally superposed on those of regional metamorphism are evident within the belt of metamorphic rocks.

The western part of the composite Coast Range batholith consists largely of foliated dioritic rocks, which Forbes (1959, p. 28–31) believed were formed chiefly by granitization.

GENERAL DISCUSSION

The Sumdum prospect as subdivided by Seraphim (unpub. data, 1960) includes five areas in numerical sequence from north to south. Areas 1, 2, and 3 are north of the Sumdum Glacier (pl. 1).

The ore deposits are largely confined to the intermediate unit (unit b) of the three metamorphic-rock units, and most of them are in areas 2, 3, and 4 (pl. 1). The deposits consist of sulfide replacements, disseminations, and open-space fillings that commonly contain abundant pyrite and (or) pyrrhotite and lesser amounts of chalcopyrite and sphalerite.

METAMORPHIC ROCKS

The metamorphic rocks form a series of northwest-trending folds that are virtually isoclinal. These folds are commonly overturned to the southwest, and their axial planes generally dip steeply northeastward subparallel to the well-defined foliation. The dominant metamorphic rocks at the prospect are schist and gneiss. Bedding is difficult to distinguish, and criteria for determining tops or bottoms of beds are lacking.

Three metamorphic-rock units were delineated during the mapping: a unit that borders the batholithic rocks throughout most of the prospect area, designated unit a; an intermediate unit, designated unit b; and a unit that underlies the western part of the prospect, designated unit c. Unit a is characterized by abundant calcareous rocks, chiefly calc-silicate hornfels, but it contains substantial amounts of impure marble, gneiss, and schist, and subordinate amphibolite. Unit b consists of intercalated felsic and mafic layers between 10 and 300 feet thick that are dominantly gneiss and subordinate schist and impure quartzite. Unit c is composed of schist and small amounts of gneiss and calcareous rocks.

UNIT A

DISTRIBUTION AND RELATIONSHIP

Unit a is the easternmost of the metamorphic rock units that were delineated. It trends about N. 35° W., parallel to the foliation, and borders the batholithic rocks throughout most of the prospect area (pl. 1). It is separated from the dioritic rocks of the batholith by a fault, which, where observed, is parallel to the foliation of the metamorphic rocks. In gross aspect, however, this fault converges with the trend of the metamorphic rocks at a small angle and cuts out unit a in area 1 near the northern limit of the prospect. The contact between units a and b is gradational.

Unit a reaches its maximum observed outcrop width, about 1,800 feet, on the ridge south of the Sumdum Glacier. On this ridge the eastern half of the unit a section consists largely of calc-silicate hornfels and schist; the intermediate quarter consists of schist, gneiss, and impure marble and of subordinate calc-silicate hornfels and amphibolite; the western quarter consists of gneiss and calc-silicate hornfels and of minor impure marble. A few of the impure marble zones are as much as 50 feet thick, but they are generally between 5 and 15 feet thick. The amphibolite is commonly a foot or less thick. In areas 2 and 3 much of the schist and hornfels of the eastern part of the unit has been faulted out, and rocks of the medial part of unit a are juxtaposed against the batholithic rocks. Unit a is cut by thin pegmatite dikes and sills, by a few lamprophyre dikes, and—locally, near the batholith—by apophyses of quartz diorite. A large part of the unit is covered by ice or snow.

PETROLOGY AND PETROGRAPHY

Unit a is characterized by abundant calcareous rocks, chiefly calc-silicate hornfels. The estimated percentages of rock constituents in unit a are: calc-silicate hornfels, 35; schist, 30; gneiss, 20; impure marble, 10; and amphibolite, 5.

The calc-silicate hornfels is diverse in color, lithology, and texture. Commonly, it is light gray either fresh or weathered, but some more mafic varieties are medium or dark gray and weather greenish brown. Less commonly, the hornfels is white or buff. Most of the calc-silicate hornfels is crudely foliated, and some of it has intercalated light- to dark-gray bands a few millimeters thick. The calc-silicate hornfels is dominantly a fine-grained rock with a crystalloblastic texture. Rarely, it is porphyroblastic and contains coarse-grained garnet porphyroblasts embedded in a fine-grained groundmass.

All the calc-silicate hornfels contains diopside. The dominant mineral assemblages in the calc-silicate hornfels are: (1) diopside-tremolite-quartz-calcite, (2) diopside-garnet-wollastonite-quartz, (3) diopside-andesine-hornblende, and (4) diopside-garnet-quartz-labradorite. Opaque minerals, sphene, and—less commonly—apatite occur in minor amounts in most of the assemblages. Small amounts of biotite and chlorite are locally associated with the minerals of assemblage 1. Staurolite is a subordinate constituent of assemblage 3; hornblende, of assemblage 4. The garnets of the calc-silicate hornfels consist chiefly of grossularite. The composition and other properties of two garnets from the calc-silicate hornfels are shown in table 1 (samples 1 and 2).

The impure marble is banded light gray and buff and consists mainly of a granoblastic mosaic of polysynthetically twinned calcite crystals about 1 mm in diameter. Its lesser constituents, which cumulatively form less than about 10 percent of the rock, are muscovite, scapolite, sphene, andesine, pyrite, magnetite(?), hematite, graphite, and chlorite. The impure marble contains a few nodes of calc-silicate rock, as much as 1 foot thick and 4 feet long, that are composed of garnet, wollastonite, and epidote.

The schists are fine-grained strongly foliated rocks that are light to dark gray and weather brown. Their dominant minerals are quartz, andesine, and hornblende or biotite. Staurolite is an accessory mineral in most of the schist, and muscovite and almandine-rich garnet (table 1, sample 4) are less common accessories. Opaque minerals, sphene, chlorite, and clay minerals are the sparsely dis-

TABLE 1.—*Properties of garnets from*

Sample	Host rock	Color	Specific gravity	Index of refraction	Unit cell dimension (angstroms)
1	Calc-silicate hornfels (unit a)	Colorless	3. 63±0. 01	1. 738±0. 003	11. 862
2	Calc-silicate hornfels (unit a) [2]	do	3. 67± . 01	1. 752± . 003	11. 854
3	Gneiss (unit b)	Pale pink	4. 16± . 01	1. 798± . 003	11. 572
4	Schist (unit a)	do	4. 15± . 01	1. 795± . 003	11. 609

[1] FeO determined by chemical analysis by Leonlece Beatty, U.S. Geol. Survey. Total iron, CaO, and MnO determined by X-ray fluorescent spectroscopy by W. W. Brannock and A. C. Bettiga, U.S. Geol. Survey. Calculated on the assumption that the five listed garnet molecules represent the only end members present, the amount of pyrope being determined by the difference between the sum of the other end members and 100 percent.

[2] Composition of sample 2 not determined.

tributed minor constituents, the latter two occurring as alteration products.

The gneiss is a fine-grained light- to dark-gray foliated rock that weathers brown. Its texture is characterized by alternating felsic and micaceous bands, each 1 to 3 mm thick. Chief minerals in the gneiss are quartz, andesine, and biotite, and subordinate minerals are muscovite and staurolite along with sparse amounts of opaque minerals, zircon, and potassium feldspar.

The amphibolite is a dark-gray rock that weathers greenish brown and is well foliated. It is fine to medium grained and is composed mainly of hornblende, generally associated with about 20 percent andesine.

UNIT B

DISTRIBUTION AND RELATIONSHIP

Unit b, the intermediate unit of the three metamorphic-rock units, trends northwestward across the prospect (pl. 1). Unit b is bounded by gradational contacts with unit a to the northeast and with unit c to the southwest, and it is faulted against the batholithic rocks near the northern limit of the prospect. Unit b is cut by a few lamprophyre dikes, by quartz diorite sills, and by veins, boudins, and irregular lenticular masses of quartz. Ice, snow, or alluvium mantles parts of the unit, and some of the smaller exposures of unit b are nunataks. The rocks of unit b are strongly folded and contain numerous small drag folds on the limbs of larger folds. The unit's maximum observed outcrop width is about 4,000 feet near the northern extremities of the prospect, but elsewhere its outcrop width averages about 2,500 feet.

PETROLOGY AND PETROGRAPHY

Unit b consists mostly of strongly foliated and folded gneiss that forms irregular intercalated layers between 10 and 300 feet thick. These layers are distinguished by the dominance of either felsic or

the Sumdum copper-zinc prospect

Composition (percent) [1]								
Almandine	Andradite	Grossularite	Pyrope	Spessartine	Fe_2O_3	FeO	CaO	MnO
3.9	2.8	86.5	6.3	0.5	0.9	1.7	33.2	0.23
49.4	3.2	2.9	10.8	33.7	1.0	21.4	2.2	14.4
46.9	4.1	3.7	10.4	34.9	1.3	20.3	2.8	15.0

mafic gneiss within them. Layers composed mainly of mafic gneiss are separated by layers rich in felsic gneiss. The felsic gneiss is about twice as abundant as the mafic gneiss. Schist forms about 10 percent of the unit and impure quartzite, a few percent. The gneiss is fine grained and is characterized by interlayered felsic and mafic folia, 3 mm or less thick, that locally are streaky and lenticular. Generally, the felsic folia are light gray and the mafic ones dark gray. Weathered surfaces of the gneiss are stained various shades of brown—commonly light brown in the felsic gneiss and greenish brown and moderate or dark brown in the mafic gneiss.

The felsic gneiss consists mainly of quartz and sodic andesine and lesser amounts of biotite and muscovite. Staurolite and garnet rich in almandine (table 1, sample 3) occur in moderate quantities in some of the felsic gneiss. Sparse minor constituents of the felsic gneiss are opaque minerals and sphene, as well as hornblende, chlorite, apatite, zircon, and clay minerals. Parts of the gneiss contain sparsely disseminated sulfides, chiefly pyrite with subordinate pyrrhotite and chalcopyrite. A semiquantitative spectrographic analysis of an andesine-biotite-quartz-gneiss, representative of the felsic gneiss, is shown in table 2 (analysis 1).

The mafic gneiss contains abundant hornblende and plagioclase, predominantly intermediate or sodic andesine. Quartz and biotite are other major constituents. The chief rock types in the mafic gneiss are andesine-hornblende-gneiss, quartz-andesine-hornblende-gneiss, and quartz-hornblende-biotite-andesine-gneiss. Actinolite, sphene, opaque minerals, chlorite, and muscovite are minor constituents of the mafic gneiss. A semiquantitative spectrographic analysis of a typical mafic gneiss is shown in table 2 (analysis 2).

TABLE 2.—*Semiquantitative spectrographic analyses of some rocks and ore from the Sumdum copper-zinc prospect*

[Analyses were made for 66 elements; only elements that were detected in at least one sample are listed; in the series 7, 3, 1.5, 0.7, 0.3, 0.15, and so on, in percent. M, major constituent, greater than 10 percent; U.S. Geol. Survey. Sample locations are shown on pl. 1]

Analysis	Rock type	Ag	Al	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe
1	Biotite-andesine-quartz gneiss from unit b.	nf	M	0.03	nf	nf	1.5	nf	0.0007	nf	0.00015	3
2	Quartz-andesine-hornblende-gneiss from unit b.	nf	M	.03	nf	nf	7	nf	.003	.007	.015	M
3	Biotite-andesine-quartz schist from unit c.	d	M	.03	0.00015	nf	3	nf	.0015	.015	.015	3
4	Hornblende-andesine schist from unit c.	nf	M	.015	nf	nf	M	nf	.003	.015	.007	7
5	Ore-bearing gneiss from area 4.	0.007	3	1.5	nf	0.007	1.5	0.015	.007	.0003	1.5	M
6	Ore-bearing schist from area 5.	d	3	.15	nf	nf	1.5	nf	.0007	.0015	.3	M
7	Ore from prospect in unit c..	.003	3	7	nf	.007	3	.015	.015	.0015	3	M
8	Ore from area 3..............	.0015	3	.3	nf	nf	1.5	nf	.0015	nf	3	M
9	.....do......................	.0007	0.7	.7	nf	nf	0.7	nf	.03	.0003	1.5	M

The schist of unit b is fine-grained strongly foliated rock that is commonly light or medium gray and that has brown-weathered surfaces, which are locally glistening and adamantine. It is composed of quartz and intermediate andesine associated with biotite, muscovite, and—less commonly—hornblende, chlorite, and subordinate staurolite and opaque minerals. Uncommon variants of the schist consist almost entirely of tremolite.

The impure quartzite is probably a poorly foliated quartz-rich facies of the felsic gneiss with which it is closely associated. It is light gray and weathers light brown. Except for the preponderance of quartz, the mineral assemblage of the impure quartzite is similar to that of the felsic gneiss.

UNIT C

DISTRIBUTION AND RELATIONSHIP

Unit c forms the bedrock between unit b and the western limits of the prospect (pl. 1). Like the other metamorphic rock units, it trends northwestward and is strongly foliated and folded. Its gradational contact with unit b is marked by the transition from the prevalent schist of unit c to the gneiss-rich unit b. The calcareous rocks, which are uncommon in unit c, crop out near the western boundary of the prospect, where they form thin layers and lenses within schist. A lamprophyre dike penetrates unit c for about 100 feet near the contact with unit b in area 4. Because it crops out at lower altitudes, unit c is obscured less by ice and snow, but more by vegetation than are the other metamorphic-rock units. The maximum outcrop width of unit c at the prospect is more than 5,000 feet, but the unit is actually much wider, as it probably underlies most of the unmapped area between the prospect and Endicott Arm. Unit c is locally covered by alluvium and glacial deposits.

numbers represent midpoints or group data on a geometric scale and are reported to the nearest number
d, barely detected, concentration uncertain; nf, sought but not detected. Analyst: R. G. Havens,

Ga	K	La	Mg	Mn	Mo	Na	Ni	Pb	Sc	Si	Sr	Ti	V	Y	Yb	Zn	Zr
0.0015	1.5	nf	1.5	0.07	nf	3	nf	nf	0.003	M	0.007	0.15	0.003	0.003	0.0003	nf	0.015
.0007	nf	nf	7	.3	nf	3	0.003	d	.007	M	.03	.3	.03	.0015	.0003	nf	.007
.0015	3	0.003	3	.07	nf	1.5	.015	0.003	.0015	M	.03	.3	.015	.003	.0003	d	.015
.0015	nf	nf	3	.15	nf	3	.007	nf	.007	M	.03	1.5	.07	.003	.0003	nf	.015
nf	nf	nf	.7	.03	<0.003	nf	.003	.3	nf	7	.015	.15	.0015	nf	<.001	7	.003
nf	nf	nf	.3	.3	<.003	.7	.003	.007	.0015	M	.003	.15	.007	nf	<.001	1.5	.0015
.0015	nf	nf	3	.07	<.003	.3	.003	.15	.0015	7	.03	.15	.015	nf	<.001	7	nf
nf	nf	nf	3	.3	<.003	.3	.003	.003	------	7	.003	.15	.007	.0007	<.001	0.15	.003
nf	nf	nf	1.5	.03	<.003	.07	.0007	.007	------	7	.003	.015	.0015	nf	<.001	0.15	nf

PETROLOGY AND PETROGRAPHY

Unit c consists of approximately 75 percent schist, 20 percent gneiss, and 5 percent semischistose calcilutite and semischistose marble. Most of these rocks are very fine grained and strongly foliated.

The schist is a dark- or medium-gray rock that weathers light brown, brown, or greenish brown. Its weathered surfaces generally have a micaceous sheen. Most of the schist is quartz-mica-schist, with or without plagioclase. Where present, the plagioclase is commonly sodic andesine and less commonly calcic oligoclase. Both biotite and muscovite are abundant, generally in near-equal proportions, but in a few of the schists either biotite or muscovite prevails to the diminution or the exclusion of the other. The lesser constituents of the quartz-mica schist are opaque minerals, chlorite, and clay minerals, and—rarely—garnet, actinolite, and sphene. Uncommonly the quartz-mica schist contains disseminated sulfides, chiefly pyrite that is associated with minor amounts of chalcopyrite. Small augen of quartz, a few millimeters long, and thin felsic lenses and streaks are in the schist at some places near the contact with gneiss. Hornblende-andesine schist constitutes a subordinate part of unit c. The major minerals of this rock, hornblende and andesine, are associated with minor amounts of quartz, chlorite, clay minerals, and opaque minerals. Semiquantitative spectrographic analyses of a quartz-mica schist (analysis 3) and of a hornblende-andesine schist (analysis 4) are shown in table 2.

The gneiss of unit c is a fine-grained rock with intervening mafic and felsic layers, each about a millimeter thick. The felsic layers are light gray and the mafic ones dark gray; both weather brown. The felsic layers are almost entirely composed of andesine and quartz, and the mafic layers consist dominantly of biotite or hornblende. Chlorite, muscovite, and opaque minerals are lesser constituents of the mafic parts of the gneiss.

The semischistose calcilutite is a finely laminated light-gray rock that is cut by a few quartz-calcite veinlets. It consists almost entirely of slightly elongate calcite grains about 0.01 mm in maximum dimension. Its lesser constituents, which compose 2 or 3 percent of the rock, are muscovite and opaque minerals.

The semischistose marble is a dark-gray rock with a granoblastic texture. It is composed mainly of calcite crystals between 0.2 and 0.4 mm in diameter but contains subordinate quantities of sphene, muscovite, quartz, and opaque minerals.

METAMORPHIC FACIES

Most of the mineral assemblages in the metamorphic rocks are indicative of the staurolite-quartz subfacies of the almandine amphibolite facies of regional metamorphism as described by Fyfe, Turner, and Verhoogen (1958, p. 228–232). Several of the mineral assemblages are ambiguous and indicate either the almandine amphibolite facies or the hornblende hornfels facies, and a few represent the hornblende hornfels or the pyroxene hornfels facies. The widespread occurrence of small to moderate amounts of almandine-rich garnet and staurolite indicates that the almandine amphibolite facies, rather than the hornblende hornfels facies, largely composes many of the ambiguous rocks in units a and b. Although both garnet and staurolite can occur in the hornblende hornfels facies, they rarely do and therefore such occurrences are considered to be anomalous (Fyfe and others, 1958, p. 207).

Some of the calc-silicate hornfelses in unit a, especially the one which contains grossularite-rich garnet and (or) wollastonite, represent the hornblende hornfels or the pyroxene hornfels facies. These rocks indicate local high-temperature environments near the batholith. Local transitions between the almandine amphibolite and the hornblende hornfels facies probably occur elsewhere throughout the metamorphic sequence.

In the prospect area, the grade of regional metamorphism within the almandine amphibolite facies seems to decrease slightly from east to west. Evidence for this transition is the absence of staurolite from unit c, the generally lower anorthite content of plagioclase, and the increase in chlorite in unit c, even though the chlorite may be entirely secondary. Furthermore, the rocks of unit c tend to be less coarsely crystalline than the other metamorphic rocks.

AGE AND CORRELATION

The metamorphic rocks antedate the rocks of the Coast Range batholith, which are probably of Cretaceous age (Matzko, Jaffe, and Waring, 1958, p. 532; Baadsgaard, Folinsbee, and Lipson, 1961, p. 694), but neither their lower age limit nor the time interval in which they formed is known. They may correlate with some of the lithologically similar rocks that border the Coast Range batholith throughout southeastern Alaska and have been described by many geologists, notably Spencer (1906, p. 16), Buddington and Chapin (1929, p. 49–73), and Forbes (1959, p. 28–34). Such correlations would be based largely on the similarity of metamorphic grades and geologic settings of the rocks and would not necessarily reflect their original contemporaneity. Definite correlations are hindered by the structural features, particularly faults and plunging folds, by the local crosscutting relations of the batholith, and probably by the different magnitudes of metasomatic replacement or granitization near the western margin of the batholith. So, even correlations parallel to the trend of the metamorphic rocks are tenuous, and attempted correlations transverse to the structural trend are more precarious because of the increased likelihood of unresolved structural complications and the disparity in metamorphic grade in the rocks involved.

Probably, no discrete primary lithologic unit persists in a consistent relationship with other units in the structurally complicated belt of metamorphic rocks adjacent to the batholith. Conversely, rocks of different ages and of diverse primary lithologies probably border the batholith throughout most of its extent. The fact that zones within the metamorphic belt are occupied by similar rocks that are generally in consistent relationship with each other reflects the extent of the regional metamorphism and to a lesser degree the original isochemical nature of the rocks.

Buddington and Chapin (1929, p. 73) cited paleontologic evidence to substantiate their belief that the metamorphic rocks along the western margin of the Coast Range batholith throughout most of the southeastern Alaska (their Wrangell-Revillagigedo belt) range in age from probably Ordovician to Jurassic or younger. The two known fossil localities in the eastern part of this belt nearest the Sumdum project are on the mainland northeast of Midway Island (fig. 2) and near Taku Harbor (fig. 1). Both of these localities are several miles from the batholith, and both contain Carboniferous fossils (Buddington and Chapin, 1929, p. 73). No fossil localities in rocks marginal to the batholith in a setting similar to that of the Sumdum prospect are known to the writers. The orginal features of any organic material that may have been present in such an environment, as well as primary lithologic features, were probably obliterated by effects of metamorphism.

Loney's (1961, p. 12–42) detailed investigations near Pybus Bay, about 30 miles southwest of the Sumdum prospect (fig. 1), disclosed the presence of metamorphic rocks of Silurian(?), Devonian, Permian, Triassic, Jurassic, and Cretaceous age and are another indication of the age diversity of the metamorphic rocks.

Reconnaissance mapping in British Columbia near the international boundary indicates that the dominant metamorphic rocks along the eastern margin of the batholith near the latitude of the Sumdum are Permian or Triassic (Kerr, 1948; Canada Geol. Survey, 1957).

The Sumdum metamorphic rocks probably formed in one or more intervals during the long time span that includes most of the Paleozoic and Mesozoic Eras; however, their actual age is unknown and attempted correlations involving these rocks are risky.

BATHOLITHIC ROCKS

QUARTZ DIORITE

DISTRIBUTION AND RELATIONSHIP

The batholithic rocks at the prospect underlie the higher terrains that are extensively covered by snow and ice. They are best exposed on the few narrow ridges that protrude above the snow and ice fields in the eastern part of the prospect, along the walls of the cirque in area 1, and in the extreme southeastern part of the prospect (pl. 1). They are separated from unit a by a fault, but locally they form apophyses that penetrate unit a and, uncommonly, unit b.

PETROLOGY AND PETROGRAPHY

Both the batholithic rocks and their satellitic apophyses consist of quartz diorite. They are medium- or coarse-grained speckled rocks that are strongly foliated and commonly contain elongated tabular inclusions and streaky mafic schlieren. The typical quartz diorite is fresh and contains only small amounts of secondary minerals. Near faults, the quartz diorite is fractured, cut by numerous calcite veinlets, and characterized by abundant secondary minerals. Most of the quartz diorite is hypidiomorphic granular, but some of it is porphyritic and contains coarse-grained plagioclase or hornblende phenocrysts embedded in a medium-grained groundmass.

Plagioclase is the dominant mineral of the rock and commonly forms oscillatorily zoned subhedral crystals that range in composition from sodic andesine to calcic oligoclase. Quartz forms anhedral crystals that constitute about 10 percent of the rock. The characterizing accessory minerals are biotite and hornblende, which generally occur in near-equal amounts and together make up between 10 and 30 percent of the rock. The pleochroism of the biotite is: X and Y, light yellowish brown; Z, dark reddish brown. The pleochroism of the hornblende is: X and Y, light brown; Z, dark greenish brown. Minor accessory minerals in the quartz diorite are: potassium feldspar, sphene, opaque minerals (probably magnetite and ilmenite), zircon, apatite, and rutile. The secondary minerals which generally are sparsely distributed, are: chlorite, after biotite and hornblende; clay minerals and sericite, after plagioclase; epidote, after biotite, hornblende, and plagioclase; leucoxene, after sphene; and calcite, after plagioclase.

AGE

The age of the batholithic rocks is not known with certainty, but most recent evidence indicates that the Coast Range batholith was formed largely or entirely during the Cretaceous Period. Matzo, Jaffe, and Waring (1958, p. 532) using the lead-alpha method determined the age of a granodiorite from Turner Lake, about 40 miles northwest of the prospect (fig. 1), as 93 million years. This granodiorite was collected and described by Plafker (1956, p. 33) and represents the only isotopic age determination from the batholith near Sumdum.

Baadsgaard, Folinsbee, and Lipson (1961, p. 694), as a result of potassium-argon determinations on biotite from many batholithic rocks in western Canada, believed that the Coast Range batholithic mass was largely formed during the middle of the Cretaceous Period.

HYPABYSSAL ROCKS

PEGMATITE

Hypabyssal rocks are uncommon at the prospect and are represented by pegmatite and lamprophyre. Granite pegmatite, having subordinate aplite facies, crops out within unit a, where it commonly forms sills and, less commonly, lenses and irregular dikes (pl. 1). The pegmatite bodies generally trend parallel to the foliation of the metamorphic rocks, but locally they are divergent and transect the foliation (fig. 6). Some pegmatite masses have deflections in their attitudes, in places forming dikes and elsewhere sills.

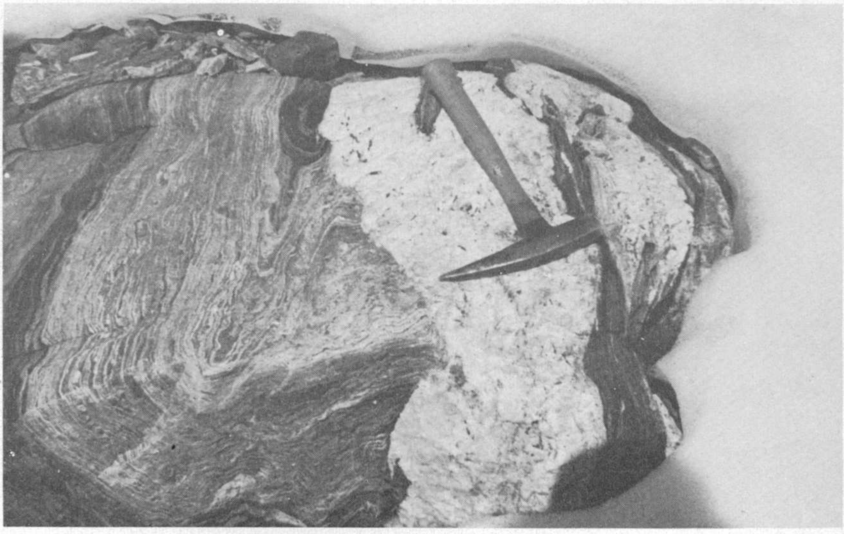


FIGURE 6.—A pegmatite dike cutting the intricately folded gneiss and schist of unit a. Hammer points north in area 3 adjacent to the Sumdum Glacier.

The largest pegmatite bodies consist mainly of sills. They are as much as 3 feet thick and traceable for several hundred feet along their strikes. The smallest are between ½ and 1 foot thick and form narrow sills and dikes a few tens of feet long or irregular lenticular masses as much as 15 feet long. Some of the pegmatite contains inclusions of host rock (fig. 6). The pegmatite consists mainly of quartz and potassium feldspar, which forms crystals as much as 2 inches long. Biotite forms a small part of the pegmatite; muscovite and, rarely, magnetite are minor constituents.

The pegmatite is probably a late-stage derivative of the batholith and, like the batholithic rocks, it is probably Cretaceous.

LAMPROPHYRE

The lamprophyre dikes are mainly in area 3 and, less commonly, in areas 1, 2, and 4. They are largely within unit b of the metamorphic rocks, although they locally penetrate the other metamorphic units.

They dominantly strike between N. 30°–50° E. and dip steeply, but the northernmost dike in area 3 and the dike in area 1, which possibly connect with each other, strike mainly northward. Most of the lamprophyre dikes are localized along faults. The dikes range from a few inches to 4 feet in thickness and are traceable for as much as 1,200 feet. The lamprophyre is a speckled grayish-brown rock, that weathers dark brown. It is spessartite and consists of scattered euhedral phenocrysts of medium-grained augite and hornblende in a fine-grained groundmass that is largely composed of diversely oriented euhedral brown hornblende in elongate crystals and anhedral plagioclase. Lesser constituents are disseminated pyrite and magnetite, as well as calcite, chlorite, and clay minerals.

Lamprophyre is probably the youngest crystalline rock at the prospect, even though its relation to the quartz diorite is obscured in the mapped area. Lamprophyre dikes that are similar in trend and lithology to those at Sumdum cut the batholithic rocks at the Tracy Arm zinc-copper prospect (fig. 3; Gault and Fellows, 1953, p. 4, pl. 3) and the quartz diorite along Tracy Arm (fig. 3; Buddington and Chapin, 1929, p. 229, 230).

SURFICIAL DEPOSITS

The surficial deposits consist of fluvioglacial material, moraines, talus, snow, and ice. They were only cursorily investigated. The fluvioglacial deposits occupy the broad U-shaped valley near the northern limit of the prospect (pl. 1). They are poorly sorted, ranging from fine sand to boulders, and are characterized by boulder-strewn surfaces. The only moraine that was mapped is a lateral moraine near the northern boundary of the Sumdum Glacier (pl. 1); this moraine was deposited during a higher stage of the glacier. Unmapped morainal material is sparsely distributed elsewhere at the prospect, notably near the lower margins of the glaciers in area 5, where the material forms a disordered array of piles of boulders with local increments of talus. Talus was not mapped. It forms near the bases of steep bare ridges and has contributed rock debris to some of the other surficial deposits. Talus partly mantles the glacier that occupies the cirque in area 1 (pl. 1), where it is derived from the quartz diorite that bounds the cirque. During warm weather, talus accumulation is increased by the almost continuous rockfalls and minor avalanches that generate along the precipitous walls of the cirque. Snow and ice cover a large part of the prospect.

The thicknesses of the discrete surficial deposits were not ascertained. The deposits are probably Quaternary, mainly Recent.

STRUCTURE

The structural history of the region is complicated, including preorogenic, orogenic, and postorogenic episodes. Additional work would be required to clarify the structure at the prospect. The preorogenic structural features have been largely obliterated by metamorphism and by the present structural features, which originated mainly in a mesozonal environment during the orogeny.

The main structural features trend northwestward, parallel to the regional structural trend. The most conspicuous of these features are numerous virtually isoclinal folds of diverse magnitude that plunge chiefly southeastward and are overturned to the southwest. The main faults, lithologic contacts, metamorphic rock units, and foliation also have predominant northwestward trends.

FOLDS

Tight virtually isoclinal folds are the dominant structural features in all the metamorphic rock units. The larger folds have exposed amplitudes of as much as 800 feet and wavelengths of several hundred feet. Numerous minor folds, including drag folds, lie intricately on the limbs of the larger folds and form a complex pattern (fig. 6). Most of the folds are overturned to the southwest and plunge 10°–40° SE. (fig. 9). Uncommonly, the folds are overturned to the northeast, and in the northern part of the prospect, they plunge northwestward, locally at high angles (pl. 1). Sharp, narrow hinges characterize most of the folds. Some of the competent rocks involved in the folding are fractured, crumpled, and contorted, and chevron or accordion folds occur locally.

Most of the folds are disharmonic and are characterized by the thickening and thinning of discrete incompetent layers within them and by local disparities in the distribution of minor folds and plications within individual layers. Quartz lenses, pods, and a few crude veins, all probably of retrograde derivation, have been incorporated into the folds, but younger quartz veins locally transect the folds.

FAULTS

The main faults at the prospect strike northwestward and are subparallel or parallel to the structural trend. They are exemplified by the fault that forms the western margin of the batholith and by a fault that extends across the western part of the prospect (fig. 8). The former fault dips 75°–80° NE. and generally strikes N. 40°–45° W., varying slightly from the gross trend of the metamorphic rocks. This fault has abundant slickensides and mullions that rake about 55° NW. The large fault near the western part of the prospect strikes approximately parallel to the foliation of its wallrock, the metamorphic rocks of unit c, and dips 70°–80° SW. Other northwest-striking faults cut the metamorphic and batholithic rocks, particularly the rocks of unit b in areas 2, 3, and 4 (pl. 1). The dips of these faults range from 60° NE. to 80° SW.

The northwest-striking faults locally form breccia zones, as much as 40 feet thick, some of which are sites of sulfide deposition but more commonly are represented by closely spaced subparallel fractures throughout zones a few feet thick or by discrete ruptures a few inches thick. Minor gouge and iron-stained altered wallrock are associated with many of these faults.

A few steep faults that strike N. 30°–50° E. cut the metamorphic rocks in the areas 3 and 4. These faults are occupied by lamprophyre dikes and generally are traceable for about 1,000 feet. They are characterized by left-lateral displacements of as much as 100 feet, and are parallel to most of the northeastward-striking joints at the prospect, which are ac joints and are probably tension features. Probably the northeast-striking faults originated by displacements along these ac joints in response to renewed and reoriented stresses.

OTHER STRUCTURES

The other structural features at the prospect comprise joints, foliation (including cleavage and schistosity), and lineation. They are commonest in the metamorphic rocks, but joints and foliation are common in the batholithic rocks.

Joints are abundant in the metamorphic rocks and are commonly spaced between 1 and 10 feet apart. In the metamorphic rocks the dominant joints strike N. 45°–65° E. and dip steeply to the northwest. They are ac joints and form surfaces approximately perpendicular to fold axes. Other joints are approximately parallel to the foliation and are virtually identical with fracture cleavage. A stereographic projection of the poles of 100 joints that cut the metamorphic rocks at the prospect (fig. 7) shows the prevalence of joints that strike northeastward and dip steeply to the northwest. These

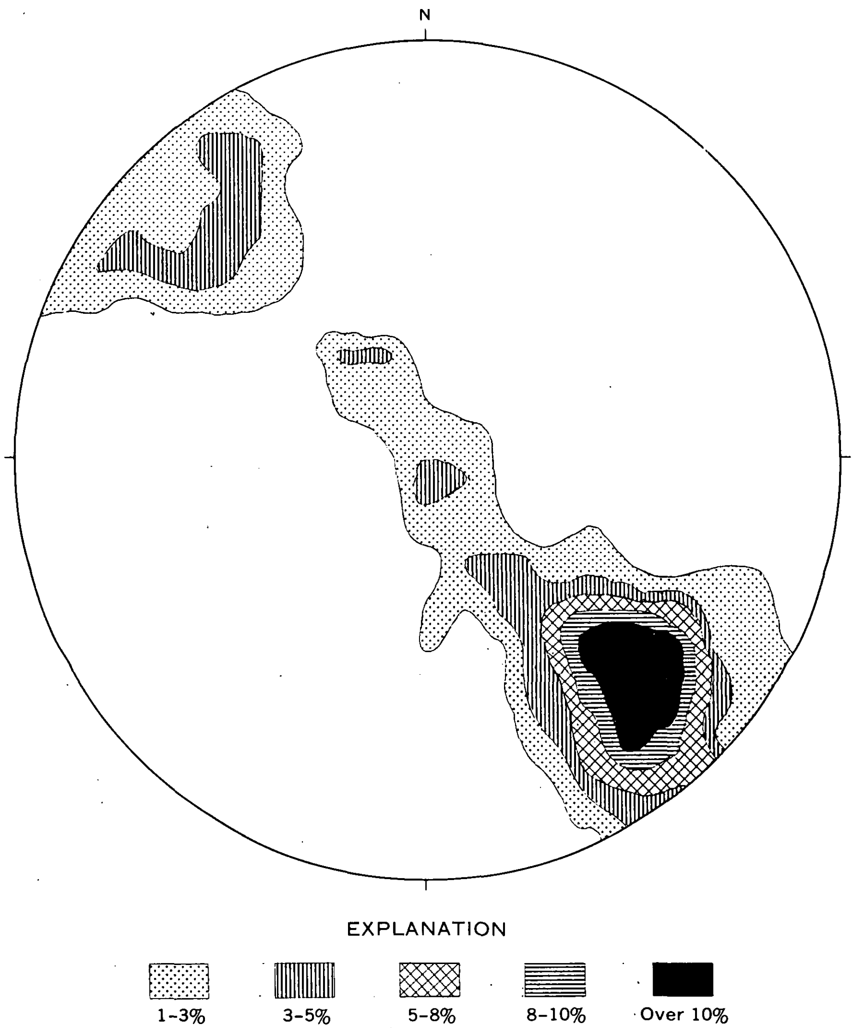


FIGURE 7.—Stereographic projection showing distribution of poles of 100 joint planes at the Sumdum prospect. Projections are on lower hemisphere.

are ac joints, as can be confirmed by comparison with the minor fold axes that are plotted on figure 9, and are similar in attitude to joints at the Tracy Arm zinc-copper prospect illustrated by Gault and Fellows (1953, fig. 2).

The term "foliation" is used in its general sense in this report and is applied to structural features having a strong planar fabric. The term includes both cleavage and schistosity. The foliation commonly strikes N. 20°–45° W., reflecting the trend of both the folds and the structural grain, and it dips steeply northeastward or vertically, except near the western margin of the prospect, where it commonly dips southwestward (pl. 1).

The foliation in the metamorphic rocks is megascopically characterized by the planar preferred orientation of micaceous minerals and the layers thus formed. Some of it is manifested by slip cleavage, particularly where the cleavage cuts dikes or veins. The effects of such slip cleavage are illustrated on figure 8, which shows the ptygmatic slip folds that have been formed by local displacements of two quartz veins that cut the rocks of unit b.

The relationships between the foliation, minor fold axes, and lineations that are shown on figure 9 are consistent and probably reflect one major structural episode. Only the predominant lineations are

FIGURE 8.—Ptygmatic slip folds formed in quartz veins as a result of slip cleavage cutting the gneiss of unit b in area 1. The quartz veins forming after the cleavage are undeformed.

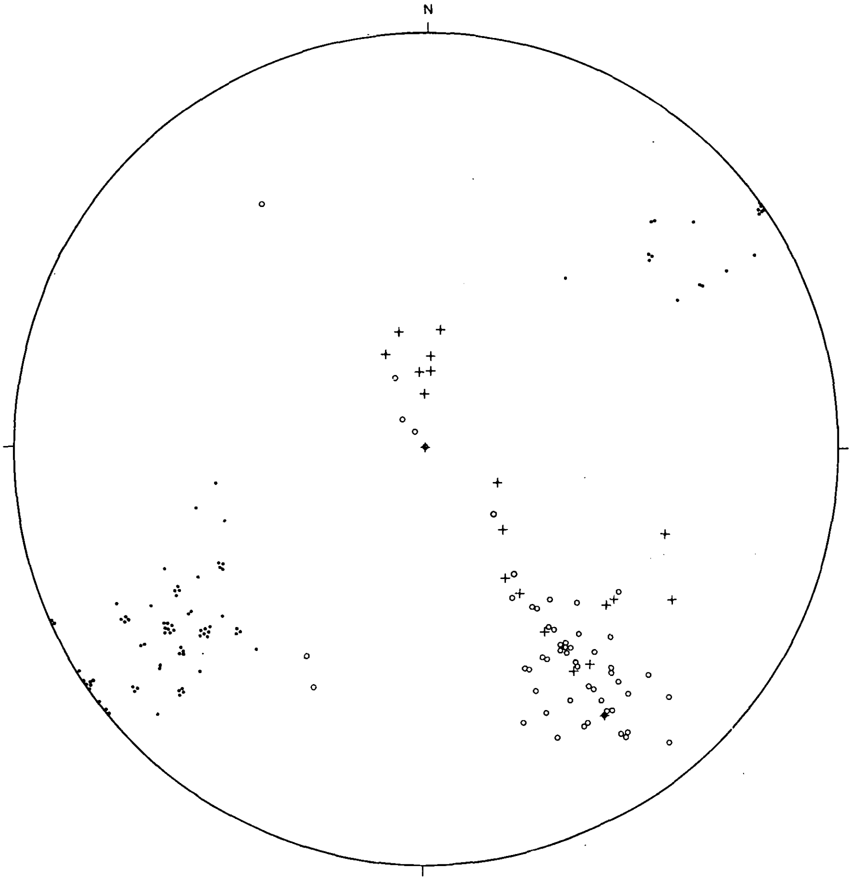


FIGURE 9.—Stereographic projection showing relationship between planar and linear structures in metamorphic rocks at the Sumdum prospect. Dots are poles to foliation planes, circles are minor fold axes, and crosses are megascopic lineations. Projections are on lower hemisphere.

plotted on figure 9. Most of these lineations are parallel to minor fold axes and are "b" lineations.

The lineations mainly rake southeastward at low angles in the foliation planes. In places, they rake to the southwest, and near the northernmost outcrops of unit a, they rake steeply to the north. Only a few of the lineations were mapped. Additional fieldwork and detailed petrofabric investigations would be required for a lucid and thorough interpretation of the lineations. Several types of lineations were noted at the prospect: (1) lineations formed by the alinement of elongate minerals are the most abundant and are largely "b" lineations, (2) lineations characterized by fine slickensides superposed on micaceous minerals, and (3) mullion and rodlike structures that are mainly formed by intersections of folded layers and cleavage. Boudinage is locally developed, particularly in quartz-rich layers of unit b.

Joints in the batholithic rocks are parallel or subparallel to their counterparts in the metamorphic rocks. They strike generally N. 45°–65° E. and dip steeply to the northwest. Less extensive joints strike northwestward and dip steeply northeastward, virtually parallel to the foliation. Flat-lying "sheeting" joints are exposed on some steep-walled outcrops of the batholithic rocks.

Foliation is well defined in the batholithic rocks, and, like the foliation in the metamorphic rocks, it strikes N. 20°–45° W. and dips steeply to the northeast. The foliation reflects the parallel orientation of platy minerals or mafic inclusions.

Lineations in the batholithic rocks chiefly reflect the alinement of elongate hornblende crystals that plunge southeastward at low angles.

ORE DEPOSITS

Most ore deposits at the prospect are within the intermediate unit (unit b) of the three metamorphic rock units (pl. 1). They originated by processes of replacement and open-space filling and consist of disseminated sulfides and sulfide-rich masses. The main ore-bearing areas, as designated by Seraphim (unpub. data, 1960), are Nos. 1 to 5 from north to south. The ore occurs in highly folded rocks. Its localization may have been partly controlled by folds, especially in areas 4 and 5, where the sulfide minerals are chiefly concentrated along the flanks of minor folds. However, in areas 1, 2, and 3 the ore-bearing zones are commonly bounded by faults, and much of the ore has formed in breccia zones associated with these faults.

The ore bodies are tabular or lenticular masses that are parallel or subparallel to the foliation and commonly strike N. 25°–50° W. and dip steeply to the northeast. They generally are not traceable for more than a few hundred feet along their strikes because of snow and glacier cover. Diamond-drilling data indicate that the ore bodies in area 4 connect with those in area 5 and these deposits probably extend beneath the Sumdum Glacier to area 3. If so, these ore bodies are at least 10,000 feet long. Individual ore zones range from 1 to 50 feet in thickness. Some of them consist largely of sulfide minerals, but others contain sporadically distributed pods, lenses, disseminations, and veins of sulfide minerals interspersed with host rock and gangue. The vertical extents of the ore bodies have not been determined. The main deposit in areas 4 and 5 crops out through a topographic range of about 1,000 feet, and the results of diamond drilling show that it extends for at least several hundred feet beneath the surface. The ore bodies that are localized along the flanks of plunging minor folds probably conform to the configuration of the folds and plunge gently southeastward.

Disseminated sulfides and secondary iron minerals which were derived from the ore bodies are widely scattered throughout the metamorphic rocks, but only the larger concentrations are shown on the geologic map (pl. 1). Generally, these concentrations are parallel to the trend of the foliation, and some of them may be indicative of concealed sulfide-rich masses.

CHARACTER OF THE ORE

The ore consists mainly of sulfide minerals and forms massive or disseminated sulfide deposits or quartz veins that contain irregularly distributed sulfide minerals. Pyrite and, less commonly, pyrrhotite are the dominant minerals of the ore deposits. These iron sulfides are generally associated with subordinate amounts of chalcopyrite and sphalerite, the chief ore minerals, and uncommonly with minor amounts of bornite, galena, and chalcocite. Some of the ore-bearing outcrops contain abundant hematite and hydrous iron oxides, as well as minor amounts of malachite and azurite. Quartz, which is the dominant gangue mineral, forms veins, lenses, and pods in many of the deposits. Many of the deposits contain scattered relicts of partly replaced rock-forming silicates. Less abundant gangue minerals are calcite, albite, and barite.

Typically, the pyrite forms a massive-appearing mosaic of anhedral crystals between 1 and 5 mm in diameter that are fractured and embayed. Ore and gangue minerals commonly occupy the interstices between individual pyrite crystals and form veinlets or irregular salients that cut or replace pyrite. Less commonly, the pyrite consists of scattered subhedral or euhedral crystals a few millimeters in diameter that are dispersed in the host rock or are irregularly distributed in veins.

Although massive-appearing pyrrhotite predominates in some of the ore, it is generally subordinate to pyrite and forms veinlets that cut or replace pyrite. The chalcopyrite and sphalerite are generally intimately associated and form irregular fine-grained masses in veinlets that cut or replace pyrite or pyrrhotite. Small quantities of bornite uncommonly form partial rims on the chalcopyrite, and minute quantities of galena are associated with some of the sphalerite. Supergene chalcocite forms some of the near-surface ore in areas 1 and 2.

The probable paragenesis of the main sulfide minerals of the deposits is: pyrite, pyrrhotite, and chalcopyrite-sphalerite. The chalcopyrite and sphalerite are commonly interdigitated, and diagnostic criteria for their age relation are lacking.

Semiquantitative spectrographic analyses of selected grab samples representing the higher grade parts of the ore are shown in table 2 (analyses 5–9). Numerous samples, both from surface cuts and from diamond-drill cores, were assayed in conjunction with an exploration program of Moneta Porcupine Mines, Ltd. The results of the assays[1] indicated that the samples generally contained between 0.5 and 1.0 percent copper, slightly less than 0.5 percent zinc, and about 0.25 ounces of silver per ton.

DESCRIPTION OF ORE-BEARING AREAS

The five main ore-bearing areas are in the predominantly gneissic unit b (pl. 1). Some outcrops in the other metamorphic-rock units are characterized by pyritized or copiously iron-stained rock, which may be indicative of ore.

AREA 1

Area 1 includes the upper part of the steep-walled valley near the northern limit of the map (pl. 1). Many of the folds in area 1 plunge steeply northwestward and contrast in attitude with the gentle southeastward-plunging folds that prevail in other parts of the prospect. Evidence indicates that ore occurs along a northwest-striking fault that extends from area 2 beyond the northern limit of the prospect (pl. 1). An iron-stained zone that contains minor amounts of pyrite and other sulfides and is as much as 20 feet thick crops out intermittently along the trace of this fault. Seraphim (unpub. data, 1960) reports that "sooty" chalcocite constitutes part of the deposit that was sampled in an exploratory trench in area 1.

AREA 2

Area 2 extends southward from area 1 to the unnamed glacier north of the Sumdum Glacier (pl. 1). The ore deposits are along and near northwestward-striking faults that cut the leucocratic gneiss and schist country rock. The chief ore zone in area 2 is on an extension of the fault that controls the principal deposit in area 1. This ore zone consists of several sulfide-rich lenses and veins, each between ½ foot and 1½ feet thick, that occupy an iron-stained zone about 25 feet wide. The veins and lenses merge and form a massive sulfide body about 50 feet long and 15 feet thick. The main ore zone in area 2 is traceable for about 1,000 feet along its strike. It consists of abundant pyrite and pyrrhotite and of subordinate chalcopyrite, sphalerite, and malachite. Quartz is the chief constit-

[1] Based on information in unpublished data by R. H. Seraphim and published with permission of the owners of the prospect, Moneta Porcupine Mines, Ltd.

uent of the veins. Part of the ore has formed by replacement, either of tremolite, which is the dominant mineral in much of the wallrock schist, or of chlorite in the schist and gneiss.

Several irregular iron-stained and sulfide zones are along and near northwest-striking faults in the eastern part of area 2. These zones are traceable for as much as 400 feet along their strikes and are from 1 to 10 feet thick. They were largely localized by open-space filling along fault and breccia zones and less extensively by sulfide minerals replacing chlorite in the wallrock gneiss and schist. Supergene chalcocite and malachite occur sporadically along some of the faults.

AREA 3

Area 3 occupies the ridge between the Sumdum Glacier and the unnamed glacier to the north and is bisected by a small prong of the Sumdum Glacier (pl. 1). The main ore deposit in area 3 is within a northwestward-striking breccia zone about 30 feet thick. The breccia zone is bounded by northwestward-striking faults that dip about 65° NE. The hanging-wall fault is marked by strong slickensides that rake about 40° SE. The breccia is traceable for nearly 1,500 feet in area 3. The richest and most extensive sulfide deposits are in the southern part of the breccia zone near the Sumdum Glacier. The deposits are leaner in the northern part of area 3, where the sulfide minerals are sporadically distributed throughout the breccia zone.

Small zones of disseminated sulfides, chiefly pyrite, occur at several places throughout area 3, and their oxidized derivatives commonly produce iron-stained outcrops.

AREA 4

Area 4 is in the high terrain on the ridge south of the Sumdum Glacier (pl. 1). The most promising ore deposits in this area form two iron-stained sulfide-rich zones that strike northwestward parallel to the structural trend. Both these zones are along the flanks of minor folds. The western zone is about 15 feet thick and is traceable for about 350 feet along the strike. The other zone, which is about 200 feet east of the western zone, consists of three sulfide masses each between ½ and 1 foot thick that are separated by similar thicknesses of intervening wallrock. This zone is traceable for about 250 feet along its strike on the surface; however, diamond-drilling data indicate that both of these zones persist beneath the ice to the south and extend into area 5. The deposits in area 4 contain pyrite and pyrrhotite in association with minor amounts of chalcopyrite, sphalerite, bornite, and galena. Quartz, which forms vuggy veins and irregular lenses and pods, is the dominant gangue mineral. Several persistent iron-stained zones that strike northwestward parallel to the foliation crop out elsewhere in area 4. Pyrite and small amounts of other sulfide minerals, which are commonly localized in the mafic folia of the wallrock gneiss, are disseminated in most of these zones.

AREA 5

Area 5 borders area 4 on the south and includes much steep terrain that is locally covered by ice (pl. 1). The two principal ore bodies in area 5 are extensions of the two largest ore bodies in area 4 and occupy the flanks of plunging minor folds. The western ore body crops out for about 1,000 feet along its strike. It forms a strongly iron-stained zone about 30 feet thick that contains both massive and disseminated sulfides and is cut by a few calcite veinlets. The eastern ore body is traceable for about 500 feet along its strike and is mantled by ice both to the north and to the south. It is as much as 50 feet thick. The ore occurs in schist that contains numerous lenticular masses of quartz, each a few centimeters long. Most of the ore has formed by sulfide minerals replacing the micaceous folia that surround augens of quartz. The ore assemblage is similar to that elsewhere at the prospect and consists of pyrite and pyrrhotite that are associated with minor amounts of chalcopyrite, sphalerite, and bornite.

A pyrite-rich zone that is masked by secondary iron minerals crops out in the eastern part of area 5 adjacent to the contact between units a and b. This zone is about 5 feet thick and is traceable for about 500 feet northwestward along its strike.

Another conspicuous northwest-striking iron-stained zone is localized along the northeast flank of a minor anticline in the western part of area 5. This zone is between 5 and 10 feet thick, and it is exposed for about 700 feet along its strike. Its outcrops consist almost entirely of secondary iron minerals with only a few scattered relicts of pyrite and chalcopyrite.

OTHER DEPOSITS

Many other iron-stained outcrops that commonly contain disseminated sulfide minerals occur throughout the metamorphic terrain. Most of these are small and poorly defined and were not mapped. They generally trend northwestward, parallel to the foliation, and are from a few inches to about 3 feet thick. Noteworthy among these outcrops are exposures at the prospect in unit c (pl. 1), which locally contain coarse-grained pyrite and minor amounts of chalcopyrite and sphalerite in a gangue that is rich in quartz and barite, and a zone of disseminated pyrite in schist near the northwest boundary of the prospect.

CONCLUSIONS

Most of the ore deposits evidently formed after the folding, faulting, and metamorphism. The deposits are commonly localized along or near faults and folds or have replaced minerals that were formed during metamorphism. The ore was probably deposited during a very late stage of the Coast Range orogeny, but whether the ore constituents were derived from late-stage fluids associated with the batholith or whether they were mobilized from the deeper parts of the folded metamorphic rocks is not known.

The deposits are probably of too low grade to be minable under present (1962) economic conditions. However, because of several factors—the size of the known deposits, the abundance of zones of disseminated pyrite and associated secondary iron minerals and the possibility that some of these zones contain enough copper to justify mining, and the possibility that significant quantities of undiscovered higher grade ore are in some of the deposits—future economic conditions might warrant additional exploration.

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