Geology of the Skagway B-3 and B-4 Quadrangles, Southeastern Alaska

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CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY OF THE SKAGWAY B-3 AND B-4 QUADRANGLES, SOUTHEASTERN ALASKA

By E. M. MacKevett, Jr., E. C. Robertson, and G. R. Winkler

ABSTRACT

The Skagway B–3 and B–4 quadrangles are near the northern extremity of southeastern Alaska in a mountainous region characterized by abundant glacier-related erosional and depositional features. The Chilkat River fault, a segment of the Chatham Strait fault which is a major tectonic element in southeastern Alaska, underlies the markedly linear Chilkat River valley and separates the quadrangles into two distinctive geologic terranes. The terrane east of the fault is dominated by igneous rocks of Cretaceous and early Tertiary age. These rocks consist of an older mafic and ultramafic assemblage that includes metamorphosed lavas, gabbro and diorite, and pyroxenite and the younger quartz diorite and related rocks of the Coast Range batholith. Structural and topographic trends east of the fault have a markedly linear northwestward orientation, which is typical of large parts of southeastern Alaska.

The terrane west of the fault is characterized by Paleozoic metamorphic rocks, by quartz diorite-granodiorite plutons that formed during the middle-Cretaceous and the middle-Tertiary, and by subordinate heterogeneous dikes and sills. The metamorphic rocks were derived from sedimentary and igneous, mainly volcanic, rocks that have been metamorphosed principally to greenschist facies assemblages. They consist of gneiss, marble, amphibolite, schist, phyllite, quartzite, slate, and undivided, largely contact-metamorphosed rocks. Structural and topographic trends west of the fault are diverse. Various Quaternary surficial deposits, including several of glacial-fluvial derivation, are widespread in the quadrangles.

The quadrangles contain deposits of gold, titaniferous magnetite, barite that is associated with silver and base metals, and nonmetallic commodities including marble, sand, and gravel. Gold-bearing placer deposits in the Porcupine District produced approximately 60,000 troy ounces of gold, but none of the other deposits have been mined. The titaniferous magnetite deposits and the barite-rich lodes are of current economic interest. Titaniferous magnetite is widely distributed in the pyroxenite mass that crops out in the Takshanuk Mountains and in the Klukwan alluvial fan along the base of the mountains. The barite-rich lodes, which were discovered in 1969 and 1971, are localized mainly in fault zones that cut metamorphic rocks near Glacier Creek. Geochemical sampling conducted during the fieldwork revealed many minor anomalous concentrations of metals.

INTRODUCTION

The Skagway B–3 and B–4 15-minute quadrangles are in the northern part of southeastern Alaska near the international boundary (fig. 1). The Haines Highway (Alaska Highway 7) crosses the quadrangles and is the major access artery. This highway links Haines, a port on the Alaska Ferry System that also is served by a commercial airline, with the Alaska Highway. The Dalton Trail of Klondike gold-rush lore formerly extended across the quadrangles following the southwest sides of the Chilkat and Klehini Rivers; only vestiges of the trail are preserved. Additional access is provided by local logging roads and by a few landing sites suitable for small fixed-wing aircraft, but most parts of the quadrangles are accessible only by helicopter or by foot. The latter is a tedious method of travel because of rugged topography, dense brush, and swift-flowing streams that are dangerous to cross.

The small population of the two quadrangles is localized at Klukwan, an Indian village of a few hundred people in the B–3 quadrangle; the remainder is scattered in dwellings along the Haines Highway. A few people occasionally occupy vacation dwellings at Chilkat Lake and buildings at the former mining camp of Porcupine. Haines, the local commercial and supply center, is about 15 miles southeast of the mapped area (fig. 1).

The physiography of the quadrangles is rugged and is characterized by highly dissected mountains, numerous high-gradient streams that discharge into rivers occupying broad glaciated valleys, and an array of glaciers and glacier-related erosional and depositional features (fig. 2). Altitudes in the quadrangles range from 7,434 feet (Mount Henry Clay at the west edge of the B–4 quadrangle) to a little less than 100 feet (along the lower reaches of the Chilkat River in the B–3 quadrangle). Timberline is at approximately 2,000 feet; except on extensive gravel bars along the broad river valleys, areas below 2,000 feet support interspersed dense brush and lush forests, which are locally logged. Outcrops generally are good in the snow- or ice-free terrains above altitudes of 2,500 or 3,000 feet. Elsewhere, rock exposures are restricted largely to roadcuts and steep-walled valleys.

The climate is rigorous with long, cold winters and frequent storms throughout the year. The mean annual precipitation in the quadrangles probably is comparable to that at Haines, approximately 60 inches. The

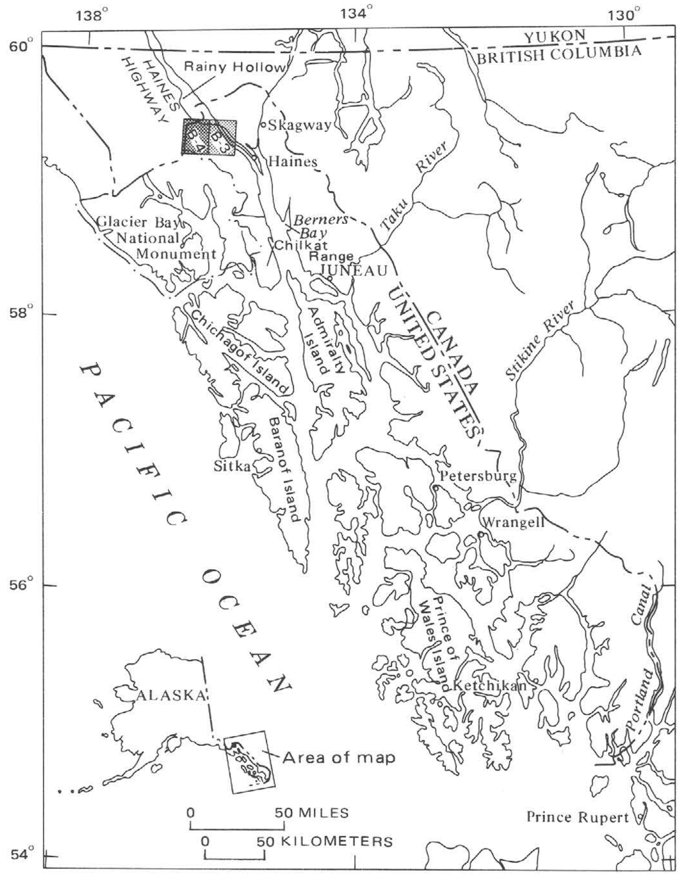


FIGURE 1.—Index map showing location of Skagway B–3 and B–4 quadrangles.

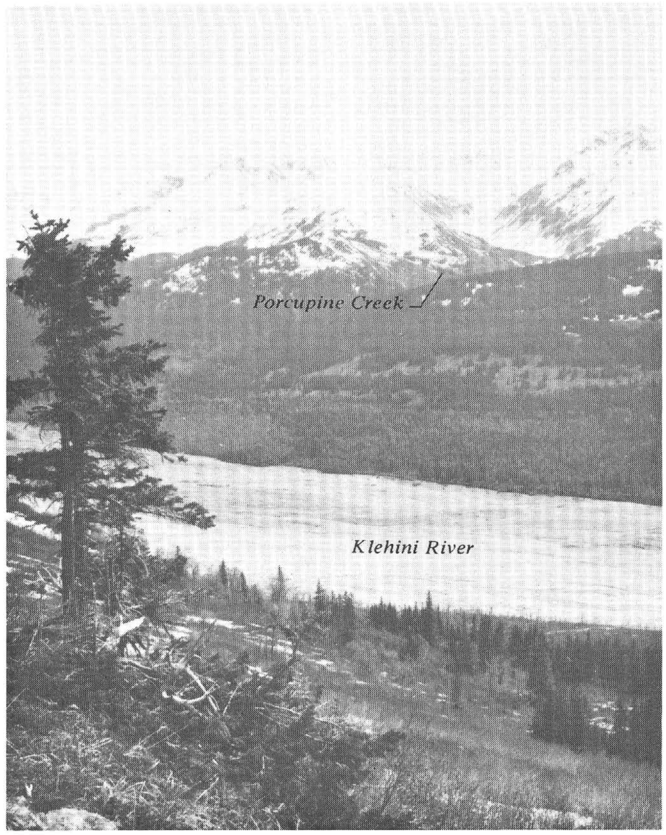


FIGURE 2.—View southeast from near Surgeon Mountain showing the environs of Porcupine Creek and the terrain bordering the Klehini River.

Chilkat River, the master drainage artery of the region, is fed by numerous tributaries, including fairly large rivers such as the Klehini, Tsirku, and Tahkin.

PREVIOUS INVESTIGATIONS

Geologic interest in the region began with the discovery of the Porcupine gold placers in 1898. Brooks (1900, p. 374–376) cursorily examined the newly discovered placers in 1899 while traveling over the Dalton Trail. More intensive investigations by Wright in the summer of 1903 focused on the Porcupine placers and contributed to a general understanding of the regional geology (Wright, 1904). Eakin (1919) updated information on the gold placers and supplemented Wright's earlier work during a 2-week period in 1916.

Recorded geologic study of the region waned until Robertson's investigations of the Haines and Klukwan magnetite deposits during 1950 and 1953. Robertson (1956) studied primarily the magnetite deposits in the Takshanuk Mountains and included geological mapping of the area between the Klehini and Chilkat Rivers and a brief airborne reconnaissance south of the Klehini. Robertson's mapping and other geologic information pertaining to the B–3 quadrangle east of the Chilkat River and some of his data relevant to other parts of the quadrangles are integral parts of this report.

Company or privately sponsored mineral exploration has been intermittent in the region since the arrival of the earliest prospectors. During recent years, most such investigations have focused on the Klukwan iron deposits.

PRESENT INVESTIGATIONS

This report is a product of reconnaissance geologic investigations during 1969, 1970, and 1971 and is supplemented by Robertson's earlier work. During 1969 MacKevett and Winkler spent a month mapping and sampling in an area west of the Chilkat River, which mainly is accessible by car or short foot traverses. Late that summer they were joined by D. A. Brew, D. H. Grybeck, and R. J. Wehr for a scheduled 10 days of helicopter-supported operations from the U.S. Geological Survey Research Vessel *Don J. Miller II*. During this period, operations were severely hampered by inclement weather which permitted working only a few days in the B–3 and B–4 quadrangles. In 1970 MacKevett and Winkler completed reconnaissance geologic mapping of the B–3 and B–4 quadrangles west of the Chilkat River during a 2-week period with helicopter support. In 1971 MacKevett spent a week field checking some of the geologic mapping and examining recently discovered barite deposits.

All mapping was done on a 1:48,000-scale topographic base augmented by interpretations from aerial photographs. Most of the results of a reconnaissance geochemical survey that accompanied the investigations are given in a report by Winkler and MacKevett (1970).

The fieldwork was supplemented by petrographic studies and mineral determinations by X-ray diffraction and by many semiquantitative spectrographic and atomic absorption analyses at the U.S. Geological Survey field laboratory at Anchorage.

The purpose and scope of this report are: (1) To describe the geology of a region that previously had been scantily investigated despite its pivotal position in the southeastern Alaska geologic and tectonic framework; (2) to ascertain the lode sources of the Porcupine gold placers and to determine geologically favorable sites for additional placer and lode deposits; and (3) to provide geologic and geochemical bases for evaluating the mineral resources of the region. We decided to concentrate on mapping the Skagway B–3 and B–4 quadrangles because such mapping would supplement Robertson's earlier work, cover large previously unmapped areas, and include the main known mineral deposits.

Despite the relatively short duration of the project for its purported scope, when the results of this project are coupled with Robertson's earlier investigations, they provide considerable new geologic information and a reconnaissance geologic map for the B–3 and B–4 quadrangles.

ACKNOWLEDGMENTS

Besides the helpful cooperation of several U.S. Geological Survey colleagues, the writers are grateful for the congenial cooperation of many local residents who shared their knowledge of the region's geography, geology, history, and mining activity. Included in this group are Hazel and "Binks" Seiffert, Fred Emerson, Merrill Palmer, and Steve Casto.

GEOLOGY

GENERAL GEOLOGIC SETTING

The Skagway B–3 and B–4 quadrangles are characterized by rugged mountains similar to those in nearby parts of southeastern Alaska. A continuation or major branch of the Chatham Strait fault (Brew and others, 1966; Ovenshine and Brew, 1972), herein called the Chilkat River fault, separates the quadrangles into two distinctive geologic terranes east and west of the Chilkat River (pl. 1). The pronounced northwestward structural and topographic trends that characterize large parts of southeastern Alaska are well developed east of the Chilkat River. Physiographic features west of the river lack conspicuous northwestward alinements, and the structural trends, although mainly northwestward, are diverse and complicated and include west-trending elements that are typical of the Muir and northern Chilkat provinces of Glacier Bay National Monument (MacKevett and others, 1971, p. 11). The terrane west of the Chilkat River contains abundant metamorphosed Paleozoic sedimentary and igneous, chiefly volcanic, rocks that probably formed in a shallow marine environment and some Cretaceous and Tertiary granitic intrusive rocks. The terrane east of the river is dominated by Cretaceous and Tertiary igneous rocks including mafic and ultramafic types that probably formed beneath a Mesozoic island arc (Berg and others, 1972). Because the geology of each terrane is so different and because descriptions of each are largely the responsibility of different authors (MacKevett and Winkler west of the Chilkat River, and Robertson east of the river), the consolidated rocks of the two fault-juxtaposed terranes are described separately.

ROCKS WEST OF THE CHILKAT RIVER

The terrane west of the Chilkat River contains lithologically diverse metamorphosed Paleozoic rocks, fairly abundant Cretaceous and Tertiary stocks and smaller intrusions, mainly of quartz diorite, and various Quaternary surficial deposits.

METAMORPHIC ROCKS

The metamorphic rocks were derived from Paleozoic sedimentary and igneous rocks. They contain mineral assemblages that reflect regional metamorphism ranging from greenschist to amphibolite facies (Turner, 1968), and, near some of the intrusions, assemblages that indicate subsequent contact metamorphism. Many of the metamorphic rocks record multiple stages of penetrative deformation.

The estimated thickness of the metamorphic sequence exceeds 10,000 feet. Interrelations among the diverse metamorphic rocks, including their relative stratigraphic positions and correlations, are not well understood because of the lack of fossils and persistent marker horizons, structural complications, disruptive effects of intrusions, and local differences in metamorphic effects.

The metamorphic rocks include schist, phyllite, amphibolite, slate, hornfels, gneiss, discrete masses of marble, and minor quartzite. Probably some of the diorite that is described under "Intrusive Rocks" is of metamorphic origin. For mapping and descriptive purposes, the metamorphic rocks are divided into the following units: (1) Gneiss, (2) marble, (3) amphibolite, (4) schist and phyllite, (5) slate, and (6) undivided metamorphic rocks.

The following terminology is used in many of the ensuing lithologic and petrographic descriptions.

1. Grain size based on estimated average dimensions of minerals:
   - (a) Coarse grained=Greater than 5 mm,
   - (b) Medium grained=1–5 mm,
   - (c) Fine grained=0.1–1 mm,
   - (d) Very fine grained=Less than 0.1 mm.
2. Mineral content based on estimated volumetric abundance:
   - (a) Predominant=Greater than 60 percent,
   - (b) Abundant=25–60 percent,
   - (c) Fairly abundant=5–25 percent,
   - (d) Minor=1–5 percent,
   - (e) Rare=Less than 1 percent.

GNEISS

The gneiss unit crops out in the northwestern part of the B-3 quadrangle and the extreme northeastern part of the B-4 quadrangle (pl. 1). It is several thousand feet thick and is in gradational contact with amphibolite and locally with schist and phyllite and in sharp contact with a small body of marble. Besides gneiss, the unit contains minor amounts of amphibolite, schist, phyllite, and marble.

The gneiss is strongly foliated and locally folded or cataclastically deformed. Its characteristic foliation is marked by alternating felsic and mafic layers, a few millimeters thick, generally conspicuously defined by alined biotite. The constituent minerals typically range from about 0.5 to 3.0 mm in maximum dimensions. Most of the gneiss is rich in quartz and oligoclase—the latter with relict fine albite twinning—and generally contains abundant biotite. Some of the gneiss contains abundant K-feldspar and muscovite. Less abundant minerals include epidote, calcite, and chlorite (largely as alteration products); opaque minerals (chiefly pyrite and hematite); and rare garnet, apatite, and staurolite. Probably most of the gneiss is orthogneiss derived from granitic rocks. Results of a semiquantitative spectrographic analysis of one gneiss sample are given in table 1.

Amphibolite, uncommon within the gneiss unit, probably represents metamorphosed mafic dikes, and the few small elongate masses of schist, phyllite, and marble may be relict roof pendants. Mineral assemblages in the gneissic rocks mainly indicate the greenschist-amphibolite transition facies (Turner, 1968).

MARBLE

Marble is widely distributed in the quadrangles and crops out boldly in masses that vary in size from several square miles in areal extent to isolated exposures a few feet thick. The largest and thickest marble bodies are in the western part of the B-3 quadrangle south of the Klehini River and in the northern part of the B-4 quadrangle (pl. 1). Besides marble that was mapped separately, small amounts of marble are included in all the other metamorphic units shown on the geologic map (pl. 1). Conversely, some mapped marbles contain minor amounts of other metamorphic rocks, chiefly schist and amphibolite. Some of the marble bodies are at least 2,000 feet thick. Some are markedly lenticular. The large marble masses in the western B-3 quadrangle and the northern B-4 quadrangle probably are partly coeval, but their correlation with the smaller marble bodies is improbable.

Marble adjoins all the rock units mapped west of the Chilkat River except the diorite. The contacts are sharp. The largest marble bodies are generally in contact with the slate and the schist and phyllite units, but the chronologic and stratigraphic relations between the units are not clear.

Most of the marble is massive, but in a few places it is thinly layered or platy. It generally is foliated and well banded with planar fabric defined by parallel stretched calcite crystals. Banding commonly is produced by alternating layers of crystals of different sizes. Some marble, lacking apparent foliation, consists of medium, coarse, and, rarely, fine sugary granoblastic mosaics. In places the marble has been cataclastically deformed by grinding and milling. Calcite veinlets are abundant, stylolites are fairly abundant, and relicts of chert nodules are rare. Some marble contains abundant indeterminate organic remnants. Typically, these are elongate ellipsoidal masses 1–2 cm long and a few millimeters in diameter that have been replaced by sparry calcite and lack internal structures (fig. 3). Some contain scattered spherical and rodlike forms less than a millimeter long.

An uncommon textural variant contains scattered aggregates of coarse sparry calcite in a matrix of finely crystalline cloudy calcite. The coarse calcite probably represents recrystallized fossil detritus, and the matrix recrystallized lime mud.

The marble is medium gray, light gray, white, and, less commonly, bluish gray. Locally, its surfaces are marked by bands or, rarely, blotches of contrasting colors. Average maximum dimensions of crystals are between 0.1 and 1 mm, but, exceptionally, they are as great as 5 mm.

TABLE 1.—*Semiquantitative spectrographic analyses of the metamorphic rocks*

[Analyst, K. J. Curry. Fe, Mg, Ca, Ti are reported in percent. All other elements are reported in parts per million (ppm) to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, and so forth. N=not detected; L=detected but below limit of determination; G=greater than amount shown in parentheses, precise amount not determined. The following elements were also looked for but not found in the spectrographic analyses. As, Au, Bi, Cd, Sb, Sn, W. All samples were analyzed for Au by atomic absorption methods, but Au (0.02 ppm) was found only in sample 69AMk–27B–2. Atomic absorption analyses by H. B. King, A. L. Meier, R. L. Miller, D. G. Murrey, and R. B. Tripp, U.S. Geological Survey]

Map No.[1]	Sample No.	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Rock name
		Percent				Parts per million (ppm)																			
											Gneiss unit														
1	69AMk–23C	5	1.5	2	0.5	1,000	N	N	300	N	7	15	15	N	N	10	10	N	10	150	150	10	N	70	Muscovite-biotite gneiss.
											Marble														
2	69AMk–2B	0.15	1	G(20)	0.015	70	N	N	70	N	N	L	L	N	N	L	N	L	N	700	15	N	N	N	Fine-grained marble (mapped in schist and phyllite unit).
3	69AMk–16D–1	.15	1.5	G(20)	.015	300	N	N	L	N	N	L	L	N	N	L	N	N	N	300	15	N	N	N	Brecciated marble.
4	69AMk–18A–1	.3	3	20	.02	70	N	N	L	N	N	10	L	N	N	L	N	N	N	200	15	N	N	N	Impure marble.
5	69AGk–540	.7	10	G(20)	.03	1,000	N	N	150	N	N	10	L	N	N	L	N	L	N	300	10	L	N	L	Dolomite marble (mapped in schist and phyllite unit).
6	69AGk–535	.15	1	G(20)	.015	100	N	N	L	N	N	N	5	N	N	L	N	N	N	700	15	L	N	L	Marble.
7	71AMk–3A–1	1.5	5	G(20)	.015	300	N	N	30	N	N	20	L	N	N	10	N	L	N	500	20	N	N	N	Banded fine-grained marble.
											Amphibolite unit														
8	69AMk–9F	10	7	2	0.3	1,500	N	L	L	N	10	70	70	N	L	L	15	L	30	200	300	15	L	70	Phyllite.
9	69AMk–9G	3	3	.7	.3	1,000	N	L	300	L	15	15	70	N	L	L	20	N	15	150	100	20	N	100	Hornblende-biotite schist.
10	69AMk–10G	3	1.5	1	.3	500	N	L	300	1	7	15	30	N	L	L	15	N	20	150	150	20	L	70	Phyllite.
11	69AMk–11A	5	1	1	.3	700	N	N	300	L	L	15	30	N	L	L	10	N	20	200	150	20	N	100	Hornblende-biotite schist.
12	69AMk–42B	15	5	2	.5	1,500	N	L	300	L	50	150	10	N	L	10	70	N	30	200	200	10	200	30	Amphibolite.
											Schist and phyllite unit														
13	69AMk–3C–1	3	1	0.7	0.3	700	N	L	300	L	L	10	30	L	N	L	7	L	20	150	150	20	L	70	Chlorite-muscovite schist.
14	69AMk–4B	3	.5	L	.3	70	1	70	3,000	L	N	70	50	N	70	L	50	20	15	L	500	L	L	70	Carbonaceous schist.
15	69AMk–15F	15	3	.3	1	200	N	70	1,000	L	5	150	20	L	L	L	30	50	20	150	500	20	N	150	Do.
16	69AGk–542A	1.5	.7	10	.1	100	1.5	70	300	L	20	70	50	N	15	L	150	L	L	500	700	15	1,500	50	Do.
17	70AMk–2A	10	2	2	.5	500	N	L	300	L	30	70	50	L	N	L	50	70	30	300	300	30	N	200	Biotite-quartz schist.
18	70AMk–11B–2	15	2	10	.7	1,500	L	15	500	L	100	700	300	N	L	L	150	20	50	300	500	30	L	100	Chloritic schist.
19	70AMk–11C	7	1.5	.3	.3	500	L	L	L	N	70	70	100	N	L	L	150	10	15	L	300	20	L	150	Do.
											Slate														
20	69AMk–19G	15	0.3	0.3	1	70	1.5	30	5,000	N	N	15	15	70	70	L	N	30	15	150	500	15	N	70	Pyrite-bearing slate.
21	69AMk–27B–2	10	.3	.7	.2	70	5	20	2,000	N	15	70	70	N	30	10	100	150	10	100	500	30	200	70	Do.
22	69AMk–52E	2	.5	.7	.15	150	L	30	300	L	20	20	50	N	L	L	50	N	7	L	50	15	L	70	Slate.
23	70AWk–6D	5	1	.7	.15	1,000	N	20	1,500	L	N	10	150	N	N	L	15	10	10	100	70	L	N	100	Do.
											Undivided metamorphic rocks														
24	69AMk–42G	5	1	2	0.5	1,000	N	10	100	1	5	20	70	N	N	L	15	N	20	200	200	15	L	50	Schist.
25	69AGk–532	10	3	2	.3	700	L	L	150	L	30	70	200	N	L	10	70	N	30	300	200	15	N	70	Hornblende-muscovite schist.
26	69AGk–533	15	5	3	1	1,000	N	10	150	L	70	150	50	N	L	10	30	L	20	300	200	30	L	70	Amphibolite.
27	69ABd–512E	15	7	7	1	1,000	N	10	150	L	100	300	70	N	N	10	150	N	30	200	300	30	L	100	Pyroxene hornfels.
28	69ABd–517B	10	3	3	.3	300	N	L	200	N	100	500	200	N	N	10	150	N	15	300	70	L	N	30	Do.
29	69ABd–518B	20	7	10	1	1,500	N	10	100	N	70	100	30	N	L	L	50	L	50	700	700	10	L	L	Do.
30	60ABd–519B	20	5	7	.7	1,500	N	10	200	N	70	10	70	N	L	10	20	N	20	500	300	15	L	20	Amphibolite.
31	69ABd–519D	7	2	2	.7	500	1	70	700	3	30	100	70	20	L	10	100	15	15	300	300	20	L	100	Hornfels.
32	69ABd–522B	20	7	5	1	1,000	N	L	300	N	70	300	70	N	N	10	100	N	30	300	300	15	N	70	Amphibolite.
33	69ABd–524B	7	1.5	2	1	300	N	70	500	2	30	150	70	L	N	10	50	20	20	100	300	20	L	150	Spotted schist.
34	70AWk–13A–2	10	.07	1	G(1)	700	N	30	2,000	1	30	150	70	N	5	10	30	20	70	L	700	10	N	200	Schist.
		Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	
Limit of determination		0.05	0.01	0.01	0.001	10	0.5	10	10	1	5	2	5	20	2	10	5	10	5	20	10	30	200	10	

[1]Sample locations are shown by the circled map numbers on the geologic map (pl. 1).

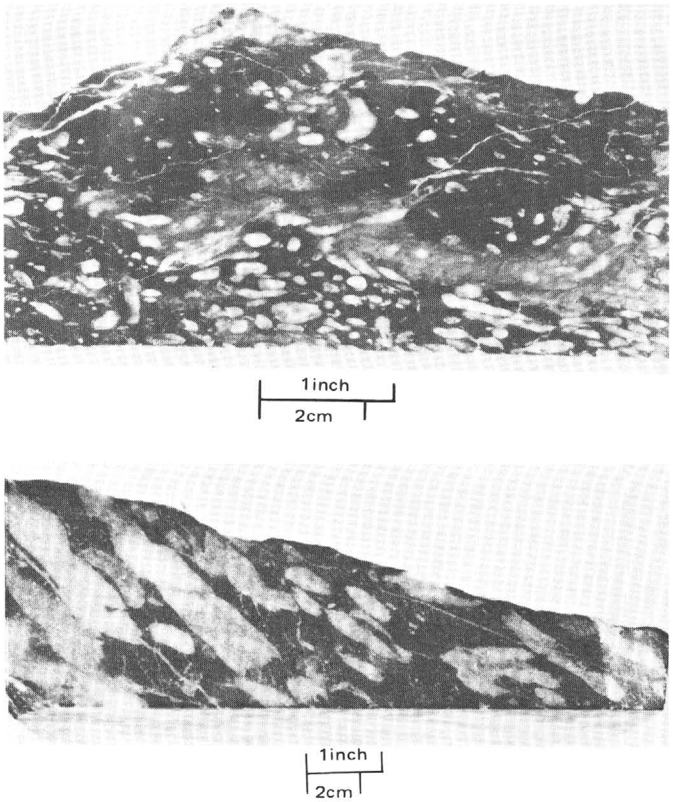


FIGURE 3—Sawn slabs of marble showing organic remnants, probably stromatoporoids.

Most of the marble consists of calcite with only a few percent of impurities—chiefly intergranular quartz and clay minerals and flecks of opaque minerals such as pyrite, graphite, and hematite. Sparsely distributed impure marble, which generally is schistose, contains fairly abundant quartz, chlorite, plagioclase, and muscovite. Dolomite, commonly mixed with calcitic marble, occurs locally, but its distribution and extent were not ascertained. Most dolomite-bearing samples came from outcrops bordering the lower reaches of the Tsirku River in the B-3 quadrangle. Semiquantitative spectrographic analyses of six marble samples are given in table 1, and chemical analyses of four others are given in table 2.

AMPHIBOLITE

The amphibolite unit is exposed in the eastern part of the metamorphic terrane in the B-3 quadrangle (pl. 1). It is in sharp contact with marble and in gradational contact with gneiss and rocks of the schist-phyllite unit, and it is locally intruded by Tertiary quartz diorite and granodiorite. The unit probably is at least several thousand feet thick. Many of its rocks have been complexly and intricately deformed.

The amphibolite unit consists of abundant amphibolite and schist, subordinate phyllite, and minor gneiss and marble. The amphibolite is dark greenish gray, fine to medium grained, and strongly foliated. It is composed dominantly of hornblende and less abundant plagioclase, chiefly andesine, metamorphic minerals diagnostic of the amphibolite facies (Turner, 1968). Most amphibolite contains minor to fairly abundant chlorite and biotite. Typically, quartz is sparsely distributed or absent, but, exceptionally, it is fairly abundant. The amphibolite contains scattered opaque minerals, chiefly hematite and magnetite, and minor amounts of calcite, epidote, and sphene. The amphibolite probably represents metamorphosed mafic volcanic rocks.

TABLE 2—*Chemical analyses of the marble, in weight percent*[1]
[Analyst, H. M. Hyman]

Sample No.	(Weight percent) 162	163	111	112
SiO_2	0.12	0.13	3.52	2.68
Al_2O_3	.14	.03	.81	.14
Fe_2O_3	0	.07	.10	.34
FeO	.08	.03	.18	.14
MgO	2.02	2.54	3.43	5.87
CaO	53.73	53.09	49.39	47.49
Na_2O	0	0	.07	0
K_2O	.02	.02	.16	.10
H_2O	.06	.08	.06	.10
TiO_2	0	0	.02	.03
MnO	.01	.01	.03	.01
P_2O_5	.01	.01	.01	.02
CO_2	44.07	44.16	42.15	43.12
Calcite	90.6	88.2	78.2	69.6
Dolomite[2]	9.2	11.6	15.8	26.9

[1]Locations of samples: 162 and 163 are contiguous samples of the marble deposit along the spur road 39 miles from Haines on the Haines Highway 112 is from a 75-foot limestone bed 29 miles from Haines and 111 is from a 50-foot limestone bed 35 miles from Haines in cuts along the Haines Highway.
[2]Maximum dolomite that might be formed.

Schist and phyllite of the amphibolite unit are mainly light to dark gray, very fine grained, and markedly foliated. They are rich in quartz and generally contain abundant hornblende and biotite and lesser amounts of chlorite, plagioclase (andesine or oligoclase), muscovite, and garnet. Their minor to rare constituents include calcite and opaque minerals, mainly hematite and magnetite and rarely ilmenite and pyrite. Some schist contains boudins and veinlets of quartz.

Gneiss in the amphibolite unit is delicately folded, fine grained, and contains abundant plagioclase (andesine or oligoclase), quartz, and hornblende. The few small masses of marble that were mapped with the amphibolite unit are similar to those in the marble unit. Semiquantitative spectrographic analyses of five rocks from the amphibolite unit are given in table 1.

SCHIST AND PHYLLITE

The schist and phyllite unit is widespread in the B-4 quadrangle north of the Klehini River and in the northwest part of the quadrangle south of the river (pl. 1). It also underlies less extensive areas in the central and northwestern parts of the B–3 quadrangle (pl. 1). Rocks of the unit are in sharp contact with marble in gradational contact with slate, amphibolite, and diorite, and locally intruded by Cretaceous quartz diorite or granodiorite and compositionally diverse dikes and sills. Quartz-calcite veins and irregular boudinlike quartz pods and lenses are locally abundant. The unit consists of a heterogeneous assemblage of schist with less abundant phyllite and minor to rare marble, slate, impure quartzite, amphibolite, and hornfels. These rocks are structurally complex (fig. 4); they have been multiply deformed and, in some places, isoclinally folded. Mineral associations in the unit indicate greenschist facies, subordinate greenschist-amphibolite transition facies, and, uncommonly, higher metamorphic grades.

Typically, the schist and phyllite are fine or very fine grained. They are cut locally by quartz-calcite veinlets. The schist and phyllite are mainly rich in chlorite, but they include mica-rich, carbonaceous, and calcareous varieties and, rarely, rocks that contain hornblende, garnet, or staurolite. The chloritic schist and phyllite are light to dark greenish gray and consist of abundant to predominant chlorite, generally abundant quartz, fairly abundant muscovite, calcite, and sodium-rich plagioclase, and minor to rare opaque minerals including hematite, magnetite, and pyrite. Some of the chloritic schist and phyllite contain biotite and epidote and traces of sphene or garnet. Most of these rocks probably represent metamorphosed mafic volcanic rocks.

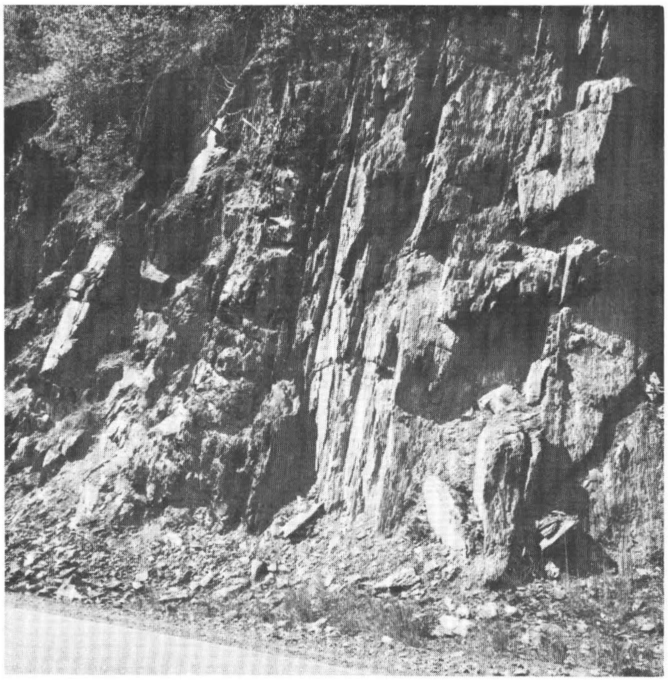


FIGURE 4.—Rocks of the strongly foliated schist and phyllite unit exposed in roadcut west of Muncaster Creek.

The mica-rich schist and phyllite are light to dark gray with brownish-weathered surfaces. They are characterized by abundant muscovite or biotite along with abundant quartz, minor to abundant sodium-rich plagioclase, generally minor but locally abundant chlorite, and sparse magnetite and hematite. Uncommonly, they contain minor amounts of calcite and traces of garnet and apatite. Mica schist near the Cretaceous granitic plutons locally reflects thermal metamorphism and may contain hornblende, garnet, andesine, and rare staurolite. Buff to pale-yellowish-brown altered schistose rocks, composed almost entirely of quartz and sericite, are developed along some of the faults. The mica schists probably are largely metamorphosed derivatives of quartzofeldspathic sedimentary rocks, although some of the lighter colored schists may represent metamorphosed tuffaceous rocks.

The carbonaceous schist is dark gray to black and rich in quartz, and contains carbonaceous material dispersed in extremely small particles or in wisplike layers. Other constituents include muscovite; minor pyrite, hematite, and limonite; and generally some plagioclase, chlorite, and calcite. The carbonaceous schist probably is metamorphosed pelite that was rich in organic material.

The calcareous schist is light gray or light greenish gray and contains abundant calcite, typically in stretched lenticular masses, and fairly abundant to abundant quartz and muscovite. Its subordinate minerals include chlorite, sodic plagioclase, biotite, and opaque minerals. It probably was derived from impure calcareous sedimentary rocks.

Impure quartzite, uncommon in the unit, is light gray and consists largely of interlocking aggregates of strained fine-grained quartz. Its weak foliation is defined mainly by parallel micaceous minerals, chiefly muscovite and uncommonly biotite. It also contains minor amounts of plagioclase, chlorite, hematite, and pyrite. The impure quartzite probably represents metamorphosed quartz-rich sedimentary rocks.

The small amounts of marble, slate, and amphibolite included in the schist and phyllite unit are similar to their separately mapped counterparts; included hornfels is like that described both in the slate unit and in the undivided metamorphic rock unit. Semiquantitative spectrographic analyses of seven rocks from the schist and phyllite unit are given in table 1.

SLATE

The slate unit is widely exposed in the B–4 quadrangle between the Klehini and Tsirku Rivers and extends into the west-central part of the B–3 quadrangle (pl. 1). It is in sharp contact with marble and in gradational contact with the schist and phyllite unit, undivided metamorphic rocks, and diorite; it is cut by both Cretaceous and Tertiary quartz diorite-granodiorite plutons and by altered mafic dikes and sills. The slate unit probably is many thousands of feet thick, but like the other metamorphic units, accurate measurements of thickness cannot be made.

Except for minor amounts of hornfels near some plutons and a few thin marble layers, the unit consists almost entirely of dark-gray, brown-weathering, extremely fine grained slates. Generally, the slate is finely laminated and characterized by pronounced slaty cleavage at a large angle to the lamination. Locally, the cleavage fractures are occupied by numerous quartz veins and veinlets. The slate is rich in quartz and contains abundant or fairly abundant muscovite and, generally, fairly abundant chlorite and sodic plagioclase. Many slates contain pyrite, mainly as scattered pseudocubes, including some with edges as much as 3 cm long, and exceptionally as small framboidal masses. Some of the slate contains widely dispersed fine particles of hematite, magnetite, and carbonaceous material. Some contains minor amounts of calcite, and, rarely, dolomite or illite.

The slates are interpreted as products of greenschist facies regional metamorphism of a thick sequence of pelitic sedimentary rocks.

Slate near the quartz diorite-granodiorite plutons has been thermally metamorphosed and locally converted to hornfels. Generally, the conversion involved recrystallization or partial recrystallization and resulted in larger crystals, the destruction of slaty fabric, and the development of new minerals. The hornfels is rich in quartz and locally contains metacrysts of cordierite or andalusite, biotite, and, uncommonly, hornblende or clinopyroxene. Mineral assemblages in the hornfels mainly indicate Turner's (1968) hornblende-hornfels metamorphic facies.

Semiquantitative spectrographic analyses of four rocks from the slate unit are included in table 1.

UNDIVIDED METAMORPHIC ROCKS

The undivided metamorphic rocks are confined to southern parts of the B–3 and B–4 quadrangles and the west-central part of the B–4 quadrangle (pl. 1). They are mainly thermally metamorphosed and occupy contact aureoles of granitic plutons, grading outward from the plutons into slate or rocks of the schist and phyllite unit. In places the undivided metamorphic rocks are in sharp contact with marble or are cut by dikes. In a few places they are in contact with diorite. The undivided metamorphic rocks are at least several thousand feet thick.

Rocks of the undivided metamorphic unit are largely contact-metamorphosed equivalents of other metamorphic units too recrystallized to subdivide. The unit comprises hornfels, amphibolite, schist, and small amounts of slate, gneiss, and marble. Quartz or quartz-calcite veinlets locally cut many of these rocks. The typical hornfels is greenish gray and is composed of granoblastic assemblages of fine- to medium-grained crystals that are mainly 1–2 mm in diameter. The hornfels contains abundant diopside, less abundant green hornblende, some calcic andesine or labradorite, and minor to trace amounts of quartz, apatite, sphene, magnetite, pyrite, hematite, and ilmenite. Some of the hornfels contains minor retrogressive chlorite and epidote.

The amphibolite is foliated and dark greenish gray with local brown weathered surfaces. Its constituent minerals, dominant hornblende and less abundant calcic andesine, are 1–4 mm long. The amphibolite generally contains small amounts of apatite, magnetite, and ilmenite, and traces of retrograde epidote and sericite.

The schists include fine-grained hornblende-bearing schist and very fine grained spotted schist characterized by andalusite metacrysts. The hornblende-bearing schist is characterized by abundant quartz, hornblende, and andesine. Its less abundant minerals generally include muscovite, chlorite, pyrite, magnetite, and hematite. In addition to the andalusite metacrysts, which are as much as 1.5 mm long, the spotted schist contains abundant quartz, fairly abundant biotite and plagioclase, and widely scattered sericite, magnetite, hematite, and graphite(?).

The slate, marble, and gneiss are similar to rocks described under their respective units except that the gneiss has accessory hornblende. Semiquantitative spectrographic analyses of 11 of the undivided metamorphic rocks are given in table 1.

The undivided metamorphic rocks probably are derived from diverse sedimentary and mafic volcanic rocks that have been contact metamorphosed to grades at least as high as Turner's (1968) hornblende-hornfels facies.

AGE AND CORRELATION

The meager paleontologic evidence for the age of the metamorphic rocks is from the marble unit. G. H. Girty (in Wright, 1904, p. 16) assigned a small collection of brachiopods and crinoids from marble on lower Porcupine Creek to the Carboniferous, probably lower Carboniferous. Subsequently, Girty restudied the collection and on the basis of revised identifications correlated the fauna with that from the Russian

Artinskian of Late Pennsylvanian or Early Permian age (Eakin, 1919, p. 11). Despite a thorough search, no fossils were found along Porcupine Creek during our investigation. Likewise, local prospectors familiar with the environs of Porcupine Creek report that they are unaware of any fossils in the vicinity.

The few fossils we collected in the study area generally are poorly preserved and undiagnostic. Silicified twiglike objects in marble collected from Tahkin Ridge in the B–3 quadrangle were examined by J. T. Dutro, Jr. (written commun., 1970), who reported that they probably are Paleozoic bryozoans. A calcified cast about 4 inches long from the marble unit along the Porcupine Road near the east edge of the B–4 quadrangle resembles the mollusk *Pycinodesma* in size and shape, according to C. W. Merriam (oral commun., 1970). However, the specimen is too poorly preserved for reliable identification. *Pycinodesma* is common in Silurian limestone in the Glacier Bay region approximately 35–50 miles south of the B–3 and B–4 quadrangles (Rossman, 1963, p. K12), and it occurs in Silurian and Devonian rocks elsewhere in southeastern Alaska. Some marbles contain irregular, elongate, cylindrical masses of white calcite a few centimeters long (fig. 3). According to Merriam, some of them resemble *Amphipora,* a Silurian and Devonian stromatoporoid widely distributed in southeastern Alaska. These trace fossils are associated with a few small poorly preserved crinoid columnals. None of the organic remnants are well enough preserved for diagnostic identifications.

Although age data are meager, the metamorphic rocks west of the Chilkat River are definitely Paleozoic. They are inferred to correlate with parts of a widespread sequence of Paleozoic rocks, the Alexander terrane of Berg, Jones, and Richter (1972), that extends from southern southeastern Alaska northward and westward to beyond the Alaska-Yukon boundary. The metamorphic rocks are similar to less metamorphosed sedimentary and volcanic rocks mapped by Lathram, Loney, Condon, and Berg (1959) in the Chilkat Range about 18 miles southeast of the study area. The Chilkat units are locally fossiliferous and range in age from Silurian to Permian.

Lathram and his coworkers (1959) mapped a similar Paleozoic assemblage on Chichagof Island, and other geologists have described occurrences of Paleozoic rocks as far as the southern tip of southeastern Alaska (for example, Buddington and Chapin, 1929; and Eberlein and Churkin, 1970).

The Skagway metamorphic rocks locally adjoin Carboniferous and Permian metamorphic rocks mapped by Watson (1948) along the international boundary at the north edge of the B–4 quadrangle. These rocks, which probably are a continuation of at least some of the Skagway metamorphic rocks, cover large tracts of Watson's (1948) Squaw Creek–Rainy Hollow area in northern British Columbia.

Farther northwest, probably correlative metamorphosed Paleozoic rocks crop out south of the Duke Depression in Yukon Territory. These rocks generally have been assigned to the Kaskawulsh Group and interpreted to range in age from Devonian to Permian. They have been mapped in the Dezadeash map sheet by Kindle (1952), in the Kaskawulsh area by Wheeler (1963), and in the Kluane Lake region by Muller (1967). The Paleozoic metamorphic belt extends westward across the international boundary into the easternmost part of southern Alaska.

INTRUSIVE ROCKS

Intrusive rocks west of the Chilkat River include abundant quartz diorite and granodiorite, less abundant diorite, and dikes and sills of diverse composition. The quartz diorite and granodiorite reflect two stages of plutonism: one during the middle Cretaceous and the other during the middle Tertiary. The dioritic rocks are early phases of the older plutonic stage. The dikes and sills were emplaced over a broad time span and include both the oldest and the youngest intrusive rocks in the quadrangles.

DIORITIC ROCKS

Dioritic rocks crop out over a large area near the headwaters of Porcupine Creek in the B–4 quadrangle and over small areas in the east-central part of the quadrangle (pl. 1). They are bounded by gradational contacts with the Cretaceous quartz diorite-granodiorite, slate, schist and phyllite, and, rarely, undivided metamorphic rocks and are cut by a few dikes and quartz veins.

It is difficult to classify the dioritic rocks because they have characteristics indicative of both metamorphic and igneous origins. The dioritic rocks are fine grained and dark gray with dark-greenish-brown weathered surfaces; they are weakly foliated. Dioritic rocks proximal to the granitic plutons appear massive, but farther from the plutons they are layered. Generally, the layering becomes progressively better developed toward distal margins of the dioritic masses where they merge into rocks of the slate or schist and phyllite units. The dioritic rocks are characterized by abundant amphibole and plagioclase. The amphibole consists of greenish-brown hornblende and less abundant actinolite and tremolite. Some of the hornblende crystals are twinned. The plagioclase is mainly sodic andesine and forms both idiomorphic and xenomorphic crystals including many that are tabular and display twinning characteristic of igneous plagioclase. Other minerals in the dioritic rocks are biotite (locally fairly abundant); minor chlorite, epidote, and opaque minerals, including magnetite, pyrite, ilmenite, and hematite, and rare apatite and sphene. A semiquantitative spectrographic analysis of a diorite is given in table 3.

The dioritic rocks are interpreted to be of hybrid origin and to represent border facies of the Cretaceous granitic plutons that formed by partial assimilation and replacement of older metamorphic rocks at favorable structural levels peripheral to the plutons. A potassium-argon age of 119±4 m.y. (million years) on hornblende from a diorite (H, table 4) is in accord with this interpretation. Similar dioritic rocks have been described by Watson (1948, p. 26, 27) from nearby parts of British Columbia.

QUARTZ DIORITE AND GRANODIORITE

Quartz diorite and granodiorite west of the Chilkat River constitute two petrographically similar groups of rocks of different ages, middle Cretaceous and middle Tertiary. A similar bimodal age distribution is reported for granitic rocks from the northern part of Glacier Bay National Monument (M. A. Lanphere, oral commun., 1972). In places rocks of the two groups are difficult to distinguish. Rocks of the Cretaceous assemblage generally are more mafic and typically have color indices between 20 and 40 in contrast to color indices between 10 and 25 for most of the Tertiary granitic rocks. Likewise, the Cretaceous quartz diorites and granodiorites generally are slightly coarser and more consistently foliated than the Tertiary granitic rocks. However, these criteria are not infallible, and a few rocks from the different groups are virtually identical.

CRETACEOUS QUARTZ DIORITE AND GRANODIORITE

Quartz diorite and granodiorite of Cretaceous age are widely distributed in the B–4 quadrangle where they are exposed in the Takhinsha Mountains, throughout the terrain between the Klehini and Tsirku Rivers, and near the Canadian boundary (pl. 1). The quartz diorite-granodiorite plutons are coextensive with similar batholithic rocks north, south, and west of the quadrangle. The plutonic rocks have intruded a variety of Paleozoic metamorphic rocks and, in places, have produced conspicuous thermal aureoles. Elsewhere they are bounded by steep gradational contacts with dioritic rocks. Contacts between the plutonic and metamorphic rocks typically are sharp, steep, and concordant, but locally they are discordant. A few dikes, mainly of aplite, cut the plutonic rocks.

Foliation typically is well developed near margins of the intrusions where it is best reflected by the parallelism of mafic inclusions and mafic minerals. Elsewhere in the plutons, foliation is generally weakly developed.

Quartz diorite exceeds granodiorite in the exposed plutons by about a 4:1 ratio. The two rock types grade into each other along contacts that are megascopically imperceptible, and detailed petrographic studies are required to estimate their abundance and distribution accurately. The Cretaceous plutonic rocks are hypidiomorphic granular in texture. Their average crystal dimensions are 2–4 mm, but they range from 1 mm in some granodiorite to more than 5 mm in some quartz diorite.

Both the quartz diorite and the granodiorite are characterized by abundant plagioclase and quartz. The plagioclase is oscillatorily zoned andesine and oligoclase and, uncommonly in the granodiorite, some late-stage albite. K-feldspar, including some microcline, is minor to rare in the quartz diorite and fairly abundant in the granodiorite. Both rock types contain fairly abundant hornblende and biotite. Hornblende pleochroism is X and Y, light greenish or yellowish brown; Z, dark greenish brown. Pleochroism in the biotite is X and Y, pale yellow brown; Z, reddish brown. The quartz diorite and granodiorite contain rare apatite, zircon, sphene, magnetite, ilmenite, and pyrite and minor alteration products including chlorite, epidote, sericite, hematite, and clay minerals.

A semiquantitative spectrographic analysis of a Cretaceous quartz diorite is given in table 3 (No. 40). Potassium-argon age determinations on hornblende and biotite from two samples of the quartz diorite (E and F) and one of the granodiorite (G) given in table 4 indicate ages between 105±3 and 111±3 m.y. The granodiorite and quartz diorite are coextensive with similar Mesozoic granitic rocks described by Watson (1948, p. 28, 29) from the nearby Squaw Creek–Rainy Hollow area of British Columbia.

TERTIARY QUARTZ DIORITE AND GRANODIORITE

Tertiary quartz diorite and granodiorite form composite plutons that are abundant in the southern part of the B–3 quadrangle and less abundant in eastern and southeastern parts of the B–4 quadrangle (pl. 1). The plutons have intruded several of the Paleozoic units and in places have produced thermal aureoles. The intrusive contacts are steep and mostly concordant, but locally they are markedly discordant. The quartz diorite and granodiorite are cut by dikes, chiefly aplite and diabase, and by veinlets rich in quartz and calcite, and, rarely, epidote or prehnite.

Granitic rocks in marginal zones of the plutons

TABLE 3.—*Semiquantitative spectrographic analyses of the intrusive rocks*

[Analyst, K. J. Curry. Fe, Mg, Ca, Ti are reported in percent. All other elements are reported in parts per million (ppm) to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1 and so forth. N=not detected; L=detected but below limit of determination; G=greater than amount shown in parentheses, precise amount not determined. The following elements were also looked for but not found during the spectrographic analyses: As, Au, Bi, Cd, Sb, and Sn; exception 20 ppm in 69AMk-13A. All samples yielded negative results when analyzed for Au to atomic absorption methods]

Map No.[1]	Sample No.	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Name or description
		Percent				Parts per million (ppm)																			
	Quartz diorite and granodiorite[2]																								
35	69AGk-531	15	7	5	0.7	1,500	N	15	300	N	70	300	100	L	L	10	100	L	30	300	300	30	N	70	Gneissic hornblende quartz diorite.
36	69ABd-513B	3	1	1.5	.3	300	N	L	700	1	10	15	5	N	L	10	15	L	5	200	50	15	N	200	Biotite quartz diorite.
37	69ABd-515B	3	1	1.5	.5	500	N	L	500	1.5	15	15	20	N	L	10	15	L	7	300	70	10	N	100	Do.
38	70AMk-3C	7	3	2	.5	700	N	L	300	L	20	20	50	N	N	L	30	70	15	500	200	15	N	300	Hornblende-biotite quartz diorite.
39	70AMk-5D	10	3	3	1	1,000	N	L	500	L	30	150	100	N	L	10	50	15	30	500	300	20	N	200	Biotite granodiorite.
40	70AWk-2A	15	3	3	1	2,000	N	10	700	N	30	150	100	N	L	L	70	15	30	500	300	15	N	50	Hornblende-biotite quartz diorite.
41	70AWk-4A	7	2	1.5	.3	1,500	N	L	500	1	15	20	70	N	N	10	15	15	15	300	150	15	N	300	Gneissic quartz diorite.
42	70AWk-6A	3	1.5	.7	.3	700	N	N	700	1.5	L	10	30	N	N	L	L	15	10	300	70	10	N	150	Biotite-hornblende granodiorite.
	Diorite																								
43	70AMk-8C	15	5	15	1	200	L	L	300	N	30	150	70	N	L	L	100	100	70	700	700	50	N	30	Hornblende diorite.
	Intermediate and mafic dikes and sills																								
44	69AMk-3B-2	15	5	7	0.7	1,500	N	L	150	N	70	700	50	20	L	10	150	N	30	500	300	15	200	70	Altered mafic dike.
45	69AMk-25B-2	7	3	3	.5	1,000	N	300	300	N	20	150	15	N	N	10	15	N	20	L	150	10	N	50	Altered dike.
46	69AMk-27B-1	7	5	1.5	.3	700	7	N	2,000	N	20	700	10	N	N	10	100	300	20	150	150	10	L	30	Do.
47	69AMk-28D-1	15	10	7	.3	1,500	L	10	150	N	70	3,000	70	N	N	10	1,000	30	30	300	300	10	N	30	Altered mafic dike.
48	69AMk-50A-2	15	5	1.5	.7	1,500	N	20	700	1	50	70	50	L	L	10	5	L	30	500	300	20	700	70	Pyrite-bearing altered sill.
49	69AGk-538A	15	5	5	.7	700	N	10	150	L	70	300	70	N	N	10	150	N	30	200	200	30	L	70	Porphyritic basalt (?).
50	69AGk-539A	10	3	3	.5	500	N	15	700	1	50	30	50	N	N	10	20	10	20	700	200	10	L	70	Pyrite-bearing altered dike.
51	69AGk-542B	15	7	5	.7	1,000	N	L	100	N	70	300	70	N	N	10	150	N	30	150	200	20	L	70	Altered basaltic sill.
52	70AMk-12A	7	3	10	.3	3,000	L	15	300	N	150	70	150	N	5	10	70	70	70	L	500	20	L	50	Pyrite-bearing altered dike.
53	70AWk-1C	15	5	5	.7	1,500	N	L	50	N	50	300	300	N	L	L	150	15	70	200	500	20	N	70	Altered mafic dike.
54	70AWk-9B-2	10	3	3	.7	1,000	N	20	2,000	1.5	30	70	150	L	5	10	50	15	30	700	500	20	300	100	Pyritiferous altered dike.
55	70AWk-9B-3	10	7	3	.3	1,500	N	L	150	L	30	200	70	N	L	L	70	15	30	300	300	15	N	30	Altered mafic dike.
	Diabase dikes and sills																								
56	70AMk-5A-1	15	7	7	G(1)	2,000	N	10	300	L	70	200	150	N	L	L	150	20	50	500	300	50	N	200	Diabase.
57	70AWk-13A-1	15	5	5	G(1)	2,000	N	10	300	2	30	10	150	L	L	10	7	15	70	300	500	70	200	300	Do.
	Quartz diorite and granodiorite dikes and sills																								
58	69AMk-7D-1	15	1.5	5	0.7	1,500	N	L	200	N	100	150	100	N	L	L	100	L	70	150	500	30	L	70	Hornblende quartz diorite dike.
59	69AMk-8A-1	15	5	2	.7	700	N	L	150	N	70	200	50	N	L	L	100	N	30	L	300	20	L	50	Altered quartz diorite dike.
	Leucocratic dikes and sills																								
60	69AMk-5A	7	5	.15	0.2	300	L	15	2,000	3	N	L	15	70	5	150	10	L	L	N	15	50	L	700	Fragmented aplite in fault zone—chip sample 10 ft. long.[3]
60A	69AMk-13A	2	.7	.15	.15	100	N	10	1,500	3	L	10	10	300	5	500	L	N	L	N	30	200	N	G(10,000)	Fragmented pegmatite in fault zone—chip sample 12 ft. long.[3]
61	70AMk-3D-2	1.5	1.5	.7	.15	300	N	N	300	L	L	L	30	N	N	N	L	30	N	1,000	30	L	N	150	Alaskite.
62	70AWk-9A-1	3	1.5	.7	.3	700	N	15	200	L	L	15	70	N	L	L	20	30	7	500	70	10	N	150	Do.
		Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	
Limit of determination		0.05	.01	.01	.001	10	.5	10	10	1	5	2	5	20	2	10	5	10	5	20	10	10	200	10	

[1]Sample locations are shown by the circled map numbers on the geologic map (pl. 1).
[2]Except for No. 40, which is from a Cretaceous pluton, the samples are of Tertiary quartz diorites and granodiorites.
[3]Sample intervals for the chip samples are approximately 6 inches.

TABLE 4.—*Potassium-argon age determinations from intrusive rocks west of the Chilkat River*[1]

[Potassium measurements were done by flame photometry using a lithium internal standard. Argon measurements were made using standard techniques of isotope dilution. Ages were calculated using the following constants: $\lambda_e = 0.585 \times 10^{-10}$ year^{-1}
$\lambda_b = 4.72 \times 10^{-10}$ year^{-1}. Abundance ratio: $K^{40}/K = 1.19 \times 10^{-4}$ atom percent. Potassium measurements: Lois Schlocker. Argon measurements and age calculation: M. A. Lanphere, Jarel Von Essen]

Location letter	Field No.	Mineral	Percent K_2O	Ar^{40}_{rad} (moles/g)	Ar^{40}_{total} / Ar^{40}_{rad}	Calculated age (millions of years)
Tertiary quartz diorite and granodiorite						
A	70AMk–3A	Biotite	8.69	2.928×10^{-10}	0.20	22.7±1
B	70AMk–3C	Hornblende	.480	2.360×10^{-11}	.35	33.0±1
C	70AWk–5D	Biotite	7.13	3.246×10^{-10}	.69	30.6±1
D	70AWk–6A	Biotite	7.225	3.147×10^{-10}	.60	29.3±1
Cretaceous quartz diorite and granodiorite						
E	70AWk–2A	Biotite	8.87	1.48×10^{-9}	0.93	110 ±3
		Hornblende	.934	1.574×10^{-10}	.87	111 ±3
F	70AMk–8A–2	Biotite	8.30	1.363×10^{-9}	.85	108 ±3
		Hornblende	.85	1.374×10^{-10}	.72	105 ±3
G	70AMk–14A–2	Biotite	7.715	1.306×10^{-9}	.91	111 ±3
Dioritic rocks						
H	70AMk–10B	Hornblende	0.417	7.587×10^{-11}	0.66	119 ±4

[1]Sample locations are shown by their location letters in plate 1.

generally are strongly foliated, but elsewhere they are weakly foliated or unfoliated. The foliation is manifested by alined mafic inclusions and by markedly parallel hornblende and biotite. Near their northernmost exposures west of Chilkat Lake and at a few other localities, the granitic rocks are conspicuously gneissic and are characterized by alternating felsic and mafic layers. Near some faults the quartz diorite and granodiorite have been cataclastically deformed and contain aggregates of fragmented and broken larger crystals in a matrix of intensely granulated very fine grained material. Such rocks, which have a pseudoporphyritic appearance, are well developed in outcrops proximal to the Chilkat River fault east of Chilkat Lake.

Most of the quartz diorite and granodiorite are medium grained with average crystal dimensions generally between 1 and 3 mm, but some are finer grained. They are dominantly hypidiomorphic granular, but they contain a few leucocratic variants that are xenomorphic granular.

Most large exposures of the plutons are composites of quartz diorite and granodiorite with quartz diorite in excess by about a 3:1 ratio. Typically, the two rock types grade into each other along contacts that are imperceptible in the field. A few of the smaller outcrops are essentially monolithologic. The quartz diorites and granodiorites are mineralogically similar to their Cretaceous counterparts. They contain abundant plagioclase, mainly oscillatorily zoned andesine and oligoclase, abundant or fairly abundant quartz, and minor to fairly abundant K-feldspar. Their fairly abundant characteristic accessory minerals include biotite whose pleochroism is X and Y, light brown, and Z, dark brown, and hornblende whose pleochroism is X and Y, yellow brown, and Z, dark greenish brown. Rare to minor accessory minerals in the quartz diorite and granodiorite consist of apatite, sphene, zircon, and opaque minerals, including magnetite, ilmenite, and pyrite. The alteration products include fairly abundant or minor chlorite and minor or rare epidote, hematite, sericite, calcite, and clay minerals.

Seven semiquantitative spectrographic analyses of rocks from the Tertiary plutons are given in table 3. These include five quartz diorites (Nos. 35, 36, 37, 38, and 41) and two granodiorites (Nos. 39 and 42). Four isotopic age determinations on the Tertiary granitic rocks (table 4, A, B, C, D) indicate ages between 22.7±1 and 33.0±1 m.y. The youngest age determination is probably invalid because of argon loss in the deformed sampled rock, but the other age determinations (29.3±1 to 33.0±1 m.y.) are probably valid. The Tertiary granitic rocks extend southward into unmapped parts of the Skagway A–3 quadrangle and probably also correlate with Tertiary granitic rocks in the northern part of Glacier Bay National Monument.

DIKES AND SILLS

Dikes and sills, although not shown on the geologic map (pl. 1), are widespread and locally abundant in the B–3 and B–4 quadrangles west of the Chilkat River. They are compositionally diverse and represent several ages of intrusion. Considered as a group, they cut all other consolidated rocks; however, certain types are restricted to the metamorphic rocks, and others occur preferentially in specific host rocks. The dikes and sills range in width from less than a foot to about 50 feet. They rarely can be traced for more than a few hundred feet, largely because of concealment by overburden.

The dikes and sills include mafic and intermediate rocks, diabase, quartz diorite-granodiorite, and leucocratic rocks. Mafic and intermediate dikes and sills are confined to the metamorphic terranes and are most abundant in the slate and schist and phyllite units. They typically are strongly altered fine-grained rocks that are medium gray with light-greenish-gray or light-brown weathered surfaces. Most are foliated. Generally, their primary textures have been obliterated, but a few retain poorly preserved porphyritic textures. Many are cut by quartz or calcite veinlets. Most mafic and intermediate dikes and sills are dominated by alteration products, chiefly calcite and chlorite. Generally, they also contain fairly abundant to abundant quartz, fairly abundant altered plagioclase, and minor amounts of pyrite, hematite, sericite, and epidote or clinozoisite. Some dikes and sills contain fairly abundant amphibole (mainly actinolite), fairly abundant biotite, and minor K-feldspar. Pyrite, in pseudocubes with edges as much as 5 mm long, locally is fairly abundant in dikes that cut slate. A few mafic and intermediate dikes are only slightly altered. These consist of fine-grained weakly porphyritic assemblages of andesine and hornblende with minor amounts of biotite, pyrite, and alteration products. These dikes are probably andesite or microdiorite. Their phenocrysts consist of embayed and altered plagioclase crystals, generally a few millimeters long but exceptionally as much as a centimeter long, in an intensely altered fine-grained groundmass. The few phenocrysts that could be identified consist of andesine with cores of sodic labradorite. Some sill-like masses in the schist and phyllite unit may be flows, but we interpret them as sills because they are lithologically similar to nearby dikes. Semiquantitative spectrographic analyses of 12 samples from intermediate and mafic dikes and sills are given in table 3.

The diabase dikes are dark greenish gray, brown weathering, and fine grained. They cut the metamorphic rocks and the Cretaceous and Tertiary quartz diorite-granodiorite. The diabase is unfoliated and not so strongly altered as the typical mafic and intermediate dikes and sills. It consists of subophitic aggregates of labradorite and clinopyroxene, probably augite. A few diabases contain fairly abundant or abundant hornblende that has replaced clinopyroxene. The minor to rare constituents of the diabase, which are mainly alteration products, include magnetite, hematite, pyrite, biotite, chlorite, calcite, sphene, sericite, and epidote. Some diabase contains sparsely distributed calcite-chlorite amygdules. Semiquantitative spectrographic analyses of samples from two diabase dikes are given in table 3.

A few quartz diorite and granodiorite dikes and sills penetrate the metamorphic rocks. These intrusions are interpreted as apophyses of the Tertiary quartz diorite-granodiorite plutons, which they resemble mineralogically. Generally, however, they are finer grained than the plutons, and their plagioclase is strongly zoned andesine-calcic oligoclase with oscillatory extinction. A few contain myrmekitic intergrowths. Some of the dikes and sills are porphyritic with plagioclase phenocrysts set in fine-grained groundmasses. Many of the quartz diorite and granodiorite dikes and sills are cut by quartz veinlets. Semiquantitative spectrographic analyses of two samples from quartz diorite dikes are given in table 3.

The leucocratic dikes and sills consist of aplite, alaskite, and pegmatite. These rocks mainly form dikes in the quartz diorite-granodiorite plutons, but they locally cut the metamorphic rocks, particularly the schist and phyllite. The aplite is fine grained with xenomorphic granular texture and contains abundant quartz and plagioclase (sodic andesine or calcic oligoclase), fairly abundant K-feldspar, and minor to trace amounts of apatite, opaque minerals, chlorite, sericite, and biotite. The alaskite is medium grained and similar to the aplite in composition, but typically it is hypidiomorphic granular in texture. Some dikes contain both aplitic and alaskitic phases. Some aplite and alaskite has been cataclastically deformed and is marked by zones of broken and milled crystals.

Pegmatite is poorly developed and sparsely distributed in the quadrangles. It forms small pods and blebs within some aplite and alaskite bodies and a few small dikes and lenses, mainly in the schist-phyllite unit. Only a few of the pegmatites display the abrupt variance in size of minerals that is typical of pegmatite. Most are dominated by quartz and contain only subordinate amounts of K-feldspar and muscovite. Some pegmatite is not clearly distinguishable from quartz-rich lenses, pods, and veins that are also fairly abundant in the schist and phyllite terrane. Semiquantitative spectrographic analyses of four samples from leucocratic rocks are given in table 3. The single analysis of a pegmatite indicates a characteristic suite of minor elements, chiefly zirconium, niobium, and lanthanum.

The ages of the dikes and sills are largely inferred from field relations. Apparently, the dikes and sills were emplaced over a broad time span. The mafic and intermediate varieties include foliated rocks that antedate the regional metamorphism and unfoliated postmetamorphic rocks. Consequently, they probably include both Paleozoic and Mesozoic rocks. The quartz diorite-granodiorite dikes and sills are probably apophyses of the Tertiary granitic plutons. The leucocratic bodies probably evolved during late stages of both the Cretaceous and Tertiary plutonic episodes and are considered to be slightly younger than their associated granitic rocks.

The diabase dikes are probably the youngest intrusive rocks in the region, although they were not observed in contact with the leucocratic rocks. The diabase probably was derived from a deep-seated source during the late Tertiary.

ROCKS EAST OF THE CHILKAT RIVER

Rocks in the B–3 quadrangle east of the Chilkat River consist of a sequence of intrusive and metavolcanic rocks that were studied by Robertson (1956) during his investigation of the Klukwan iron deposits. They include altered mafic lava flows (herein termed metabasalt), gabbro and diorite, pyroxenite, quartz diorite, leucogranodiorite, and mafic and felsic dikes. The dikes have not been distinguished on the accompanying geologic map (pl. 1). The rocks document two stages of igneous activity: a middle-Cretaceous stage characterized by metabasalt, gabbro-diorite, and pyroxenite, and a Late Cretaceous and early Tertiary plutonic episode dominated by the major granitic phases of the Coast Range batholith.

METABASALT

Metabasalt is exposed in a northwest-trending belt as much as half a mile wide along the base of the Takshanuk Mountains bordering the Chilkat River (pl. 1) where it is in gradational contact with the gabbro-diorite complex. Most of the metabasalt lacks primary structural features, but discrete layering, probably relicts of flows, is discernible in a few outcrops. No pillow structures and only a few pyroclastic rocks were recognized in the metabasalt sequence. Most of the metabasalt is characterized by near-vertical foliation that strikes northwestward approximately parallel to the Chilkat River fault and the Takshanuk Mountains. Minor upmapped faults with similar orientations locally cut the metabasalt.

The few metabasalts that are fresh enough for diagnostic petrographic studies are mainly andesitic, but the name metabasalt is retained to conform with Robertson's (1956) previous usage. However, additional analytical information probably will necessitate a change in nomenclature.

The metabasalt is typically a dark-greenish-gray fine-grained rock that, where only slightly altered, retains its primary intergranular and intersertal textures. However, alteration generally has obliterated original textural and structural features. Some of the metabasalts are amygdaloidal and contain widely scattered amygdules or feldspar or epidote.

The metabasalt is divisible into three main phases: (1) Slightly altered basalt, (2) amphibole basalt, and (3) epidote-chlorite basalt. The interphase contacts that are seen are irregularly gradational, but most are masked by vegetation. The amphibole basalt is by far the most abundant. Modal compositions of the metabasalt estimated from petrographic studies by Robertson (1956) are given in table 5.

The slightly altered basalt consists of abundant augite and plagioclase, chiefly andesine, fairly abundant chlorite, and minor clinozoisite and opaque minerals, chiefly magnetite. Small halos of leucoxene rim some of the opaque minerals.

The amphibole basalt is characterized by abundant andesine and hornblende and subordinate actinolite (table 5). The hornblende is pleochroic in shades of

TABLE 5.—*Estimated modes of the metabasalt, in volume percent*

	Slightly altered basalt[1]		Amphibole basalt[2]		Epidote-chlorite basalt[1]	
	Range	Estimated median	Range	Estimated median	Range	Estimated median
Augite	15–40	34	0–15	<1	....	....
Amphibole, chiefly hornblende	....	....	30–70	47	0– 5	<1
Chlorite	3–12	6	0– 5	<1	0–20	12
Biotite	....	....	0–15	<1	....	....
Clinozoisite	0– 3	<1	0–15	7	2–40	17
Epidote	....	....	....	....	0–45	18
Plagioclase	45–75	60	10–70	45	20–80	50
Quartz	....	....	0–10	<1	0– 5	3
Magnetite and ilmenite	0– 3	<1	0–10	1	....	....

[1]Four thin sections studied.
[2]Sixteen thin sections studied.

bluish or brownish green, and the actinolite in shades of light green. Some of the amphibole is arranged in radial divergent aggregates. A few relicts of augite that have been largely replaced by amphiboles are preserved. Other subordinate minerals in the amphibole basalt include quartz, clinozoisite, biotite, chlorite, sphene, pyrite, magnetite, ilmenite, leucoxene, and hematite.

The epidote-chlorite basalt is largely confined to dikes, but it also forms a few irregular masses. It is mainly composed of plagioclase (chiefly sodic andesine), epidote, chlorite, and clinozoisite, but it also contains minor amounts of other minerals (table 5).

GABBRO AND DIORITE

A complex of altered gabbro and diorite occupies an extensive northwest-trending belt, as much as 2 miles wide, along the southwest flank of the Takshanuk Mountains (pl. 1). It is in gradational contact with the metabasalt and quartz diorite and is intruded by pyroxenite along sharp, steep contacts that strike mainly northwestward and generally transect foliation of the gabbroic rocks. According to Taylor and Noble (1969, p. 222), clearly defined pyroxenite dikes cut the gabbroic rocks near their contacts with the main pyroxenite mass, and a small septum of highly metamorphosed gabbro is enclosed in the pyroxenite body. Both the gabbroic rocks and the pyroxenite are cut by en echelon anorthositic dikes that typically are largely altered to clinozoisite. Contact relations between the gabbro and diorite complex and the leucogranodiorite are obscure. The gabbro and diorite generally displays steep northeastward or vertically dipping foliation that strikes northwestward concordant with the regional structural and topographic grain.

Rocks of the gabbro and diorite complex exhibit various degrees of alteration. The alteration is most intense near the pyroxenite where the gabbroic rocks are strongly epidotized and saussuritized.

The gabbro and diorite are light to medium greenish gray, fine or medium grained, and mainly equigranular. They consist of abundant to predominant plagioclase, abundant or fairly abundant hornblende, and an array of less abundant constituents including epidote, chlorite, biotite, augite, sericite, clinozoisite, opaque minerals, sphene, and, rarely, quartz and K-feldspar (table 6). The plagioclase consists of andesine and labradorite. Some rocks of the gabbro and diorite complex contain scattered clotlike mafic aggregates as much as 5 mm wide. Alteration products are abundant and generally best developed near the edges of crystals. The dominant alteration products, epidote, clinozoisite, and chlorite, have formed mainly at the expense of hornblende. Sericite locally has formed from some of the plagioclase.

PYROXENITE

Pyroxenite forms an irregular outcrop approximately a mile wide and 4 miles long, high on the southwest flank of the Takshanuk Mountains northeast of Klukwan, and several nearby small outcrops (pl. 1). The pyroxenite is well exposed throughout vertical extents of as much as 3,000 feet. It intrudes rocks of the gabbro and diorite complex along sharp, irregular contacts that mainly dip steeply northeastward and generally crosscut foliation of the invaded rocks. Gabbroic rocks near the pyroxenite have been intensely altered and metasomatized. The largest pyroxenite body encloses two septa of metamorphic rocks, one a relict of gabbro and the other of metasedimentary rocks. Locally, the pyroxenite is transected by altered anorthositic dikes that are arranged in en echelon patterns. A few faults with small displacements cut the pyroxenite. According to Robertson (1956, p. 13), a similar but smaller pyroxenite body near Haines surrounds diorite and is bounded on its perimeter by metabasalt.

The pyroxenite is dark green to black, medium or coarse grained, and mainly xenomorphic granular in texture. From a distance, the pyroxenite that forms bold outcrops at higher altitudes appears layered, but layering is not apparent when the outcrops are examined at close range. Layering is also suggested by the distribution of magnetic minerals (Robertson, 1956, p. 13), and more detailed investigations may reveal additional evidence of cryptic layering.

The pyroxenite consists dominantly of diopsidic augite with accompanying opaque minerals (mainly titaniferous magnetite), hornblende, and minor olivine, enstatite, actinolite, epidote, biotite, spinel, apatite, and chlorite. Locally, it contains trace amounts of hematite, chalcopyrite, pyrite, pyrrhotite, and leucoxene. Most of the pyroxenite contains sufficient hornblende to be called hornblende pyroxenite. The hornblende probably is a deuteric alteration product of the pyroxene. The titaniferous magnetite is rather uniformly distributed throughout the pyroxenite and also forms segregations as much as a foot thick and several feet long. Taylor and Noble (1969, p. 222) estimate that titaniferous magnetite constitutes 15–20 percent of the pyroxenite. Much of the magnetite shows an idiomorphic relationship with hornblende. Ilmenite and green spinel occur as exsolution products along lamellae in some of the magnetite and as small crystals surrounded by granular magnetite.

TABLE 6.—*Estimated modes of the gabbro and diorite and quartz diorite, in volume percent*[1]

	Gabbro and diorite		Quartz diorite	
	Range	Estimated median	Range	Estimated median
Augite	0– 5	1	0– 3	<1
Amphibole (mainly hornblende)	3–35	25	0–20	5
Chlorite	0– 7	2	0– 1	<1
Biotite	0–10	1	0–15	2
Muscovite	0–20	<1	....	....
Clinozoisite	0–10	1	0– 4	1
Epidote	1–20	4	....	....
K-feldspar	0– 3	<1	0– 5	2
Plagioclase	23–70	65	20–80	70
Quartz	0– 3	....	5–35	20
Magnetite and ilmenite	0– 1	1	0– 2	1
Sphene	0– 1	<1	0–1	<1
Apatite	....	....	0–1	<1

[1]Thirteen thin sections studied.

QUARTZ DIORITE

Quartz diorite underlies a large area that extends from near the crest of the Takshanuk Mountains to beyond the eastern and northern boundaries of the B–3 quadrangle (pl. 1). It constitutes a major phase of the Coast Range batholith and probably extends well beyond the confines of the quadrangle, particularly to the northwest and southeast parallel to the trend of the batholith. The western margin of the quartz diorite is mainly a steep gradational contact with diorite that strikes irregularly northwestward. Locally, near the northern extremity of the quadrangle, the quartz diorite is bounded on the west by leucogranodiorite along an ill-defined, probably gradational contact.

The quartz diorite is foliated and has several compositional and textural variants. Locally it contains elongate tabular schlierenlike mafic inclusions and small septa of metamorphic rocks. Most of the quartz diorite has been deformed, as indicated by granulation and widespread strained quartz. The quartz diorite ranges from a mafic variety rich in hornblende or biotite to a type that contains sparsely distributed mafic minerals and compositionally approaches granodiorite. Generally, the quartz diorite is medium grained and hypidiomorphic granular in texture, but it also includes finer and coarser phases and some gneissic and porphyritic rocks. Myrmekitic intergrowths occur locally. The typical quartz diorite contains predominant plagioclase, fairly abundant quartz and hornblende, minor biotite and K-feldspar, and rare augite, chlorite, clinozoisite, opaque minerals, sphene, and apatite (table 6). Most of the plagioclase is oscillatorily zoned andesine and calcic oligoclase.

LEUCOGRANODIORITE

Leucogranodiorite underlies a small area near the northern boundary of the B–3 quadrangle and extends into the C–3 quadrangle (pl. 1). It probably represents a late stage of the Coast Range batholith and, with the possible exception of some dikes, is the youngest intrusive rock east of the Chilkat River. It is bounded by obscure, probably gradational and locally discordant contacts with quartz diorite and diorite. Foliation in the leucogranodiorite, which generally is poorly developed, conforms to the regional northwestward trend. The leucogranodiorite locally contains intensely granulated zones and bent or fragmented crystals that suggest a protoclastic or semisolid mode of emplacement. It is an uncommon rock type with alkalic affinities. Typically, it is medium grained with relict hypidiomorphic- or xenomorphic-granular textures that are partly obliterated by late-stage albite flooding and granulation. It is locally porphyritic and contains widely scattered large microcline phenocrysts set in a medium-grained groundmass. Some of these coarser phases are granite in composition. Most leucogranodiorite is characterized by crystals of quartz, oligoclase, and lesser amounts of strongly embayed microcline that are partly engulfed by late-stage albite. The leucogranodiorite contains sparsely distributed epidote, sphene, biotite, and amphibole and pyroxene that probably are rich in sodium, and rare to trace amounts of apatite, magnetite, sericite, chlorite, zircon, and tremolite.

DIKES

Besides the previously described pyroxenite dikes, felsic and mafic dikes are sparsely distributed in the Takshanuk Mountains. These dikes have not been mapped or studied in detail. The felsic dikes, which are as much as 2 feet thick, mainly cut the quartz diorite. Most are fine-grained aplites and alaskites that are rich in sodic plagioclase and quartz and contain small amounts of mafic minerals.

Mafic dikes consist of en echelon anorthositic dikes that cut the gabbro and diorite and pyroxenite and of epidote-chlorite basalt dikes within the metabasalt unit. The anorthositic dikes are generally highly altered and rich in clinozoisite. According to Taylor and Noble (1969, p. 222), these dikes are similar to the late-stage gabbroic pegmatites associated with most southeastern Alaska complexes of mafic and ultramafic rocks except that they contain more plagioclase. The basalt dikes contain andesine and an array of alteration products, chiefly epidote, chlorite, and clinozoisite.

ORIGIN, AGE, AND CORRELATION

Igneous rocks east of the Chilkat River constitute a dichotomous sequence that includes an older group or mafic and ultramafic rocks consisting of metabasalt, pyroxenite, and rocks of the gabbro and diorite complex, and a younger group consisting mainly of granitic rocks of the Coast Range batholith. The mafic and ultramafic rocks occur together and probably have a common origin. A plausible explanation purports that the pyroxenite and most of the gabbro and diorite are products of crystallization in magma chambers beneath a volcano, and that the basaltic rocks are their related effusive phases. Irvine (1967, p. 96) has postulated that rocks of the Duke Island ultramafic complex developed in a reservoir beneath a volcano, and other geologists have expanded this concept and applied it to many of the southeastern Alaska ultramafic-mafic irruptive rocks and nearby volcanic assemblages (H. C. Berg and D. L. Jones, oral commun., 1972). The validity of such a concept for the Klukwan mafic and ultramafic rocks is strengthened by the evidence for their intrusive emplacement and by indications that the pyroxenite and at least some of the gabbroic rocks largely originated by cumulus magmatic processes similar to those well documented for other southeastern Alaska mafic and ultramafic assemblages (Irvine, 1967, Taylor, 1967, and Taylor and Noble, 1969). Furthermore, the close spatial relation between the mafic and ultramafic rocks suggests a common ancestry.

The concept is weakened by the difference in metamorphic effects between the pyroxenite and the mafic rocks, particularly between the well-developed foliation in most of the mafic rocks and the inconspicuous foliation in the pyroxenite, and by the distribution of the gabbro and diorite, which is rather extensive for confinement beneath a volcano.

Taylor and Noble (1969, p. 223, 224) present compelling evidence that differentiation in place by fractional crystallization of gabbroic magma does not adequately explain the origin of the southeastern Alaska hornblende pyroxenites. They conclude that the ultramafic and the mafic rocks formed from separate magma phases that conceivably are related and differentiated at depth.

The metavolcanic rocks are part of a late Mesozoic volcanic and sedimentary sequence that is widespread in southeastern Alaska. Berg, Jones, and Richter (1972) interpret this sequence as remnants of a Mesozoic island arc that extended at least from southernmost southeastern Alaska northwestward through Canada into east-central Alaska. Sedimentary rocks in the inferred arc assemblage locally contain plant and marine invertebrate fossils indicative of Late Jurassic and Early Cretaceous ages.

The age of the gabbro and diorite complex is not well known. The complex as mapped probably includes some pyroxenite and metabasalt and some younger rocks associated with early stages of the Coast Range batholith. Some of the older diorites and gabbros appear to be closely associated with the metabasalt, and they may be coeval with parts of that volcanic sequence. Rocks of the gabbro and diorite complex that surround the pyroxenite mass are clearly older than the pyroxenite. The generally gradational contacts between the gabbro and diorite complex and the quartz diorite of the Coast Range batholith and the locally mafic border zone of the batholith suggest that parts of the gabbro and diorite complex are genetically related to the batholithic rocks. Mafic rocks near Haines, dated as 109 m.y. old on the basis of potassium-argon determinations on hornblende (M. A. Lanphere, written commun., 1970), probably are congeners of the older gabbro and diorite. According to Knopf (1911, p. 25), diorite in the Berners Bay region, about 45 miles southeast of the B–3 quadrangle (fig. 1), is younger than the main rocks of the batholith, but no diorite or gabbro younger than the main batholithic rocks was found in the B–3 quadrangle. Dioritic and gabbroic rocks, including some that are believed synchronous with similar rocks in the B–3 quadrangle, are widely distributed in southeastern Alaska and occur in nearby British Columbia northwest of the B–3 quadrangle.

The pyroxenite is similar to the numerous ultramafic masses that crop out near the western margin of the Coast Range batholith throughout southeastern Alaska (Taylor and Noble, 1969, p. 210). Radiometric dating of many of these rocks (Lanphere and Eberlein, 1965, p. 1559, 1560) indicates broadly synchronous emplacement during the middle part of the Cretaceous Period. Potassium-argon determinations on hornblende from drill cores from the pyroxenite mass near Klukwan yielded ages of 96 and 99 m.y. which may be too young because of alteration (M. A. Lanphere, written commun., 1970). Correlative pyroxenite from exposures at Battery Point near Haines gave potassium-argon ages of 109 m.y. on hornblende and 108 m.y. on biotite, which Lanphere (written commun., 1970) believes more accurately reflect the age of the pyroxenite.

Quartz diorite of the Coast Range batholith is abundant in the B–3 quadrangle. It is inferred to be a product of large-scale magmatic processes operative at moderate depths during the Late Cretaceous and early Tertiary. The Coast Range quartz diorite closest to the B–3 quadrangle that has been radiometrically dated was from Lutak Cove near Haines. Lanphere (written commun., 1970), on the basis of potassium-argon determinations on hornblende, dated this quartz diorite as 69 m.y. old. Potassium-argon determinations on biotite from batholithic rocks northeast of Skagway indicate ages between 54 and 70 m.y. (Douglas, 1970, map 1256A). The quartz diorite and associated batholithic rocks thus appear to have crystallized during a lengthy timespan, and additional radiometric dating will probably show a still larger spread of Late Cretaceous and early Tertiary ages.

The leucogranodiorite is early Tertiary in age and is interpreted as a late-stage phase of the batholith. Potassium-argon age determinations on leucogranodiorite from the southern part of the Skagway C–3 quadrangle that is coextensive with the B–3 leucogranodiorite indicate ages of 64.2 ± 2 m.y. on hornblende and 55.5 ± 2 m.y. on biotite (M. A. Lanphere and Jarel Von Essen, written commun., 1972). The pyroxenite dikes and the epidote-chlorite basalt dikes probably are roughly contemporaneous with the main pyroxenite and basalt. The anorthositic dikes are inferred to have crystallized from a late-stage residuum of the pyroxenite magma after the emplacement of the pyroxenite (Taylor and Noble, 1969, p. 223). Felsic dikes associated with the batholith are probably late-stage magmatic products that consolidated in the early Tertiary.

SURFICIAL DEPOSITS

The widespread and abundant surficial deposits in the B–3 and B–4 quadrangles were only briefly examined during our investigations. They include a variety of unconsolidated or poorly consolidated materials mainly of glacial or fluvioglacial origin. They are best developed in the lowlands along and contiguous to broad river valleys, but they are widely scattered throughout all parts of the quadrangles (pl. 1). Constituents of the surficial deposits range from the silt and fine sand of some ephemeral river bars to the large boulders that characterize some moraines. The deposits include alluvial and fluvioglacial deposits (mainly outwash), tufa, landslides, talus, colluvium, and a variety of moraines both off and on ice (fig. 5). Only the moraines on ice are distinguished from the other surficial deposits on the geologic map (pl. 1). Besides the extensive modern deposits that are conspicuous along the major rivers and streams, the alluvial deposits include older bench or terrace gravels and tracts of ancient alluvium that support vegetation. In places the older alluvial deposits appear to merge into morainal drift, and extensive detailed work is required to delineate these two deposits.

Alluvial fans have formed near several junctions between high-gradient tributaries and flood plains of the main streams. The largest of these, the Klukwan fan (pl. 1 and fig. 6), has formed near the mouth of a short, steep creek that enters the Chilkat River valley at the base of the steep-fronted Takshanuk Mountains. The fan has a radius of about 1 mile and an apex height about 700 feet above the Chilkat River. This voluminous fan consists largely of magnetite-bearing pyroxenite and gabbro and diorite derived from the Takshanuk Mountains and constitutes a large resource of low-grade iron ore. Its detrital constituents range in size from silt to large boulders. A compositionally similar but smaller compound alluvial fan borders the Takshanuks about a mile northwest of the Klukwan fan. A large fan that is composed mainly of quartz diorite and diorite detritus borders the range front about 4 miles southeast of the Klukwan fan.

During a period of protracted heavy rainfall in September 1967, Big Boulder Creek overflowed its banks and deposited boulder-laden debris over the highway near the mouth of the creek and over a large part of the nearby ancient forested flood plain of the Klehini River. During the same period a large volume of water-saturated rock debris slid from the precipitous front of the Takshanuk Mountains in the nearby B-2 quadrangle and covered the highway over a length of about a quarter of a mile. Such phenomena attest to the rapid formation of some surficial deposits in the region.

Calcareous tufa is intermittently exposed along the base of the mountains north of the Haines Highway from near the west edge of the B-3 quadrangle westward for about 7 miles. The tufa is as much as 20 feet thick and unconformably overlies metamorphic rocks. It is chalky white, porous, and friable and consists dominantly of calcium carbonate. The tufa contains locally abundant twigs and leaves of modern flora, chiefly willows. It originates by precipitation from calcium-carbonate-saturated solutions emanating from springs along the base of the mountains north of the highway.

The landslides and talus are best developed along the oversteepened walls of deeply incised stream valleys. Colluvium and similar products of creep and solifluction are widespread in the mountainous terrain above timberline.

The widespread moraines are mainly terminal and ground moraines but also include lateral and medial moraines, both on and off ice (fig. 5). They contain

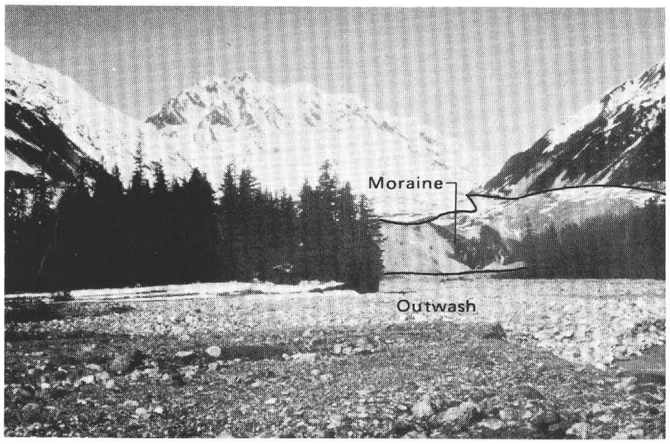


FIGURE 5.—View to southwest up Jarvis Glacier showing extensive outwash near junction of Klehini River and Jarvis Creek and moraines associated with Jarvis Glacier. Snow-free bedrock consists mainly of schist and phyllite and marble.

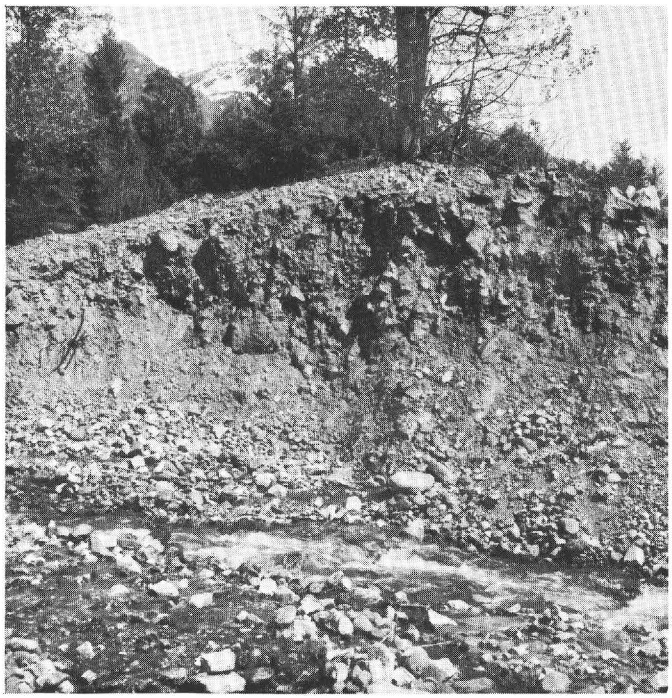


FIGURE 6.—Stream-cut bank, about 20 feet high, in the Klukwan fan.

compositionally diverse boulders, including some of rock types that have not been found in the B–3 and B–4 quadrangles. Generally, the boulders are angular or subangular and form disarrayed aggregates with interstitial voids. However, some older moraines contain weathered and subrounded boulders surrounded by soil and partly decomposed rock fragments. Locally the moraines overlie glacially-scoured striated bedrock.

The surficial deposits are Quaternary, probably mainly Holocene, in age; however, their exact ages have not been ascertained.

STRUCTURE

The Skagway B–3 and B–4 quadrangles are divisible into two terranes with distinctive structural styles that are separated by the Chilkat River fault (pl. 1). East of the fault the terrane is characterized by dominant northwestward trends that reflect the grain of the Coast Range batholith throughout much of southeastern Alaska. West of the fault the trends are diversely oriented, and although they include many northwest-striking elements, they also reflect the westward-trending grain typical of the parts of the Muir and Chilkat provinces in Glacier Bay National Monument (MacKevett and others, 1971, p. 11) and several other orientations.

FAULTS

Faults in the quadrangles include the concealed Chilkat River fault, numerous lesser faults, including many that were not mapped, and most of the features shown as lineaments on the geologic map (pl. 1). The Chilkat River fault is a continuation of a major strand of the Chatham Strait fault (Brew and others, 1966, p. 154; Ovenshine and Brew, 1972), a fault of regional tectonic significance that is inferred to extend for hundreds of miles south of the Skagway quadrangles. The Chilkat River fault continues northwestward into Canada where it probably connects with structural elements of the Denali fault system. In the B–3 quadrangle, the Chilkat River fault underlies and parallels the Chilkat River valley, a remarkably linear topographic trough that trends N. 33° W. and transects the quadrangle. Besides having a strong topographic expression and juxtaposing terranes with distinctive geological and structural styles, the faulting has produced numerous subsidiary faults and cataclastic zones in the nearby rocks, particularly the Tertiary granitic rocks and the Cretaceous metabasalt. These fault-induced planar features generally parallel the strike of the Chilkat River fault and dip nearly vertical, and they are exposed in many outcrops along both sides of the Chilkat River. The marked linearity of the fault trace and its parallelism with related nearly-vertical subsidiary structures in nearby bedrock on both sides of the fault suggest that the fault dips steeply and that the dominant displacement, at least during later stages, was lateral. Lateral displacement is also indicated by nearly horizontal slickensides on some of the ancillary nearly vertical faults. Evidence for the direction of lateral displacement on the Chilkat River fault is not apparent in the B–3 quadrangle. Lathram (1964, p. 249) concluded that the Chatham Strait fault has a right-lateral separation of about 120 miles. Subsequently, Brew, Loney, and Muffler (1966, p. 154) postulated a 50-mile right-lateral separation of pre-Tertiary rocks along the Chatham Strait fault. Probably the best measurement of lateral separation on the Chatham Strait fault is provided by an offset Silurian facies change which indicates a right-lateral separation of about 126 miles (Ovenshine and Brew, 1972, p. 252). Except for the fact that the Chilkat River fault separates terranes containing rocks as young as mid-Tertiary, evidence for the age of faulting is lacking in the B–3 quadrangle. Disparities in offsets of geologic features along the Chatham Strait fault document Cenozoic displacement and also suggest earlier faulting, including some that may be pre-Late Triassic (Ovenshine and Brew, 1972, p. 245–253). Brew, Loney, and Muffler (1966, p. 154) believe that movement on the Chatham Strait fault may have begun in the Cretaceous or earlier. In nearby parts of British Columbia, fault strands that are probably continuations of the Chilkat River fault cut Tertiary rocks that may be as young as Miocene (Watson, 1948).

Although no large earthquake epicenters are reported from the Chilkat River fault near the mapped area, Boucher and Fitch (1969, p. 6645) have documented relatively high microseismicity along the fault near Haines. These authors conclude that microseismicity along the fault in this area and along parts of its continuation in Canada are comparable to that of the San Andreas fault in California.

Other mapped faults and lineaments in the quadrangles strike northwestward, between north and N. 20° E., and, rarely, in other directions (pl. 1). Of these trends, northwest-striking faults nearly parallel to the Chilkat River fault are the most abundant. They are best developed in nearby rocks west of the fault. Almost all the observed faults dip steeply.

Most of the faults are marked by zones of sheared, altered, and fragmented rocks a few feet thick. A few such zones are much thicker. No gently dipping faults were mapped, but low-angle fractures that probably are minor faults were noted in some outcrops of metamorphic rocks, and possibly unrecognized larger and more significant low-angle faults occur in the metamorphic terrane. The northwest-striking faults and most other faults probably reflect the diastrophism that produced the Chilkat River fault and, by inference, the faults are largely Tertiary in age. Some faulting may be related to the deformation that folded the metamorphic rocks or that accompanied emplacement of some of the granitic masses, but such relations have not been confirmed.

OTHER STRUCTURAL FEATURES

Metamorphic rocks west of the Chilkat River have been strongly deformed on all scales and during several periods of deformation. Although only a few folds were mapped, small folds are common in many outcrops, and large folds are indicated by the distribution of some rock units, by airborne reconnaissance, and by examination of aerial photographs. The distribution of the marble bodies near the Klehini River, for example, suggests large-scale folding (pl. 1). Also, the preferred localization of the main marble bodies in low-altitude terranes near the base of the mountains, together with their gross outcrop patterns, suggest that they may be parts of a large nappelike structure. Isoclinal folds are especially well developed in the schist and phyllite and amphibolite units. Many of these rocks record multiple stages of deformation and are marked by conspicuous slip cleavage. Although these features are most apparent in rocks west of the Chilkat River, some metabasalts east of the river appear to be tightly folded.

Foliation is conspicuous in almost all the metamorphic rocks and in many of the igneous rocks. Generally, it closely parallels lithologic contacts, but in places it is discordant. The foliation typically dips steeply. Foliation in rocks east of the Chilkat River strikes northwestward, parallel to the regional batholithic trend. West of the river the foliation is diversely oriented, although northwest trends are still common. Joints were not mapped, but they are widespread and locally abundant in many of the rocks.

Most folds and foliation in the metamorphic rocks probably reflect an early or middle-Mesozoic regional tectonic event. Younger batholithic intrusions locally modified some of the earlier structures and may have induced additional folding in the invaded rocks. Stresses that generated the Chilkat River fault probably produced some of the minor folds and planar structures, particularly those near the fault. Jointing, in varying degrees, probably accompanied all the tectonic events.

SPECULATIONS AND IMPLICATIONS

The tectonic implications of a terrane of ancient Paleozoic continental crust bounded largely by Mesozoic oceanic rocks throughout southeastern Alaska has evoked much speculation during recent years. Earlier stabilistic concepts of intense downwarping along elongated zones near the continental margins to form Mesozoic eugeosynclines have, under the impetus of plate tectonics, been largely superseded by mobilistic concepts. These include models involving large-scale lateral transport of many hundreds or thousands of miles (Jones and others, 1972) or modifications stressing the roles of Mesozoic island arcs (Berg and others, 1972). Although the mobilistic models probably best account for the southeastern Alaska Paleozoic belt, they doubtless will be modified to accommodate new geologic data. Correlations between the southeastern Alaska Paleozoic rocks and remote Paleozoic sequences, such as those in the western United States, are at best tenuous. The amount of fault displacement required by some models appears inordinate and far exceeds that which can be reasonably documented geologically.

Another possibility is that the southeastern Alaska Paleozoic rocks were detached from the main continental mass lying just to the east either by rifting or by westward overthrusting over an east-dipping subduction zone. However, corroborative evidence for such speculation probably was largely obliterated by the Coast Range batholith or masked by late Mesozoic rocks.

ECONOMIC GEOLOGY

Besides gold placers, which account for the only mineral production, the B–3 and B–4 quadrangles contain placer and lode deposits of titaniferous magnetite, barite-rich lodes with associated silver and diverse base metals, a few gold lodes, and minor occurrences of several ore minerals. In addition, a variety of nonmetallic mineral materials of potential use in local construction or industry, such as marble, sand, and gravel, are available in the quadrangles.

Current mining activity is focused on the exploration and development of the iron and the barite-rich deposits. Chances for significant deposits for other commodities within the quadrangles are regarded as poor, even though several minor anomalous concentrations of metals were detected by geochemical sampling (table 8 and Winkler and MacKevett, 1970).

GOLD

Mining activity in the region dates from the summer of 1898 when placer gold was discovered along Porcupine Creek (fig. 7) by prospectors en route to the Klondike goldfields (Wright, 1904, p. 12). The placer mining peaked within a few years after the initial

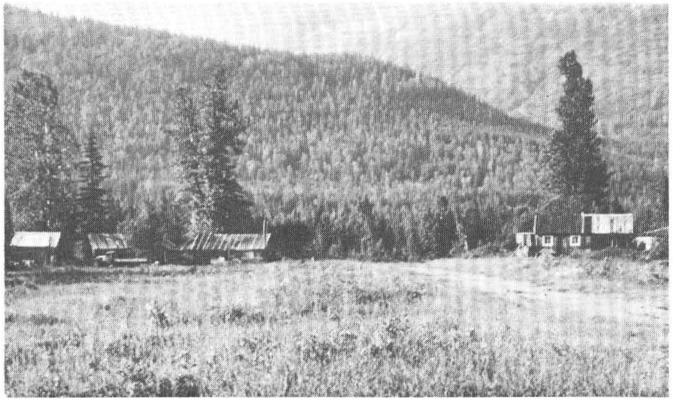


FIGURE 7.—Remnants of the town of Porcupine, the main placer gold camp in the study area. View to northwest.

discovery, and since then it has continued only intermittently on a diminished scale. Most of the gold deposits are in the Porcupine district, an ill-defined tract that includes the Porcupine Creek drainage basin and nearby areas in the B–4 quadrangle. The deposits include widespread placers and a few small lodes. The lode occurrences are localized mainly in or near the slate in the central part of the B–4 quadrangle, and the placers are mainly along streams that drain the slate terrane.

PLACER DEPOSITS

Most of the following description is summarized from reports by Wright (1904) and Eakin (1919). The placer deposits are mainly near Porcupine Creek and its tributaries and along Glacier, Nugget, and Cottonwood Creeks (pl. 1). Leaner or smaller deposits are reported on the Klehini River near Jarvis Creek, on Big Boulder (Yokeak) Creek, and on the upper stretches of the Tahkin and Tsirku Rivers (Wright, 1904, pl. v). Probably most other fluviatile deposits in the quadrangles contain some gold. Production was almost entirely from the environs of Porcupine Creek and its tributaries, McKinley and Cahoon Creeks; however, placers along Glacier Creek and near the mouth of Nugget Creek account for some of the production. Production data, given in table 7, show that between 1898 and 1955 the placers produced approximately 60,000 troy ounces of gold. Production since 1955 is probably less than 100 ounces, and the limited recent activity in the placer fields consists mainly of small-scale exploration. Historically, the mining operations have been impeded by ravaging floods and by the presence of gigantic boulders. Descriptions of individual deposits and of the mining methods used are given in Wright (1904) and Eakin (1919).

According to Wright (1904, p. 19), the placers include creek, side-bench, and high-bench gravels. The creek gravels occupy modern streams and merge laterally and upward with older gravels of the side benches. The high-bench gravels occupy parts of ancient stream channels that have withstood the depredations of erosion. Although the gold placers are interpreted to be mainly of fluviatile origin, glacial processes that shaped much of the region probably influenced the formation and localization of many of the deposits. The complex Quaternary geology of the region has not been thoroughly investigated, so relations between the fluviatile and glacial processes are not well understood.

TABLE 7.—*Estimated gold production from the Porcupine placer district, 1898–1955*

Years	Approximate production (troy ounces)	Approximate value (dollars based on prevailing price at time of mining)
1898–1906	44,000	900,000
1907–1916	15,000	300,000
1920–1929	1,000	20,000
1935	250	10,000
1941	14	500
1950–1955	100	3,500
Approximate total (rounded)	60,000	1,200,000

NOTE.—The data for 1898–1916 are from Wright (1904) and Eakin (1919). The data for 1920–29 and 1941 are from various records. The estimates for 1935 and 1950–55 are based only on the number of men employed and local information.

The placer gold generally is worn and flattened and ranges from minute flakes and flour gold to nuggets weighing several ounces. The only gold that was detected in stream-sediment samples from the B–3 and B–4 quadrangles was from Porcupine Creek and its tributaries (Winkler and MacKevett, 1970). The placer gold is believed to be of local derivation and to reflect concentration of gold from multiple nearby lode sources that are described in the following section.

LODE DEPOSITS

Almost all the known lode gold occurrences are in the mountains bounded by the Klehini and Tsirku Rivers and the west edge of the B–4 quadrangle (pl. 1). Only a few have ever been staked, and exploration on them is minimal; none has produced. The lodes consist of zones of closely spaced quartz and calcite veinlets, disseminations of auriferous pyrite, and discrete quartz and calcite veins. In addition, gold is a minor constituent of the barite-rich lodes near Glacier Creek (table 8).

The quartz and calcite veinlets and the pyrite disseminations are components of several mineralized zones in the slate terrane of the B–4 quadrangle between the Tsirku River and Glacier Creek. Little is known regarding the shape, size, and grade of these zones, although they apparently trend northwestward. The zones contain abundant closely spaced quartz and calcite veinlets, less than an inch thick, that typically

TABLE 8.—*Semiquantitative spectrographic analyses of veins, lodes, and altered zones*

[Analyst, K. J. Curry. Fe, Mg, Ca, Ti are reported in percent. All other elements are reported in parts per million (ppm) to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1 and so forth. N=not detected; L=detected but below limit of determination; G=greater than amount shown in parentheses, precise amount not determined. The following elements were also looked for but not found during the spectrographic analyses: Au, Sn, W; exception, 10 ppm Au in 69AMk-25D. All samples were analyzed for Au by atomic absorption methods, but Au was found only in five samples. 69AMk-25D, 10 ppm; 70AMk-11B-1, 0.04 ppm; 70AMk-15E-1, 2.4 ppm 70AMk-15E-2, 0.25 ppm; 70AMk-15E-3, 0.06 ppm. Atomic absorption analyses by: H. B. King, A. L. Meier, R. L. Miller, D. G. Murrey, and R. B. Tripp, U.S. Geological Survey]

Map No.[1]	Sample No.	Fe	Mg	Ca	Ti	Mn	Ag	As	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr
		Percent				Parts per million																						
63	69AMk- 4C-2	15	0.7	5	0.03	2,000	L	N	L	70	N	N	N	70	10	300	N	L	L	10	L	N	L	N	15	N	L	N
64	69AMk- 5E	10	.05	1.5	.7	700	N	N	30	3,000	L	N	N	20	30	70	20	L	10	30	20	N	30	100	200	30	L	300
65	69AMk- 8B-2	2	5	.05	.015	70	N	N	N	100	N	N	N	L	L	10	N	N	L	N	N	N	N	N	30	N	L	N
66	69AMk- 8C	3	.3	10	.3	1,500	L	N	70	500	L	N	N	7	70	50	N	L	L	70	15	N	10	300	100	15	L	50
67	69AMk-13D-1	3	.7	.7	.3	500	L	N	L	200	N	N	N	L	15	70	N	L	L	50	N	N	5	N	500	10	1,500	70
68	69AMk-13E	3	.7	7	.3	1,500	N	N	N	L	N	N	N	N	L	L	N	N	L	10	N	N	7	L	50	10	N	20
69	69AMk-15C	3	.03	5	.05	100	N	N	N	150	N	N	N	L	L	30	N	N	L	20	N	N	N	L	20	N	N	L
70	69AMk-21C-3	G(20)	.05	.15	.015	100	2	N	20	100	N	N	G(500)	150	20	7,000	N	5	L	200	L	N	30	L	10	L	G(10,000)	L
71	69AMk-14D	7	1.5	1.5	.3	300	N	N	20	200	N	N	N	7	50	70	N	L	10	20	L	N	15	100	200	10	N	70
72	69AMk-27B-3	.7	.7	7	.03	1,000	.5	N	N	300	N	N	N	N	150	L	N	N	L	15	30	N	7	700	30	10	N	L
73	69AMk-28C-2	10	1.5	5	.003	1,500	.5	N	10	300	N	N	N	7	L	L	N	N	10	20	30	N	N	150	15	10	N	L
74	69AMk-32A	7	1	7	.3	1,000	N	N	30	300	1.5	N	N	15	100	30	L	L	10	70	15	N	15	150	150	15	L	70
75	69AMk-35A-1	2	.3	1.5	.1	700	N	N	10	150	L	N	N	N	L	10	N	N	L	20	N	N	N	150	30	10	N	70
76	69AMk-40A-1	.3	.03	L	.005	20	N	N	N	L	L	N	N	L	10	L	N	N	L	10	N	N	N	N	15	L	N	L
77	69AMk-40E	5	1.5	.7	.3	700	N	N	L	100	L	N	N	10	15	70	N	N	10	30	N	N	15	L	200	10	L	30
78	69AMk-50A-1	3	.7	.15	.3	300	L	N	15	300	L	N	N	5	L	50	N	L	10	20	10	N	5	300	70	10	300	70
79	69AMk-52B	G(20)	.1	.5	.007	300	2	N	20	L	N	N	N	300	L	300	N	7	10	100	10	N	N	L	15	L	N	20
80	69AMk-52E-1	15	7	1.5	1	300	L	N	10	200	L	N	N	70	150	150	N	L	10	70	10	N	30	300	500	20	L	70
81	69AMk-55C-1	15	1	20	.05	2,000	N	N	L	700	N	N	N	70	15	150	N	L	10	30	10	N	7	300	100	15	L	20
82	69AMk-55D-1	15	.05	.7	.003	100	1.5	N	10	L	N	N	N	300	10	3,000	N	5	15	300	N	N	N	L	15	L	L	L
83	69AMk-56C	10	.3	.7	.7	70	10	N	15	G(5,000)	L	N	N	70	10	20	N	10	10	30	700	N	30	500	500	30	700	70
84	69AWk-24D-1	2	2	5	.2	300	L	N	30	1,000	L	N	N	L	70	30	N	7	L	50	L	N	7	300	150	15	500	70
85	70AMk- 4A-2	10	.3	.3	.15	150	L	N	L	700	1	N	N	N	10	150	N	L	10	5	70	N	N	100	20	L	N	70
86	70AMk- 5E-3	10	1.5	1.5	.7	500	N	N	15	700	L	N	N	15	200	150	L	10	10	70	15	N	20	200	300	30	N	300
87	70AMk-11B-1	10	1.5	2	.07	700	15	N	L	L	N	N	N	150	20	7,000	N	N	L	150	N	N	10	N	150	L	N	L
88	70AMk-13C	7	1.5	.7	.3	700	.5	N	50	1,500	L	N	N	20	70	150	L	L	10	70	10	N	30	300	500	20	N	200
89	70AMk-13E	10	3	1.5	.5	500	1.5	N	10	500	N	N	N	30	300	700	N	L	10	300	70	N	70	100	300	15	N	40
90	70AMk-14B-2	5	1.5	10	.3	1,000	N	200	15	150	L	N	N	15	L	30	N	N	10	L	N	N	20	500	150	30	N	100
91	70AMk- 8B	15	5	10	1	1,500	L	N	L	1,000	N	N	N	50	30	150	N	L	L	30	300	N	70	700	700	50	N	30
92	70AWk-14A	1.5	.05	.05	.03	30	N	N	150	L	N	N	N	N	10	150	N	N	N	15	N	N	N	L	15	N	N	L
93	70AMk-11F-2	.15	.07	L	.007	70	2	L	N	700	N	N	N	N	N	L	N	N	N	L	70	N	N	L	15	N	N	N
	Barite prospects near Glacier Creek																											
I	69AMk-25D	5	L	L	0.015	L	700	N	N	G(5,000)	N	N	N	N	30	500	N	5	10	N	G(20,000)	1,500	N	5,000	150	N	L	L
I	70AMk-11D-1	3	1.5	15	.03	2,000	N	L	N	L	N	N	N	7	L	15	N	N	N	15	L	N	15	300	70	20	N	L
I	70AMk-11E-2	10	.7	L	.1	300	N	L	10	L	N	N	N	50	L	70	N	5	10	20	L	N	7	L	100	20	300	30
I	70AMk-12B	7	2	3	.7	300	L	N	15	1,500	L	N	N	30	30	100	70	L	10	20	70	N	70	L	500	70	200	300
I	70AMk-15E-1	.07	L	L	L	N	700	N	N	G(5,000)	N	N	N	N	L	200	N	L	N	N	G(20,000)	700	N	G(5,000)	30	N	1,000	N
I	70AMk-15E-2	15	L	.3	.15	500	150	L	N	G(5,000)	N	100	300	N	150	15,000	L	7	10	50	G(20,000)	200	7	G(5,000)	700	30	G(10,000)	30
I	70AMk-15E-3	15	.03	.1	.2	N	100	200	L	G(5,000)	N	N	N	7	20	1,500	L	20	L	20	2,000	300	20	5,000	200	L	3,000	30
I	71AMk- 6B	15	3	.5	.7	300	3	N	10	1,500	L	N	N	70	700	70	N	7	L	70	70	N	50	100	500	30	N	150
I	71AMk- 6D	G(20)	.2	.07	.3	70	1	N	L	700	N	N	N	L	70	300	N	7	L	15	70	N	20	L	300	20	1,000	30
I	71AMk- 7A-1	10	.07	1.5	.1	300	70	700	N	G(5,000)	N	70	300	N	70	15,000	30	L	L	20	15,000	300	10	5,000	300	30	G(10,000)	30

	Sample	Fe	Mg	Ca	Ti	Mn	Ag	As	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr
I	71AMk- 7A-2...	2	.03	.07	.07	L	70	L	N	G(5,000)	N	L	20	N	30	3,000	L	15	N	N	3,000	150	5	G(5,000)	150	L	1,000	L
I	71AMk- 7A-3...	15	.3	L	.3	30	5	N	10	G(5,000)	N	N	N	20	30	700	N	30	L	70	150	N	30	L	300	N	L	L
I	71AMk- 7A-4...	G(20)	.03	L	.1	L	2	N	L	3,000	N	N	N	70	L	150	N	10	L	7	50	N	10	L	50	L	N	L
I	71AMk- 7B-1...	1.5	L	L	.015	70	10	300	N	G(5,000)	N	L	N	N	20	70	N	15	L	N	500	1,000	L	G(5,000)	100	N	200	N
I	71AMk- 7B-2...	7	.03	L	.1	L	70	700	N	G(5,000)	N	20	N	N	30	150	N	100	L	N	1,500	300	5	G(5,000)	150	L	L	L
I	71AMk- 7B-3...	.3	.03	L	.15	N	30	N	N	G(5,000)	N	L	N	N	30	70	N	10	N	N	1,500	100	L	G(5,000)	150	L	200	20
I	71AMk- 7B-4...	10	.7	L	.5	30	3	N	30	G(5,000)	N	N	N	30	100	70	N	L	L	70	200	N	30	100	500	20	N	50
I	71AMk- 8A-1...	20	1.5	.05	.5	300	7	L	10	G(5,000)	N	N	N	L	300	3,000	N	10	L	7	700	N	30	150	300	L	3,000	50
I	71AMk- 8A-2...	10	L	L	.007	L	70	N	N	G(5,000)	N	N	N	N	20	1,000	N	70	L	N	20,000	300	L	G(5,000)	150	N	700	N
I	71AMk- 8A-3...	3	L	L	.005	10	30	N	N	G(5,000)	N	30	N	N	10	150	N	30	N	N	1,500	L	N	G(5,000)	100	N	300	N
I	71AMk- 8A-4...	10	1.5	.15	.3	1,500	3	L	30	G(5,000)	1.5	N	N	70	150	3,000	N	7	L	200	200	N	20	L	300	30	5,000	100
I	71AMk- 8B-1...	15	3	.2	.3	1,500	15	N	15	3,000	L	N	300	70	70	20,000	N	L	L	100	1,500	N	30	L	300	50	G(10,000)	70
I	71AMk- 8B-2...	15	.3	L	.15	70	70	200	N	G(5,000)	N	100	N	N	30	3,000	N	50	L	L	15,000	500	7	G(5,000)	150	L	7,000	L
I	71AMk- 8C-1...	10	.3	15	.07	3,000	300	L	L	G(5,000)	N	150	150	L	50	G(20,000)	N	L	L	30	20,000	L	L	700	50	30	G(10,000)	L
I	71AMk- 8C-2...	10	.7	3	.15	2,000	300	N	L	G(5,000)	N	L	300	L	150	15,000	N	20	L	20	G(20,000)	150	N	G(5,000)	300	20	G(10,000)	70
I	71AMk- 8C-3...	10	L	.2	L	30	700	N	N	G(5,000)	N	N	100	N	10	10,000	N	15	L	N	G(20,000)	1,500	N	G(5,000)	500	10	7,000	N
I	71AMk- 8C-5...	1	L	.3	L	N	300	N	N	G(5,000)	N	N	N	N	30	3,000	N	20	N	N	G(20,000)	200	N	G(5,000)	300	10	700	N
II	71AMk-A- 1.....	5	1	2	.05	2,000	15	N	N	G(5,000)	L	N	N	10	70	150	30	L	L	30	1,000	L	15	G(5,000)	700	70	700	70
II	71AMk-A- 2.....	.7	L	.05	.2	15	200	N	N	G(5,000)	N	N	N	N	30	70	N	150	L	N	5,000	1,000	L	G(5,000)	70	L	700	70
II	71AMk-A- 8.....	2	L	L	.15	50	500	3,000	N	G(5,000)	N	N	150	N	L	3,000	N	70	N	10	15,000	1,500	N	3,000	150	N	G(10,000)	L
II	71AMk-A- 9.....	.7	L	L	.1	N	15	L	N	G(5,000)	N	N	N	N	15	50	N	30	N	N	500	150	N	G(5,000)	150	N	300	L
II	71AMk-A-10.....	2	L	L	.02	L	300	300	N	G(5,000)	N	N	N	N	10	700	N	7	N	N	7,000	1,000	L	G(5,000)	80	N	700	L
		Fe	Mg	Ca	Ti	Mn	Ag	As	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc	Sr	V	Y	Zn	Zr
	Limit of determination...........	0.05	.01	.01	.001	10	.5	200	10	10	1	10	20	5	2	5	20	2	10	5	10	10	5	20	10	10	200	10

Description[2]

Sample	Description
69AMk- 4C-2	Iron-stained quartz-calcite vein, 1 ft. thick.
69AMk- 5E	Altered zone, 10 ft. wide.
69AMk- 8B-2	Chlorite-bearing quartz vein, ½ ft. thick.
69AMk- 8C	Chip sample across 30-ft.-wide altered zone.
69AMk-13D-1	Quartz stringers in carbonaceous schist.
69AMk-13E	Quartz-calcite vein, ½ ft. thick.
69AMk-15C	Quartz-calcite lens.
69AMk-21C-3	Sulfide-rich quartz vein (float).
69AMk-14D	Chip sample across 5-ft.-wide altered zone.
69AMk-27B-3	Quartz-calcite vein, ½ ft. thick.
69AMk-28C-2	Pyrite-quartz-calcite vein, ½ ft. thick.
69AMk-32A	Altered zone, 1 ft. wide.
69AMk-35A-1	Quartz vein, 1 ft. thick.
69AMk-40A-1	Quartz lens.
69AMk-40E	Altered zone, 3 ft. wide.
69AMk-50A-1	Quartz vein, ½ ft. thick.
69AMk-52B	Pyrite-rich quartz vein, 1 ft. thick.
69AMk-52E-1	Iron-stained quartz vein, 1 ft. thick.
69AMk-55C-1	Pyrite-quartz-calcite vein, 1 ft. thick.
69AMk-55D-1	Sulfide-bearing quartz vein, (float).
69AMk-56C	Barite-rich vein (float).
69AWk-24D-1	Channel sample across 3-ft.-wide altered zone.
70AMk- 4A-2	Quartz vein, ½ ft. thick.
70AMk- 5E-3	Altered zone, 1½ ft. thick.
70AMk-11B-1	Sulfide-bearing quartz vein, ½ ft. thick.
70AMk-13C	Altered zone, 30 ft. thick.
70AMk-13E	Altered zone, 25 ft. thick.
70AMk-14B-2	Breccia zone, 1 ft. thick.
70AMk- 8B	Altered zone, 1 ft. thick.
70AWk-14A	Quartz stringers.
71AMk-11F-2	Quartz vein, ½ ft. thick.
69AMk-25B	Barite-rich lode, (float).
70AMk-11D-1	Quartz-calcite vein, ½ ft. thick.
70AMk-11E-2	Pyrite-rich zone, 1 ft. thick.
70AMk-12B	Altered zone, more than 50 ft. thick.
70AMk-15E-1	Barite-rich lode, 15 ft. thick.
70AMk-15E-2	Barite-rich lode, 20 ft. thick.
70AMk-15E-3	Barite-rich lode, 20 ft. thick.
71AMk- 6B	Chip sample across 6-ft.-wide altered zone.
71AMk- 6D	Breccia zone, ½ ft. thick.
71AMk- 7A-1	Barite-rich lode, 15 ft. thick.
71AMk- 7A-2	Chip sample across 15-ft.-thick barite-rich lode.
71AMk- 7A-3	Selected sample at south contact of barite-rich lode.
71AMk- 7A-4	Pyrite-rich vein a few inches thick.
71AMk- 7B-1	Chip sample across northernmost 5 ft. of 18-ft.-thick lode.
71AMk- 7B-2	Chip sample across intermediate 6 ft. of 18-ft.-thick lode.
71AMk- 7B-3	Chip sample across southernmost 6 ft. of 18-ft.-thick lode.
71AMk- 7B-4	Altered zone 30 ft. thick, south of lode.
71AMk- 8A-1	Chip sample across northernmost 6 ft. of 24-ft.-thick lode.
71AMk- 8A-2	Chip sample across intermediate 10 ft. of 24-ft.-thick lode.
71AMk- 8A-3	Chip sample across southernmost 8 ft. of 24-ft.-thick lode.
71AMk- 8A-4	Altered zone 12 ft. thick adjacent to lode.
71AMk- 8B-1	Chip sample across 5-ft.-thick copper-stained zone bordering lode.
71AMk- 8B-2	Chip sample across 4-ft.-thick barite-rich lode.
71AMk- 8C-1	Sulfide-rich lens, 5 ft. thick.
71AMk- 8C-2	Chip sample across 25-ft.-thick barite-rich lode.
71AMk- 8C-3	Selected sample near south margin of lode of 8C-2.
71AMk- 8C-5	Selected sample from barite-rich lode of 8C-2.
71AMk-A- 1	Near lower contact of nunatak lode.
71AMk-A- 2	4 ft. above lower contact of nunatak lode.
71AMk-A- 2	7 ft. above lower contact of nunatak lode.
71AMk-A- 9	12 ft. above lower contact of nunatak lode.
71AMk-A-10	Near top of nunatak lode, 18 ft. above lower contact.

[1]Sample locations are shown by the circled map numbers on the geologic map (pl. 1).
[2]Unless otherwise specified, the samples are representative grab samples. Sample intervals for the chip samples are approximately 6 inches.

cut the foliation at high angles. Slate that contains sparsely to abundantly disseminated pyrite, chiefly as pseudocubes, also characterizes the mineralized zones. The veinlets are spaced at intervals varying from about an inch to 3 or 4 feet, and generally they do not persist for more than 50 feet along strike. They contain pyrite, local sphalerite, and rare to trace amounts of galena and chalcopyrite. Some of the altered mafic dikes in the Porcupine district are similarly mineralized and contain networks of quartz-calcite veinlets and disseminated pyrite. Information on the grades of the mineralized zones is scant. Wright (1904, p. 20) reports that mineralized slate from Porcupine Creek assayed 0.12 ounce of gold per ton and 0.08 ounce of silver per ton. Random samples across a mineralized slate belt near the mouth of Cahoon Creek yielded gold values from a trace up to several dollars per ton although most values were between $1.00 and $2.00 per ton (computed at $20.00 per ounce) (Eakin, 1919, p. 14). A sample of pyrite-bearing slate from Cahoon Creek contained 0.02 ppm (parts per million) gold (table 1, no. 69AMk–27B–2).

The individual veins, although not so abundant as the veinlets, are more widely distributed and cut most of the metamorphic and granitic rocks. They are best developed in the slate and in the schist and phyllite and granitic rocks in the west-central part of the B–4 quadrangle. The veins are generally between ½ and 1 foot thick and are traceable for at least 100 feet. They typically dip steeply, but their strikes are diverse. Most of the veins are mineralogically similar to the veinlets, and besides quartz and calcite, they contain abundant pyrite and its alteration products, locally abundant sphalerite, and in a few places, trace amounts of galena and chalcopyrite. Many of the veins contain some sericite or chlorite. Some of the veins contain little or no sulfide minerals. The veins and veinlets probably have a common genesis and may be late-stage hydrothermal derivatives of the quartz diorite-granodiorite magmas. A few quartz-rich ledges that contain minor amounts of gold and that have been periodically prospected are briefly described by Wright (1904, p. 18). The few lodes prospected for gold are on these ledges or on quartz veins that generally are strongly iron stained. A gold-bearing quartz vein north of Jarvis Glacier on the Canadian side of the international boundary has been the site of intermittent small-scale exploration for many years. This vein, which cuts granitic rocks, is traceable for about 2,000 feet along strike and is between 1–4 feet wide (Eakin, 1919, p. 14). Gold was detected in only one of the quartz veins sampled during our investigations (table 8, no. 70AMk–11B–1).

IRON AND TITANIUM

Most of the following information on the iron and titanium deposits has been abstracted from Robertson (1956). These deposits include the magnetite-bearing pyroxenite lode in the Takshanuk Mountains north of Klukwan, the Klukwan alluvial fan, and a compositionally similar but smaller fan about a mile northwest of the Klukwan fan (pl. 1). The small amounts of magnetite in some contact-metamorphic rocks, notably north of Saksaia Glacier, are probably of negligible economic potential. The deposits near Klukwan were originally staked in 1908 and, between 1910 and 1919, were restaked by different companies. The early staking resulted in very little exploration and development, and interest in the deposits lapsed until after World War II. Renewed interest resulted in relocating the deposits and extensive claim staking in 1946 and inaugurated intermittent exploration and development that is still in progress. This work included constructing access roads, mainly on the Klukwan fan, some diamond drilling, mapping, and various metallurgical and concentration testing. Current activity at the prospects is under terms of an arrangement with the Klukwan Indian Council. Metallurgical and concentration problems pertinent to both the lode and the placer deposits are discussed by Wells and Thorne (1953); some of the problems have been alleviated by modern technological advances.

PLACER DEPOSITS

The known iron- and titanium-bearing placer deposits are in the voluminous Klukwan fan and in a small fan to the northwest (pl. 1). Some aspects of the Klukwan fan are described in this report in the section "Surficial Deposits" (fig. 6). Additional data relevant to its configuration, composition, and distribution of detrital components are provided by Robertson (1956). The small fan is compositionally similar to the Klukwan fan but is too small to have warranted detailed investigation. The Klukwan fan is composed of pyroxenite and gabbro and diorite detritus that ranges from silt to large boulders. Some parts of the fan are composed almost entirely of pyroxenite; other parts contain as much as 50 percent gabbro and diorite. The iron and titanium are concentrated in titaniferous magnetite that is widely distributed in the pyroxenite. Details of the ore mineralogy are given in the following section; the petrography of the pyroxenite and the gabbro and diorite are described on pages 14–15.

Robertson's (1956, p. 35, 36) reserve estimates for the Klukwan fan are based on the assumption that the fan can be represented by a wedgelike cone segment

700 feet high with a basal radius of 6,000 feet and a sectional arc of 167°, and that a ton of fan material occupies 20 cubic feet. Accordingly, the indicated volume of the fan is about 10 billion cubic feet; Robertson estimates that the fan contains some 500 million tons of material averaging 10 percent magnetite.

LODE DEPOSITS

The only known iron- and titanium-bearing lode deposit in the B–3 and B–4 quadrangles is the mineralized pyroxenite mass in the Takshanuk Mountains north of Klukwan (pl. 1). The pyroxenite has an irregularly shaped outcrop approximately a mile wide and 4 miles long and several small nearby satellitic outcrops.

Titaniferous magnetite forms disseminated grains and sparsely distributed irregular branching masses as much as several feet long within the pyroxenite. The magnetite is typically interstitial to pyroxene and idiomorphic against hornblende; these facts are an indication that it formed after pyroxene and before hornblende. Robertson (1956, p. 11) estimates that the magnetite and ilmenite content of the pyroxenite ranges from 5 to about 51 percent. However, Taylor and Noble (1969, p. 222) report that the titaniferous magnetite content is relatively uniform throughout the pyroxenite and constitutes 15–20 percent of the rock. Besides its dominant silicate minerals, the pyroxenite also contains minor to trace amounts of hematite, chalcopyrite, pyrite, pyrrhotite, spinel, and leucoxene. The opaque minerals occur mainly in two finely blended phases: (1) relatively pure magnetite and (2) magnetite intimately associated with subordinate amounts of ilmenite. The titaniferous magnetite grains range from 0.01 to 5.0 mm in diameter and have an average diameter of about 0.5 mm. About half of the ilmenite occurs in lathlike crystals, approximately 0.003 mm long, that form cubic or octahedral exsolution patterns in the magnetite. The rest of the ilmenite is equigranular, is about 0.05 mm in diameter, and forms discrete grains in granular masses of magnetite. Green spinel is intimately associated with most of the ilmenite.

Robertson's (1956) investigations reveal that samples of the magnetite-bearing pyroxenite contained 0.01–0.02 percent each of sulfur and phosphorous. Spectrographic analyses of concentrates of these samples detected small amounts of copper, manganese, nickel, chromium, vanadium, scandium, aluminum, magnesium, and calcium. Pertinent details of Robertson's investigations, including descriptions of sampling techniques, analyses of samples, and results of magnetic surveys, are given in his 1956 report. Seven of 10 bulk samples of pyroxenite from the Klukwan fan that were analyzed for selected platinum-group elements contained detectable platinum and palladium (Clark and Greenwood, 1972). The maximum concentrations of platinum and palladium in these samples were 0.100 ppm for each of the elements; average concentrations were 0.046 ppm platinum and 0.040 ppm palladium. Detection limits for the analyses were 0.010 ppm platinum and 0.004 ppm palladium.

On the assumption that the pyroxenite body has an average depth of 1,000 feet, Robertson (1956, p. 22) estimates that the deposit contains between 1 and 5 billion tons of pyroxenite with an average grade of about 13 percent magnetic iron. Robertson qualifies his average grade estimate by stating that the deposit may contain as much as 20 percent or as little as 11 percent magnetic iron. A zone in the lower part of the exposed pyroxenite that is estimated to contain 500 million tons of material averaging 20±5 percent magnetic iron is included in the above estimate. Robertson's (1956) analyses indicate that the TiO_2 content of the pyroxenite ranges from 1.6 to 3.0 percent and averages 1.8 percent. According to Taylor and Noble (1969, p. 222), the magnetite shows considerable variation in TiO_2 content; magnetite from the massive segregations commonly contains 4–5 weight percent TiO_2 and the disseminated magnetite between 2 and 3 weight percent TiO_2.

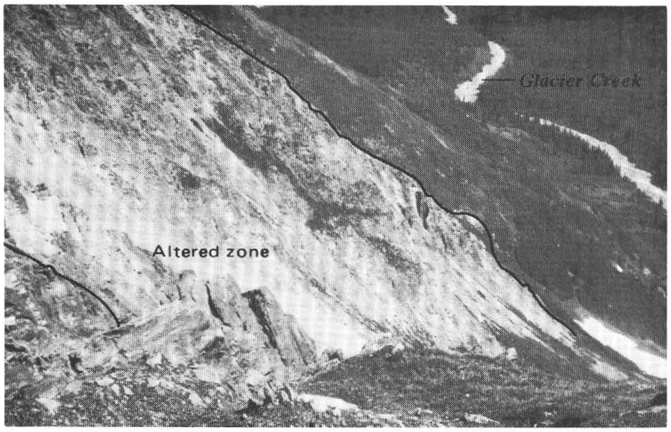
The titaniferous magnetite deposits are magmatic deposits that formed late in the crystallization sequence of the hornblende pyroxenite magma. According to Taylor and Noble (1969, p. 227), textural evidence indicates that the titaniferous magnetite recrystallized deuterically prior to crystallization of the hornblende.

BARITE, SILVER, AND BASE METALS

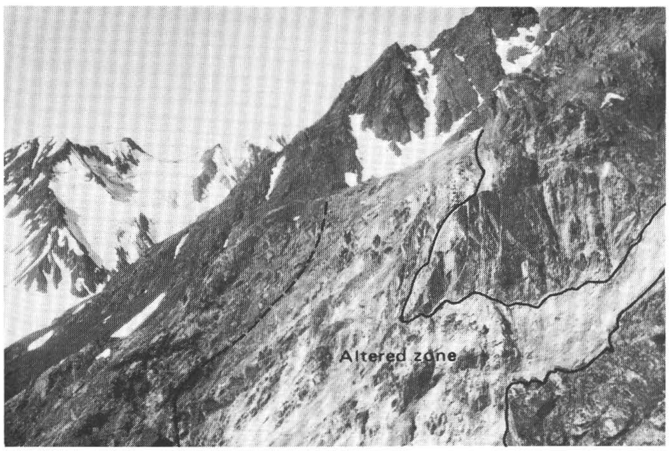
Barite-rich lodes that contain silver and several base metals crop out in the western part of the B–4 quadrangle near Glacier Creek (pl. 1). A prospect near the mouth of Summit Creek in the B–3 quadrangle that according to Eakin (1919, p. 18), explored narrow veins containing silver, lead, and a little copper could not be found during our investigations

The deposits near Glacier Creek are in rugged glaciated terrain at altitudes between 3,500 and 5,700 feet. They are 4–6 miles southwest of the Haines Highway but are separated from the highway by the Klehini River. The deposits were discovered during the summers of 1969 and 1971 by Merrill Palmer of Haines and his associates. Analytical data on samples and brief geologic descriptions pertinent to the two largest deposits are given in a report by MacKevett (1971). These two deposits, herein termed the main lode and the nunatak lode, are, respectively, about a mile northwest of the head of Glacier Creek and in a nunatak in Saksaia Glacier (pl. 1). Two apparently smaller deposits crop out in the steep mountains north of Saksaia Glacier (pl. 1).

The main deposit is localized within a large altered fault zone that cuts rocks of the schist and phyllite unit (figs. 8*A*, *B*). Near the deposit these rocks consist of greenschist and subordinate quartzite with foliation that mainly strikes between N. 75° W. and west and dips steeply northward. The schist, rich in quartz, chlorite, and calcite, commonly contains fairly abundant sodic oligoclase or albite and muscovite, and locally some biotite, pyrite, hematite, and limonite. The quartzite consists of fine-grained quartz with minor amounts of calcite, chlorite, muscovite, and pyrite. The schist and quartzite are cut by altered dikes with relict porphyritic textures and by a few quartz veins. Typically, the dikes consist of fine-grained assemblages of chlorite and albite with lesser amounts of calcite and quartz and minor to rare pyrite, hematite, sphene, and muscovite. Blocks of schist and quartzite enclosed in the fault zone generally have been bleached and altered to quartz-sericite rock that in places contains some barite, pyrite, and hematite, and traces of galena and sphalerite.



A, View east. Glacier Creek in background.



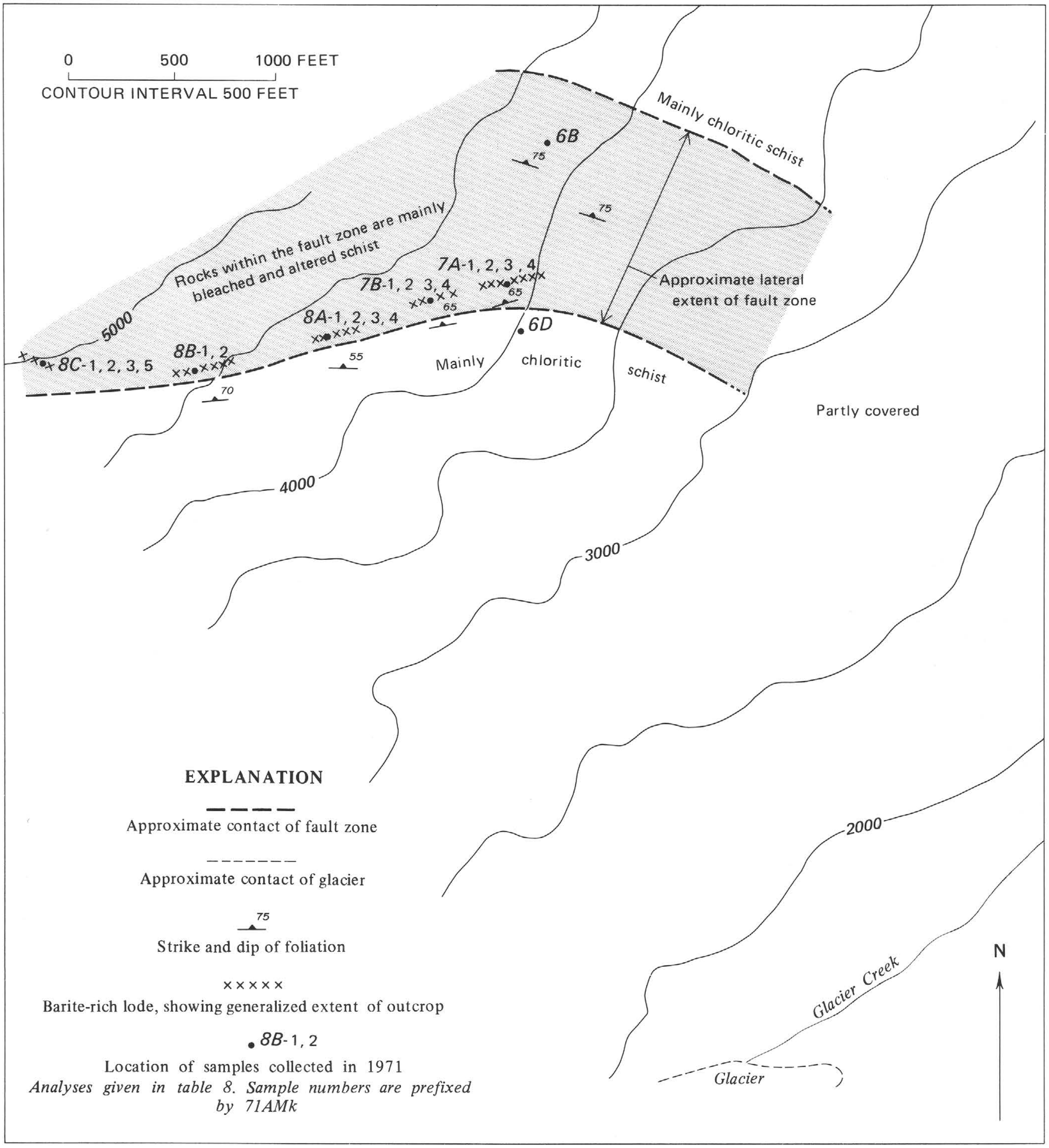
B, View southwest.

FIGURE 8.—Altered zone at main barite-rich prospect.

The fault zone is as much as several hundred feet wide and can be traced from the north side of Glacier Creek to the upper reaches of Little Jarvis Glacier (pl. 1). Except for local divergences, the fault zone is roughly concordant with foliation in the adjacent metamorphic rocks. Near its easternmost exposures, the fault zone strikes about N. 60° W.; progressively westward, its strike changes through east-west to about N. 85° E. Throughout its extent the fault zone appears to dip steeply northward. Numerous discrete fault strands marked by shear zones, gouge, and breccia, along with blocks or horses of altered or partly altered country rock, are within the fault zone. The buff, yellowish- or reddish-brown highly altered material of the fault zone contrasts strongly in color with the greenish-gray unaltered wallrock (fig. 8). The fault zone splays to the northwest where its constituent strands cut rocks that typically are only slightly altered.

The main barite-rich lode, as much as 30 feet wide, is intermittently traceable for about half a mile along strike through a vertical extent of more than 1,000 feet (fig. 9). Most lode outcrops appear to conform in attitude with the fault zone. However, continuity of the lode has not been conclusively established because many of its outcrops are separated by sizeable snow- or talus-covered slopes. The highest lode outcrop deviates from the dominant trend and may represent a faulted offset or a bifurcation of the main lode. Both the westward and the southeastward on-strike projections of the lode are concealed by ice or surficial deposits.

The main barite-rich lode is buff, dull white, or light gray with local yellowish-brown weathered surfaces. Some near-surface parts of the lode are porous and friable. The lode is sheared in places and consists mainly of a sulfide-flecked mosaic of barite crystals 0.3–1.5 mm in diameter (fig. 10*A*, *B*, *C*). Besides the sparsely disseminated sulfides, the lode locally contains narrow sulfide-rich bands that are parallel to its strike. Minor amounts of sericite, chlorite, and quartz occur along interfaces between some of the barite crystals. The sulfides include pyrite and lesser amounts of galena, sphalerite, and chalcopyrite. Secondary minerals including gypsum, azurite, chrysocolla, limonite, and rare anglesite, cerussite, and smithsonite locally

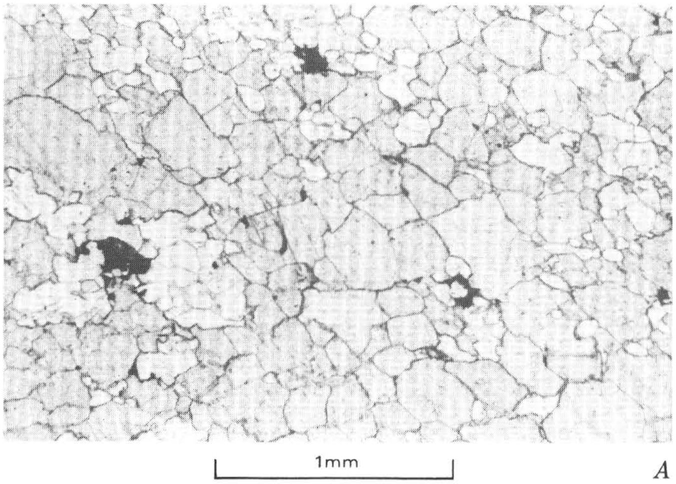


Base from U.S. Geological Survey 1:63,360 Skagway B-4, 1954

Mapped by E. M. MacKevett, Jr., July 18, 1971

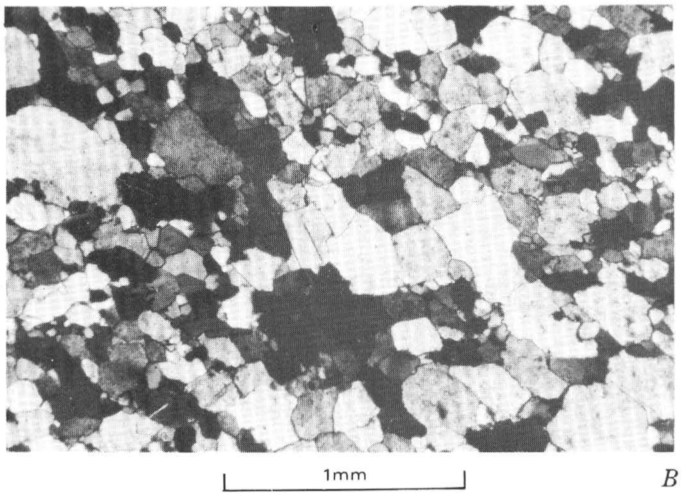
FIGURE 9.—Geologic sketch map showing sample locations at main barite-rich deposit north of Glacier Creek.

coat near-surface fractures or encrust small parts of the lode. Semiquantitative spectrographic analyses of samples from the lode are given in table 8 and in more detail in the report by MacKevett (1971). Analytical results for samples from both the main and the nunatak lodes that were tested for barium by gravimetric methods are given in table 9. Many of the barite-rich samples contained more than 5,000 ppm stron-



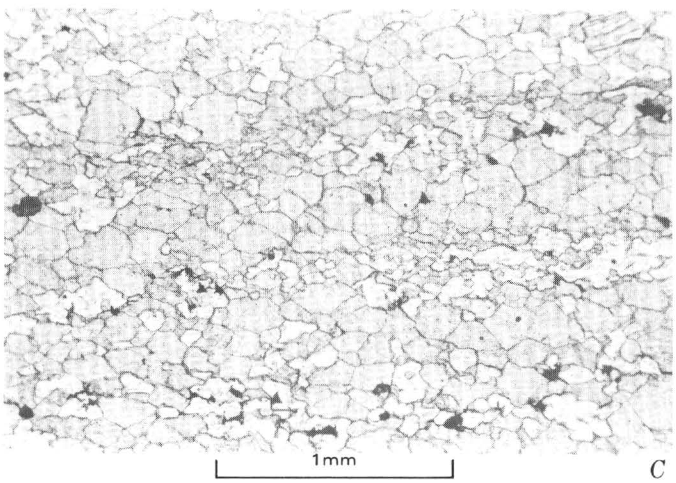
A

A, Barite-rich lode with minor impurities, chiefly quartz. Ordinary light.



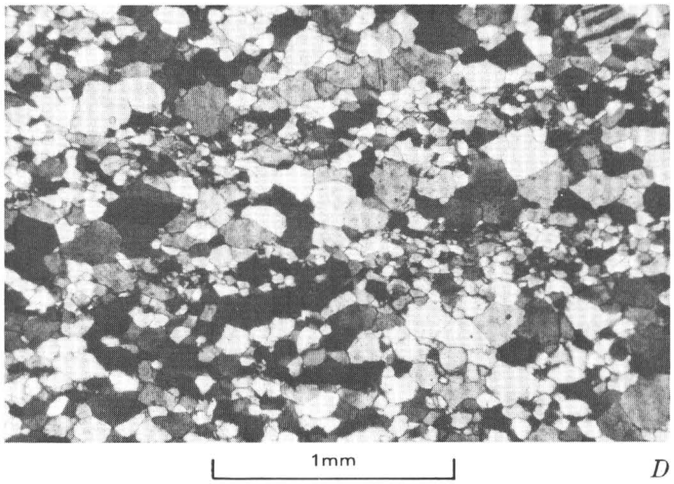
B

B, Same. Crossed nicols.



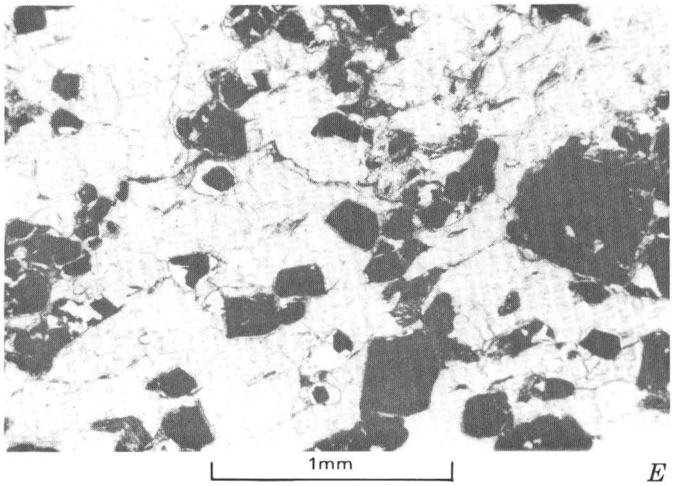
C

C, Sheared barite-rich lode. Ordinary light.



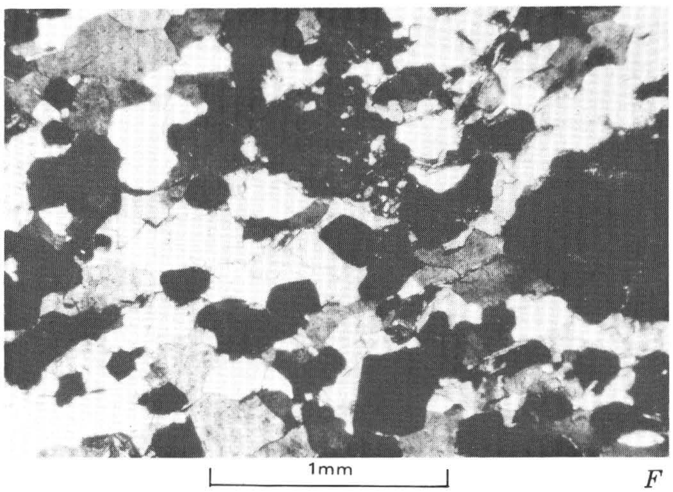
D

D, Same. Crossed nicols.



E

E, Barite-rich lode with scattered opaque minerals, chiefly pyrite. Ordinary light.



F

F, Same. Crossed nicols.

FIGURE 10.—Photomicrographs of barite-rich samples from main deposit.

TABLE 9.—*Gravimetric analyses for barium*

[Analysts, J. C. Negri and Z. C. Stephenson. Sample descriptions are given in table 8]

Field No.	Barium (percent)
71AMk–7A– 1	19.9
7A– 2	39.2
7B– 1	42.3
7B– 2	43.9
7B– 3	46.9
8A– 2	43.0
8A– 3	47.9
8B– 2	35.1
8C– 2	28.9
8C– 3	35.2
8C– 5	35.6
A– 1	38.5
A– 2	53.1
A– 8	48.1
A– 9	49.8
A–10	50.4

tium, although the strontium sulfate, celestite, was not detected during our studies. According to Palache, Berman, and Frondel (1951, p. 410), strontium can substitute for barium, and a complete series exists between the phases barite and celestite. Probably such isomorphous substitution has occurred in the strontium-rich samples; however, because the strontium:barium ratios are undoubtedly less than 1:1, the requisite ratio for celestite, the sulfate probably should be mineralogically classified as strontium-rich barite. Some of the barite-rich samples that are anomalously high in lead but carry little or no galena probably contain lead that has substituted for some of the barium in barite. According to Palache, Berman, and Frondel (1951, p. 411), such substitution of lead for barium may take place in ratios of as much as 1:4. A few of the samples contain minor amounts of gold. The presence of such elements as antimony, arsenic, and bismuth suggests that the deposit also contains some sulfosalts. Most of the silver is probably incorporated in argentiferous galena. The distribution of the metallic ore minerals indicates a crude zonal pattern with the main concentrations of zinc and copper near the southern margins of the lode, but more detailed work is required to substantiate the apparent zonation. In addition to the barite-rich lode, some of the altered wallrock, breccia zones, and quartz veins within the fault zone contain low-grade concentrations of copper, silver, and zinc.

The nunatak deposit (pl. 1) is a northwest-striking, probably fault-controlled lode in metavolcanic rocks of the schist and phyllite unit. The metavolcanic rocks are greenish-gray, crudely foliated, porphyritic, and weakly amygdaloidal lava flows composed of albitized plagiocase phenocrysts in a highly altered groundmass. They consist chiefly of albite and chlorite with lesser amounts of calcite, biotite, epidote, quartz, sericite, pyrite, and hematite. The lode is as much as 20 feet thick and is compositionally and mineralogically similar to the main lode (tables 8 and 9, and MacKevett, 1971).

A series of barite-rich veins is exposed adjacent to the north edge of Saksaia Glacier (pl. 1). The veins, which strike northwestward and dip steeply, are as much as a foot thick and localized within a zone about 50 feet thick. They cut metavolcanic rocks near a cupola of quartz diorite and contain mineral assemblages similar to the other barite-rich lodes. Magnetite- and jasper-bearing rock, probably of contact-metamorphic origin, crops out over a small area northeast of the cupola.

Other deposits crop out at altitudes of about 5,600 feet near the head of Little Jarvis Glacier (pl. 1). They are localized in or near a northwest-striking altered dike that dips steeply northward. The dike is 4–8 feet thick and cuts metavolcanic rocks. The deposits consist of ladder veins within the dike, and a vein along the footwall. The ladder veins are as much as 6 inches thick and contain quartz, calcite, sphalerite, galena, and minor chalcopyrite. The footwall vein is 1–2 feet thick and contains fairly abundant galena and minor pyrite, sphalerite, and chalcopyrite in a barite-rich gangue. Barite-rich float has been found at a few other localities in the vicinity.

The barite-silver-base metal deposits are interpreted as vein deposits of hydrothermal origin. They probably are genetically linked with late-stage fluid emanations from the Cretaceous quartz diorite-granodiorite magma, but the precise nature of this association and whether the emanations also contained elements derived from country rocks are not known. Except for local shearing, the deposits are undeformed, and they postdate the regional metamorphism. They appear to have been localized along favorable structural sites near exposed plutons or inferred concealed plutons.

OTHER COMMODITIES

Other mineral commodities in the B–3 and B–4 quadrangles that have potential use in local industry and construction include marble, construction stone, and sand and gravel. Analyses of the marble (tables 1 and 2) indicate that some marble may be suitable for the manufacture of cement. Most large marble bodies crop out close to the Haines Highway, and access to them is reasonably good. Development of the large marble resource south of the Klehini River (pl. 1) probably would entail improving the present bridge across the Klehini or constructing a new bridge. Rock suitable for various construction purposes such as road metal or riprap is locally available. Such rock includes the marble, which could be crushed for certain uses, and rocks of the gabbro and diorite complex along the front of the Takshanuk Mountains. The tendency for the strongly foliated metamorphic rocks to slab when broken limits their use. Deposits of sand and gravel are best developed along flood plains and river bars of the Chilkat and Klehini Rivers and are readily accessible. Some of these deposits have been exploited on a small scale.

GEOCHEMICAL SAMPLING

Geochemical sampling conducted during the investigation consisted of collecting 249 stream-sediment samples and 209 bedrock samples including veins and altered rocks. Except for a sediment sample from a stream on the Klukwan fan, the B–3 quadrangle east of the Chilkat River was not sampled during our investigations. All samples were analyzed for 30 elements by semiquantitative spectrographic methods and for gold by atomic absorption methods. Sample locations, analytical procedures, and results of all the stream-sediment samples and the 149 bedrock samples that were collected in 1969 are given in Winkler and MacKevett (1970). Tables 1, 3, and 8 incorporate 60 additional analyses of rocks, veins, and altered zones and 66 analyses of the bedrock samples collected during 1969. Analyses of the 66 samples are included because they provide background geochemical data on rocks in the quadrangle or contain anomalous concentrations of metals. Locations of samples included in the tables are shown on plate 1. The geochemical sampling revealed numerous, mainly minor, anomalous concentrations of metals, which are summarized in the following section.

PRECIOUS METALS

Gold was detected in samples from the main barite-rich lode north of Glacier Creek in amounts ranging from 0.06 to 10 ppm, from a sulfide-bearing quartz vein north of Glacier Creek (0.04 ppm), and a pyrite-bearing slate in the Porcupine District (0.02 ppm). The few stream-sediment samples that revealed gold were from Porcupine Creek and its tributaries, and these contained between 0.1 and 1.0 ppm gold.

Most anomalous concentrations of silver are in the northern part of the B–4 quadrangle south of the Klehini River. The largest concentrations are in the barite-rich lodes near Glacier Creek, which contain as much as 700 ppm silver. Some sulfide-bearing veins, mainly in the Porcupine and Glacier Creek drainages, contain between 0.5 and 15 ppm silver. Barite-rich float on Jarvis Glacier contained 10 ppm silver, an indication that barite-rich deposits similar to those near Glacier Creek extend into the Jarvis Creek watershed. Two altered zones north of Jarvis Creek contained 0.5 and 1.5 ppm silver. Pyrite-bearing slates in the Porcupine District contained as much as 5 ppm silver, and an altered mafic dike on Cahoon Creek contained 7 ppm silver. Silver in amounts of 1 and 1.5 ppm was detected in two carbonaceous schists and in a hornfels. Minor anomalous amounts of silver ranging from 0.5 to 1.5 ppm were found in stream-sediment samples from the Porcupine drainage, from Glacier and Jarvis Creeks, and from many south-flowing tributaries of the Tsirku River.

BASE AND RELATED METALS

The richest and largest concentrations of copper are associated with the barite-rich deposits near Glacier Creek. A sample from a sulfide-rich lens within the main barite-rich lode contained more than 20,000 ppm copper, and samples from mineralized wallrock bordering the lode contained as much as 20,000 ppm copper. Other samples from the lodes contained as much as 15,000 ppm copper. Copper was detected in amounts as much as 7,000 ppm from sulfide-rich quartz veins in the Porcupine and Glacier Creek drainages. The copper content of other sampled quartz veins in the quadrangles generally ranged from 150 to 300 ppm. Samples from a few altered zones, notably those north of Jarvis Glacier, contained between 150 and 300 ppm copper. Minor anomalous amounts of copper (150–300 ppm) were detected in many rock samples, particularly from the altered mafic dikes and the diabase. Copper in minor anomalous quantities of 150 or 200 ppm was found in numerous stream-sediment samples, mainly from Jarvis and Glacier Creeks and the Tsirku River drainage.

The main concentrations of lead are associated with the barite-rich deposits near Glacier Creek. Several samples from the barite-rich lodes contained more than 20,000 ppm lead, and a sample from a sulfide-rich lens within the main lode contained 20,000 ppm lead. Altered wallrock samples near the lodes contained as much as 1,500 ppm lead, but their lead contents were generally much lower. Anomalous amounts of lead were found in only a few other bedrock or vein samples from elsewhere in the quadrangles. These samples include barite-rich float on Jarvis Glacier that is similar to the Glacier Creek lodes and contained 700 ppm lead, pyrite-bearing slate (150 ppm) and an altered dike (300 ppm) from the Porcupine Creek drainage, and an altered zone (300 ppm) north of the upper Tsirku River. Lead in concentrations of 100 ppm was detected in three stream-sediment samples from widely scattered localities.

Like the other base metals and silver, the largest concentrations of zinc are associated with the barite-rich lodes near Glacier Creek. Zinc is sporadically distributed in the lodes and in nearby altered wallrock and sulfide-rich lenses. Several samples from the lodes contained more than 10,000 ppm zinc whereas others lacked detectable zinc. The altered zones, sulfide lenses, and breccia zones associated with the barite-rich deposits showed similar variances in zinc content. Zinc is widely distributed in rocks, altered zones, and veins elsewhere in the quadrangles. Its notable anomalous concentrations are in sulfide-rich quartz vein float from Porcupine Creek (greater than 10,000 ppm), in carbonaceous schist laced with quartz veinlets from Big Boulder Creek and west of Chilkat Lake (1,500 ppm), in barite-rich float on Jarvis Glacier (700 ppm), and from a pyrite-bearing sill west of Summit Creek (700 ppm). Zinc in anomalous amounts between 200 and 2,000 ppm was detected in many stream-sediment samples, particularly those from streams emerging from the mountains between the Klehini and Tsirku Rivers. Although samples from Glacier and Porcupine Creeks and nearby streams yielded many anomalous zinc values, the largest and the most numerous zinc anomalies were in samples from south-flowing tributaries of the Tsirku.

Cadmium, a geochemical affiliate of zinc, was found in amounts greater than 500 ppm in sulfide-rich quartz vein float from Porcupine Creek and in lesser anomalous amounts in some samples from the Glacier Creek barite deposits. It was not detected in the stream-sediment samples.

Minor anomalous amounts of arsenic, antimony, and bismuth were found in the barite-rich deposits near Glacier Creek, but except for 200 ppm arsenic from a breccia zone south of Glacier Creek, these elements were not detected in other samples, including the stream sediments. Tin was detected in only one sample, 20 ppm in fragmented pegmatitic material in a fault zone on Boulder Creek.

IRON AND FERROALLOY METALS

Iron in concentrations of 20 percent or more was detected in amphibolite and hornfels from Tahkin Ridge, in two pyrite-rich quartz veins, and in pyrite-rich parts of the main Glacier Creek barite deposit and a nearby breccia zone. It was found in similar quantities in several stream-sediment samples, particularly from streams in the Porcupine drainage and from a stream draining the Klukwan fan.

Several minor manganese anomalies were detected in both the bedrock and the stream-sediment samples. Titanium in amounts greater than 1 percent was found in the two sampled diabase dikes and in a schist south of the upper part of the Tsirku River. The few stream-sediment samples that contained more than 1 percent titanium were from the Porcupine drainage and near the headwaters of the Tsirku.

Cobalt in amounts of 150 or 300 ppm was found in a few pyrite-rich quartz veins in the environs of Glacier and Porcupine Creeks and near the headwaters of the Tsirku River and in a pyrite-bearing dike north of Glacier Creek. The maximum cobalt detected in the stream sediments, 100 ppm, was in samples from Glacier Creek and a south-flowing stream draining Tahkin Ridge.

The largest amount of chromium detected, 3,000 ppm, was from an altered mafic dike near the junction of Porcupine and McKinley Creeks. Chromium in concentrations between 300 and 700 ppm was detected in several other mafic dikes from widely scattered localities. It was found in similar concentrations in some of the metamorphic rocks including hornfelses and amphibolites from Tahkin Ridge and a chloritic schist north of Glacier Creek. Altered zones north of Jarvis Glacier and at the main Glacier Creek barite prospect contained 300 and 700 ppm chromium, respectively. A stream-sediment sample from a southward-flowing stream draining Tahkin Ridge contained 700 ppm chromium. Several stream-sediment samples from Porcupine Creek and its tributaries contained between 300 and 500 ppm chromium.

The richest molybdenum sample contained 150 ppm molybdenum and came from the barite-rich lode at the nunatak prospect. Several other samples representative of lodes and associated veins and wallrock at the Glacier Creek barite prospects contained between 10 and 100 ppm molybdenum. Carbonaceous schist from a roadcut west of Big Boulder Creek and pyrite-bearing slate from Porcupine Creek each contained 70 ppm molybdenum. Lesser anomalous amounts of molybdenum were found in a few other metamorphic rocks, veins, and altered zones. Stream-sediment samples from the Tsirku River and its south-flowing tributaries rather consistently contained anomalous quantities of molybdenum in the range of 7 to 30 ppm. Molybdenum in concentrations of 7 or 15 ppm was detected in several other stream-sediment samples, chiefly those from the Porcupine drainage.

A sample of the altered mafic dike near the confluence of Porcupine and McKinley Creeks contained 1,000 ppm nickel, and a few altered zones and sulfide-rich quartz veins from the vicinities of Porcupine, Glacier, and Jarvis Creeks contained 200 or 300 ppm nickel. Several of the metamorphic rocks contained minor but probably anomalous amounts of nickel.

Concentrations of 150 ppm nickel were found in many of the stream-sediment samples.

Vanadium in the 500–700 ppm range is common in many of the intrusive and metamorphic rocks, altered zones, and veins. The only important quantities of vanadium that were found in the stream-sediment samples were 1,000 and 1,500 ppm from a stream on the Klukwan fan. Some stream-sediment samples from the Porcupine and Tsirku drainages contained 500 or 700 ppm vanadium. Tungsten was not detected in any of the samples.

MISCELLANEOUS METALS

The geochemical sampling disclosed anomalous concentrations of several elements, herein termed miscellaneous metals, including boron, barium, beryllium, lanthanum, niobium, strontium, yttrium, and zirconium.

The largest amount of boron detected, 300 ppm, was from an altered porphyritic dike sample collected in the mountains west of Mosquito Lake. Samples of carbonaceous schist from the schist and phyllite unit contained 70 ppm boron, and one sample of carbonaceous schist laced with quartz stringers contained 150 ppm boron. A hornfels from Tahkin Ridge and an altered zone exposed on the highway about half a mile west of Muncaster Creek (fig. 11) contained 70 ppm boron. The only markedly anomalous boron concentrations in the stream-sediment samples (100 ppm) were from Big Boulder Creek and a small creek about 1½ miles east of Pleasant Camp. A few stream-sediment samples from upper parts of the Tsirku drainage contained 70 ppm boron.

Besides the major amounts of barium disclosed in most samples from the prospects near Glacier Creek, barium was found in concentrations greater than 5,000 ppm in barite-rich float on Jarvis Glacier and in lesser quantities in many other samples. Among these are pyrite-rich slate from Porcupine Creek (5,000 ppm), carbonaceous schist west of Boulder Creek (3,000 ppm), and an altered zone in a roadcut west of Little Boulder Creek (3,000 ppm). Many other bedrock samples contained 2,000 ppm barium. Stream-sediment samples yielded concentrations of barium as much as 2,000 ppm from south-flowing tributaries of the Tsirku and from the Porcupine drainage, and 2,000 ppm from a creek discharging near milepost 30 on the Haines Highway; numerous samples contained 1,500 ppm barium.

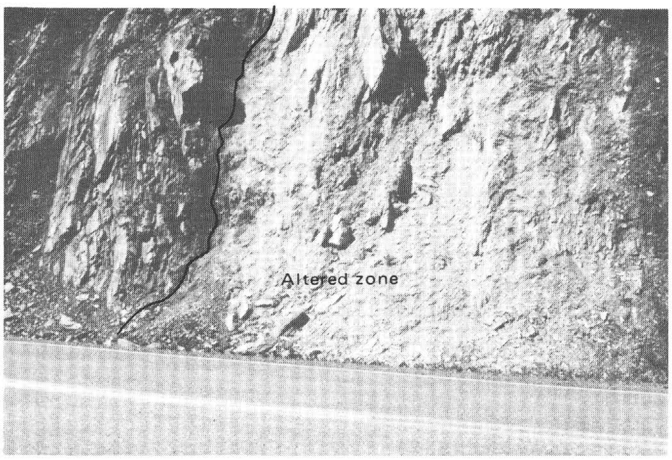


FIGURE 11.—Altered zone exposed in roadcut west of Muncaster Creek in rocks of the schist and phyllite unit and marble (at left extremity of photo).

Beryllium was not detected in significant amounts in any of the samples. Its largest concentrations, 3 and 2 ppm, were, respectively, from hornfels and spotted schist on Tahkin Ridge. It was not found in amounts greater than 1.5 ppm in any of the stream-sediment samples.

Lanthanum constituted 300 ppm of a chip sample across a fault zone containing fragmented pegmatitic material on Big Boulder Creek. It was found in amounts of 70 ppm in three other bedrock samples. Stream-sediment samples from tributaries of the Tsirku contained as much as 300 ppm lanthanum, and similar samples from Big Boulder Creek and a nearby creek and from Muncaster Creek contained 150 ppm lanthanum.

The only anomalous concentrations of niobium found in the bedrock samples were 500 ppm in the chip sample of fragmented pegmatitic material from Big Boulder Creek and 150 ppm from a fault zone west of the Big Boulder Creek bridge. The most niobium detected in stream-sediment samples, 30 ppm, was from a creek west of Big Boulder Creek.

Strontium is intimately associated with barium in barite from the Glacier Creek deposits, and several samples from these deposits contained more than 5,000 ppm strontium. The highest strontium value other than from barite-rich samples was from an alaskite dike south of Chilkat Lake that contained 1,000 ppm strontium. The highest strontium content in the stream sediments was in two samples from the Tsirku drainage (700 ppm).

200 ppm yttrium was detected in the Big Boulder Creek chip sample containing fragmented pegmatite; it constituted 70 ppm of a diabase; however, only negligible amounts of yttrium were found in the other bedrock samples. Stream-sediment samples that contained 70 to 100 ppm yttrium were mainly from the Tsirku River and its tributaries.

Zirconium was detected in quantities greater than 10,000 ppm in the fragmented pegmatite sample from

Big Boulder Creek and 700 ppm occurred in the sample of fragmented aplite west of the Big Boulder Creek bridge. It was found in amounts of 300 ppm in several rocks containing zircon as a minor accessory mineral and in a few altered zones. Stream-sediment analyses revealed 500 ppm zirconium in one sample from Big Boulder Creek and one from the Tsirku, and 300 ppm zirconium in other samples from these and nearby streams and from the Porcupine drainage.

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