GEOLOGY AND GEOCHEMISTRY OF THE CRAIG A-2 QUADRANGLE AND VICINITY, PRINCE OF WALES ISLAND, SOUTHEASTERN ALASKA

By
Gordon Herreid, Thomas K. Bundtzen, and Donald L. Turner

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Gordon Herreid,[1] Thomas K. Bundtzen,[1] and Donald L. Turner[2]

SUMMARY

The Craig A-2 quadrangle, on the southern part of Prince of Wales Island, contains copper deposits and anomalously old layered rocks, which include the Wales Group, the oldest known unit in southeastern Alaska. The Wales Group is about 3,400 m thick in the western part of the area. It contains varying amounts of marble, tuffaceous schist and phyllite, metakeratophyre tuff(?), metaspillite, quartz sericite schist, migmatitic gneiss, and slightly recrystallized limestone and phyllite. A trondhjemite dated at 730 m.y. intrudes the Wales Group (Churkin and Eberlein, 1977), providing evidence that the group is Precambrian. The date of cessation of the most recent regional thermal event affecting Wales Group rocks was determined to be about 475 m.y. B.P. (Turner and others, 1977).

In fault contact with the Wales Group are marine turbidites of the Descon Formation, which has been faunally dated west of the map area as Middle to Late Ordovician (Eberlein and Churkin, 1970). The Descon Formation in the study area consists of an 8,000-m-thick section of unmetamorphosed turbidite, graywacke, mudstone, and basalt. Calc-alkaline granitoid rocks with a minimum age of 421 m.y. (Turner and others, 1977) apparently intrude the Descon Formation near Max Cove.

After folding and deep erosion, the Descon Formation and associated intrusives were overlain by over 2,500 m of Middle Devonian sedimentary rocks. This section contains locally derived basal conglomerate, gray mudstones, green graywacke, pebble conglomerates, and minor limestone. These Devonian sediments are capped by andesite flows and andesite breccia of probable Devonian age. A conjugate system of numerous steeply dipping dikes of intermediate and mafic composition intrudes the bedded rock units.

Granodiorite plutons in the area have ^{40}K-^{40}Ar ages averaging 102 m.y. (Turner and others, 1977). Other Cretaceous plutons include altered diorite, alaskite, and gabbro. No mafic or intermediate dikes are believed to cut the Cretaceous intrusives.

Crenulations and minor folds near the base of the Descon Formation and in the Wales Group indicate that there have been two periods of penetrative deformation. The last major folding episode occurred between post-Middle Devonian and pre-Cretaceous time. A prominent thrust fault cuts Middle Devonian sedimentary rocks and is in turn penetrated by a Cretaceous granodiorite pluton. High-angle faults are widespread. A set of northeast-trending high-angle faults is cut by a younger northwest-trending high-angle fault system. These faults are responsible for many of the present-day topographic lineaments in the study area. Low-angle thrust faults are not clearly reflected by topography.

During Pleistocene time, the area was covered by an ice sheet. The glacial topography is preserved today as accordant ridges and scattered higher hills of resistant rock. Wisconsin-age valley glaciers have carved classic U-shaped depressions in the valleys, and glacial till covers most of the bedrock there. Today the area has steep, heavily forested slopes and long, deep fiords.

The principal productive mineral deposits in the area are skarns containing copper, zinc, molybdenum, and gold around the Copper Mountain pluton (Cretaceous). The largest known deposit, the Jumbo Mine, produced 10,194,264 lb of copper, 87,778 oz of silver, and 7,676 oz of gold during the first part of the century (Kennedy, 1953). Museum-quality epidote and quartz crystals have been won from the skarns around the pluton. Several small copper-zinc-gold deposits (Corbin, Copper City, Keete, and Nutkwa Lagoon mines) in the Hetta Inlet area occur as sulfide zones parallel to foliation and associated with bimodal sodic volcanism in the Wales Group. The deposits, which are all in about the same stratigraphic position, probably represent stratiform volcanogenic mineralization. Along the South Arm of Cholmondeley Sound lead, zinc, and silver vein deposits, lenses, and disseminations occur near large siliceous zones in the Wales Group. Two deposits are not near intrusive exposures and could be partly remobilized stratiform deposits. Dolomite deposits are of variable age, occurring as older boudins in the Wales Group and younger remobilizations along faults associated with mafic dikes. Many quartz veins were formed before the end of regional penetrative deformation and are preserved at thickened hinges along fold axes. Younger nonfolded quartz veins fill high-angle fractures and are sometimes mineralized with sulfides.

Throughout the area 1,270 stream-sediment, soil, and rock samples were collected and analyzed by atomic absorption spectrophotometry (Cu-Pb-Zn) and by emission spectrography (30-element scan). Stream-sediment fractions (-80 mesh) show copper anomalies in the Hetta Inlet area and strong lead, zinc, beryllium, zirconium, and silver anomalies along Cholmondeley Sound.

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Distinct rare-earth anomalies in the Kassa Inlet area are probably the geochemical signature of the Devonian(?) volcanic rocks there. Some of the anomalies found in the study area may be the geochemical signature of undiscovered mineral deposits.

SCOPE OF PRESENT INVESTIGATIONS

This report summarizes three field seasons of a geologic mineral appraisal in a well-known copper mining district on Prince of Wales Island west of Ketchikan. Field work began in 1970 and was completed in 1972. Geologic mapping of about 720 km^2 was completed at 1:40,000 scale (fig. 1). Geologic field assistants were J.C. Pray and T.K. Bundtzen. Marilyn Herreid worked gratis as boat handler, expeditor, and cook all three seasons. Most of the stream-sediment samples were taken by Pray and Bundtzen. During the latter part of the work, both did much detailed mapping around Copper Mountain, Cholmondeley Sound, and Kassa Inlet. D.L. Turner of the University of Alaska Geophysical Institute joined the field party in 1972 and collected ^{40}K-^{40}Ar age dating samples, the results of which have been published (Turner and others, 1977).

The generally excellent outcrops along shores of inlets and lakes were mapped with the aid of two 13-foot inflatable boats. Geology along the shore was plotted from 1960 U.S. Forest Service 1:20,000-scale black-and-white aerial photographs. Foot traverses along the shore were difficult. Mapping above timberline was done on foot from air-supported spike camps and helicopter landings. Steep valley walls account for a large percentage of the area and are accessible only on foot. Although much of the bedrock is covered with moss, berry bushes, 'devil's club,' trees, and glacial till, outcrops along small creeks, beneath roots of wind falls, and along cliffs provided valuable data during geologic mapping.

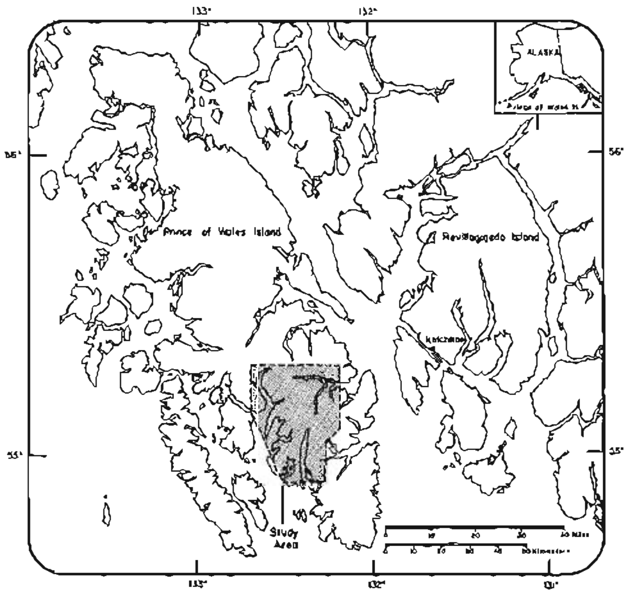

Figure 1. Location of study area, Prince of Wales Island, southeastern Alaska.

In this report, linear dimensions have been expressed in the metric system; however, the English system has been retained for weights and altitudes. During discussion of rock units, the reader is referred to the geologic map (pl. 1).

PREVIOUS INVESTIGATIONS

Brooks (1902) looked briefly at prospects on Cholmondeley Sound and Hetta Inlet in 1901 and described the history of prospecting in southeast Alaska. From 1905 to 1908 the Wright brothers made wide-ranging geological investigations in southeastern Alaska. They produced a reconnaissance map of the Copper Mountain area (Wright and Wright, 1906), reported developments in the area (Wright, 1907, 1908), and published a reconnaissance report on the Ketchikan and Wrangell mining districts that contained a 1906 geological map of the Copper Mountain area (Wright and Wright, 1908). Detailed mapping by C.W. Wright in 1908 was later published (Wright, 1915); his work also includes a regional reconnaissance map of southeastern Alaska.

Chapin (1916, 1918) briefly described mineral prospects at Keete Inlet, Nutkwa Lagoon, Green Monster Mountain, and the areas northeast of Sulzer. Buddington and Chapin (1929) showed the area on their 1:500,000 geologic map of southeastern Alaska. Twenhofel and others (1949, p. 17-20) described the prospects at Lime Point and Nutkwa Lagoon. Kennedy (1953) contributed an excellent geologic study of the origin of the skarn deposits in the Jumbo basin. Condon (1961) composed a useful geologic map of the Craig 1:250,000 quadrangle from previous sources of information and his own aerial photographic interpretation. Eberlein and Churkin (1970), Churkin and others (1970), and Churkin and Eberlein (1977) have provided valuable fossil and radiometric age control for the area.

GEOGRAPHY

The area mapped is part of Prince of Wales Island, the largest island in southeastern Alaska; the eastern border of the map area is about 50 km west of Ketchikan (fig. 1). The area is composed of steep, heavily forested mountains and long ocean fiords. Inlets include Klakas, Hetta, Kassa, Nutkwa, Keete, and the West and South Arms of Cholmondeley Sound (hereafter referred to simply as "West Arm" and "South Arm"). Copper Mountain, 3,916 feet above sea level, is the highest peak on Prince of Wales Island.

A crude pattern of land forms in the map area are due to erosion of a structurally complex terrane. Klakas Inlet and South Arm are aligned along a major north-trending fault, whereas the upper reaches of Hetta Inlet and West Arm are aligned with the West Arm fault. Several of the larger north-northwest-flowing creeks are located in fracture zones. Uplands are made of resistant rock such as intrusives and siliceous schists. In some areas, sinkholes form an interconnecting network of hazardous, steep-walled pits, 6 to 35 m in diameter. In areas covered by vegetation, these pits indicate that the bedrock is marble or calcareous schist.

Accordant ridge tops throughout the area are remnants of an older surface of moderate relief (fig. 2) that has been scoured by a Pleistocene ice cap and subsequent valley glaciers of Wisconsin age (Péwé, 1975). Modern stream valleys are classic U-shaped glacial valleys with lakes and bogs in bedrock depressions and are mantled with up to several meters of till.

The ocean inlets (fiords) are glacial troughs with floors extending several hundred feet below sea level. Except where major streams drain into inlets, the shores are steep and have abundant bedrock exposures.

The climate is cool and wet. In January the mean daily minimum temperature is 30°F (-1°C); in July the mean daily maximum is 64°F (18°C). The mean annual precipitation is 406 cm (160 inches) (Wahrhaftig, 1965).

Principal industries are logging and fishing, and in the past, mining. Small percentages of the available commercial stands of Sitka spruce, hemlock, and cedar have been logged. Commercial salmon, halibut, and shrimp fishing occurs mainly in Hetta Inlet. At the turn of the century, several mineral deposits, most notably the Jumbo Mine, were mined for copper, silver, lead, and gold.

The area is accessible by boat and aircraft from Ketchikan. Roads and trails are rare; there are short logging roads near Miller Lake on South Arm and north of Jumbo Creek on Hetta Inlet. Ruins of an old corduroy wagon road from Hetta Inlet to West Arm were still in existence in 1972. At the Jumbo Mine, a 3-km-long trail from the lower adit to the beach is in fairly good condition. The remains of the old aerial tram at Jumbo were still visible.

There are few permanent residents in the area. Hydaburg, a small fishing village, is 13 km northwest of Eek, on Sukkwan Strait. The Alaska Department of Fish and Game maintains weirs on creeks draining into Hetta Cove, South Arm, and on Klakas Lake, a king-salmon spawning area. David Drury had a small semipermanent logging camp on the east shore of South Arm. In the past, coastal Indians chipped designs on boulders along the beach. These petroglyphs can be found along Hetta Inlet in the tidal zone.

GEOLOGIC UNITS

WALES GROUP

INTRODUCTION

Brooks (1902) named the regionally metamorphosed rocks (marble, phyllite, and schist) on Prince of Wales Island the Wales Series and considered them to be probably Silurian or older. Many of the rocks he originally included in this unit are now mapped as Ordovician, Silurian and, near Ketchikan, Mesozoic. Buddington and Chapin (1929) mapped unfossiliferous regional metamorphic rocks as Wales Group of "probable Devonian to pre-Ordovician age," and attempted to exclude Ordovician and younger rocks whenever possible.

In this report the more strongly metamorphosed rocks are classified as Wales Group. They contrast with nonfoliated Middle Ordovician Descon Formation and Devonian and younger bedded rocks nearby. All of the Wales Group rocks in the area mapped appear to have had the same metamorphic history, but could include rocks of different ages. In the vicinity of Eek Point near the western edge of the map area (pl. 1), Wales Group schists and metakeratophyre may grade upward, with a gradual decrease in metamorphism, into the rocks of the

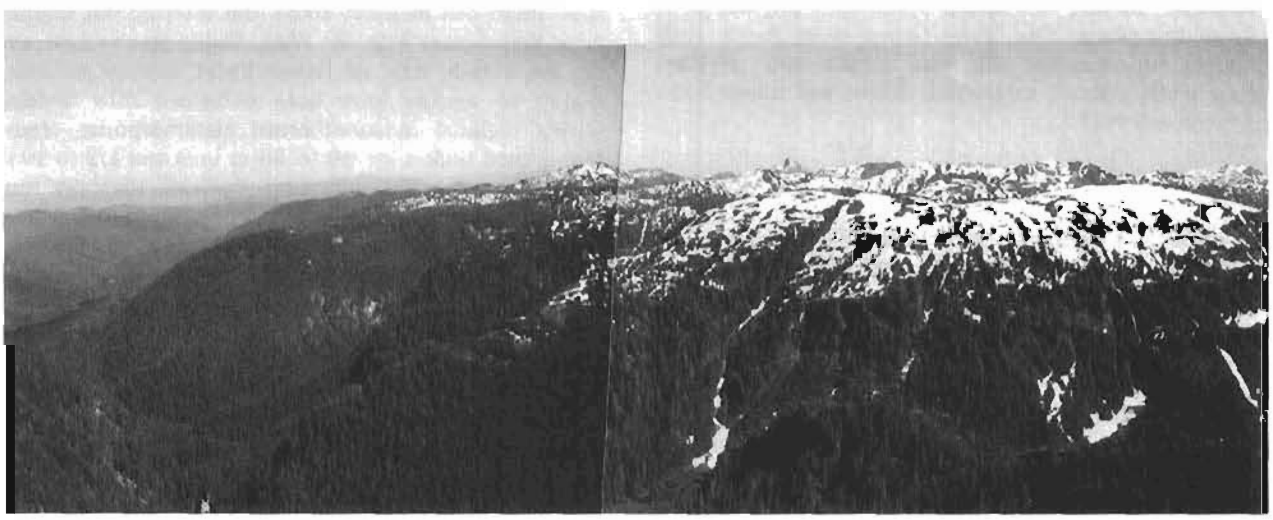

Figure 2. Accordant ridge tops showing the preglacial terrane, looking southeast from near the top of Green Monster Mountain. West Arm is on the left.

Descon Formation. The gradual nature of this transition makes the exact placement of the Descon-Wales contact difficult. Because green schists[3] and metakeratophyres were mapped to the western boundary of the mapped area, the problemmatical Descon-Wales contact was not delineated during this study. In the east-southeast portion of the area, the Wales Group is thrust under the Descon Formation along the Keete thrust.

The Wales Group is a thick pile of volcanogenic turbidite, mudstone, tholeiitic(?) marine keratophyre, and related volcanic rocks and carbonate that have undergone greenschist-facies metamorphism (Winkler, 1967). It varies in composition over its aerial extent (pl. 1).

On the west, near Eek Point, the Wales Group is predominantly green tuffaceous schist and dark-gray phyllite. Scattered metakeratophyre beds make up to 15 percent of this section. Near Deer Bay metakeratophyre and metakeratophyre lapilli(?) tuff are of mappable size. Occasional beds of mafic metavolcanic rocks, marble, siliceous schist, and quartz sericite schist are present in the section. Near Corbin Point a 300-m-thick section of quartz-sericite schist overlies the green tuffaceous schist unit. Between Eek and Corbin Points the Wales Group section is about 3,400 m thick. These units extend southeast into Kassa Inlet. Near Hetta Inlet this entire section is overlain by a thick thrust sheet of Wales Group marble and dark-gray phyllite.

To the east along the south side of West Arm, metafelsite beds and megascopic albite grains in the Wales Group section pinch out at the entrance of South Arm. In addition, metabasalt flows increase in abundance in the Wales Group section eastward from Hetta Inlet to South Arm. Rocks on the north and south sides of West Arm are displaced by the West Arm fault. On the north side of the fault the Wales Group consists largely of homogeneous green-gray schist without megascopic albite, whereas on the south side the mafic metavolcanics, marble, and green schist and phyllite constitute the group. The Wales Group along South Arm consists of abundant siliceous schists and phyllite, green schist without megascopic albite, and minor basic metavolcanic rocks.

MARBLE (Wm)

Marble is a distinctive unit in the Wales group. Thin marble beds are interbedded with the Wales Group schists throughout much of the map area. South of West Arm a thrust sheet consists of marble and minor green schists.

Most of the marble is very light to medium-gray fine-grained crystalline rock that weathers medium gray. Near intrusive contacts it is recrystallized into a coarser grained very light gray rock. In some areas it has thin color or composition bands parallel to bedding; elsewhere it is massive with no hint of bedding on fresh surfaces. Minor folds within marble beds are common. Beach outcrops are pitted by solution. Intersecting solution pits up to 30 m in diameter and 10 m deep in upland areas make foot travel hazardous, particularly west of Big River.

In some areas medium-gray fine-grained marble with dolomitic nodules contains a large percentage of crosscutting, very light gray crystalline calcite veinlets with sharp contacts. The rock imperceptibly grades into a very light gray crystalline marble with no dolomitic nodules. In other areas very light gray marble and medium-gray limestone occur close enough to suggest that the color change is not due to metamorphism. An aureole of very light gray crystalline marble up to 200 m wide is present around the Copper Mountain pluton, suggestive of recrystallization by the intrusive.

Buddington and Chapin (1929) report finding "possible coral fragments" of Silurian appearance at Lime Point. Neither we nor Eberlein (pers. comm., 1972) found any fossils during field work in Wales Group rocks. The marble (Wm) and dark-gray phyllite (Wp) in the upper thrust plate at the north end of Hetta Inlet make up a major member of the Wales Group. Wm and Wp may be younger than the Wales Group rocks on Hetta Inlet and Sukkwan Strait, since units there underlie(?) them.

DOLOMITE-RICH MARBLE (Wdm)

Dolomite-rich marble crops out at Hetta Inlet and in the Big River thrust sheet on West Arm. Similar-appearing but less extensive replacements(?) of marble by dolomite exist in the Wales Group on South Arm.

On the north shore of West Arm dolomite forms thick, planar, fine-grained medium- to-light-gray beds that stand out in relief above the interlayered marble. Near the contact with the Wales Group green schist, and on the islands west of Sunny Point, tabular dolomite bodies in marble have been deformed into boudins during regional dynamothermal metamorphism. These lens-shaped bodies are 10 to 30 m long and 1/2 to 10 m thick. Ridges and terminations indicate that the long axes of the boudins plunge steeply 45 to 80 degrees southwest. Elsewhere there are highly irregular dolomite bodies that stand up in relief on shoreline outcrops (fig. 3). Usually, irregular, folded dolomite bodies have marble beds draped around them, suggesting deformation of the rocks after deposition of the dolomite.

On the north shore of Divide Head, dolomite in marble forms thin partings parallel to bedding and small subangular lumps several centimeters across. In a few places there are many dolomite veinlets crosscutting the marble.

On the west shore of Hetta Inlet a thick marble bed in the phyllite-marble-green schist (Wpmg) 1/2 km south of Perry Creek has rounded irregular masses of

[3] In this report the term 'greenschist' means mafic meta-igneous rock that has a schistose texture. 'Green schist' is a schist with a distinctive green color but is not necessarily meta-igneous.

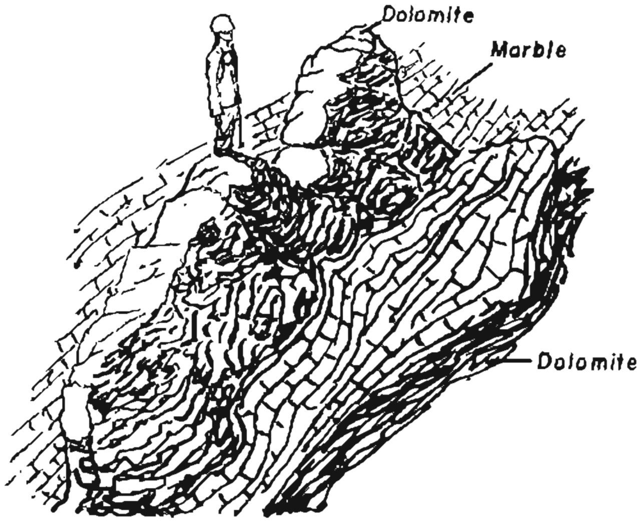

Figure 3. Sketch of two large dolomite boudins surrounded by marble (Wm), north shore of West Arm.

pinkish-gray dolomite up to 1 m thick. These are somewhat elongated with the enclosing marble and show evidence of plastic flow. The rock is essentially identical to dolomite-rich marble units on West Arm.

DARK-GRAY PHYLLITE (Wp)

Phyllite is a major unit of the Big River thrust sheet and of the northern portions of Hetta Inlet, near Gould Island, where it is interbedded with thick beds of marble. It is also present in the hornfels zone southeast of Dell Island. Scattered beds of phyllite occur along West Arm (included with the Wpmg unit) and adjacent to a fault zone on the west shore of Nutkwa Inlet.

This rock unit has finely crenulated foliation surfaces and commonly cleaves into 2-cm-thick plates. It is dark gray and fine size except in shear zones, which have many deformed quartz veinlets.

PHYLLITE, MARBLE, AND GREEN SCHIST (Wpmg)

This is a heterogeneous unit of the Wales Group that constitutes all the islands in West Arm. It occurs on the south shore of West Arm and makes up a similar lithology on Hetta Inlet. These rocks are greenish- to dark-gray phyllite, greenish-gray, limy, sericitic tuffaceous schist with twinned albite crystals, and marble. Unit Wpmg overlies the marble (Wm) and dark-gray phyllite (Wp) in the Big River thrust sheet.

GREEN TUFFACEOUS SCHIST (Wg)

Green tuffaceous schist is the most abundant rock along Hetta and Kassa Inlets (fig. 4) forming great thicknesses of well foliated greenish-gray schist, interbedded with occasional metakeratophyre, and basic metavolcanic layers 1/4 to 3 m thick. West of Eek Point the rocks grade into green and gray albite-bearing phyllites of identical composition.

The green tuffaceous schist is typically greenish gray to greenish black, fine grained with thin lenticular alternating quartzose and chloritic layers that range from 1 mm to several centimeters thick. The rock commonly contains a scattering of white 1/2-to 3-mm-long grains of albite that make up as much as 5 percent of the rock. The foliation swirls around the grains, indicating that they formed prior to the end of deformation. The foliation of the rock is due to the platy orientation of chlorite flakes. Almost everywhere foliation is parallel to composition bands in the green-schist and metakeratophyre beds.

The rock is believed to have originated as chloritic mudstone with a scattering of albite grains of tuffaceous origin (fig. 5). The minerals present are quartz, large subangular twinned albite (An 0 to 5), chlorite, carbonate, iron ore, leucoxene, and very minor actinolite. Biotite is rare, except in thermally metamorphosed rocks.

On the west shore of Hetta Inlet, shearing is more pronounced than recrystallization. Deeper in the section, on the east shore of Hetta Inlet, recrystallization has resulted in a more schistose fabric. Here the albite crystals have lost their lath shape and become part of an increasingly equant-grained granoblastic fabric. Large, twinned albite grains are preserved even in the rocks with granoblastic matrix, but it is not possible to differentiate tuffaceous mudstone from porphyritic metakeratophyre tuff once the albite has been recrystallized to granoblastic grains.

METAKERATOPHYRE TUFF(?) AND RELATED ROCKS (K, Kxt, Kd)

Beds of metakeratophyre tuff(?), metakeratophyre flows, and metaspilite occur in the green tuffaceous schist (Wg) of the Wales Group, particularly in the northern shores of Hetta Inlet and Sukkwan Strait near Eek Point. When of mappable size, these rock types are found on plate 1 as subunits within the green tuffaceous schist (Wg). On the east shore of Hetta Inlet and on Kassa Inlet they are somewhat less abundant. The rhyolite unit mapped in the Jumbo Basin by Kennedy (1953) is metakeratophyre. To the east on the West an South Arms, there is only minor green tuffaceous schist (Wg) and almost no metakeratophyre tuff(?) and related rocks.

Metakeratophyre tuff(?), the dominant metavolcanic rock type, occurs as conspicuous, nearly massive porphyritic metafelsite beds 1/4 to 3 m thick in green tuffaceous schist and phyllite and rarely makes up more than 10 percent of any particular section of the Wales Group (fig. 6). These beds parallel foliation and layering in the Wales Group schists and have contacts that range from sharp to gradational over a few centimeters. The metakeratophyre beds, usually light to medium gray,

Figure 4. Wales Group green tuffaceous schist along the shore on the north side of Keete Inlet, near the entrance.

sometimes take on a green or blue hue because of their chlorite content. The unfoliated or slightly foliated metafelsite usually contains about 3 percent macroscopic albite phenocrysts. A smaller percentage of megascopic quartz anhedra are usually present. The metakeratophyre tuff(?) beds are more brittle than the enclosing greenschist beds and are slightly stretched as a result. Fractures that formed in the metakeratophyre beds during brittle deformation are often filled with quartz veinlets. The megascopic evidence for the tuffaceous origin of the felsic beds is their apparent igneous texture (blastoporphyritic metafelsite) and their thinness (1/4 to 3 m).

A photomicrograph of metakeratophyre tuff(?) (fig. 7) shows the distinctive albite phenocrysts in a finer grained matrix. The albites are 1/2 to 3 mm long, often euhedral, but show slightly ragged borders. They often form in groups of several crystals that display complex twins that form a checkerboard pattern. Bent phenocrysts are sometimes present. The albite microlites(?) in the groundmass have albite twinning and ragged borders, are lath shaped (length to width ratio up to 10:1), and may be trachytic. Other minerals that make up the groundmass are equant quartz grains, chlorite flakes and veinlets, carbonate, magnetite(?), and leucoxene.

Blastoporphyritic metakeratophyre lapilli(?) tuff forms thin beds on the east shore of Nutkwa Inlet. A typical thin section shows albite phenocrysts(?) with carlsbad and albite twinning and ragged borders. The groundmass consists of quartz, albite, chlorite, opaques, and leucoxene. Twinned albite microlites(?) surround the phenocrysts(?) in a trachytic or fluidal pattern. Because the beds are thin (≤ 1 m), this texture may have originated as tuff. The tuff fragments are large enough (up to 3 cm) to preserve a primary igneous texture. Outer borders of the lapilli(?) are only rarely preserved and generally not visible.

Along the north and south shores of Deer Bay (pl. 1)

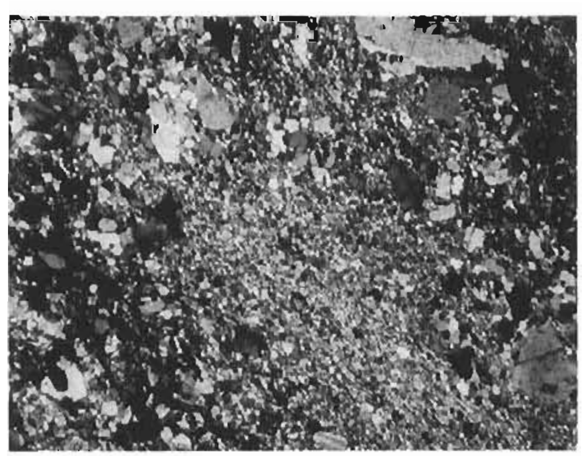

Figure 5. Photomicrograph of Wales Group green tuffaceous schist (Wg), west shore, Hetta Inlet. Sheared lapilli in a fine-grained matrix has produced a blastoporphyritic texture.

Figure 6. Metakeratophyre tuff(?) beds on west side of Hetta Inlet, 7.3 km south of Deer Bay. The rock below the pick is green tuffaceous schist (Wg).

are several graded crystal tuff(?) (Wkxt) beds up to 30 m thick that range from coarse fragmental rock at the base to fine-banded green-gray phyllite at the top. Figure 8 shows a photomicrograph of a metakeratophyre crystal(?) tuff from a coarse-grained basal bed at Deer Bay. Lapilli(?) fragments containing complexly twinned albite crystals occur in a chlorite-rich matrix and likely originated as a pyroclastic accumulation.

Green chloritic metakeratophyre flows crop out over a width of 300 m in a cove west of Eek Point. They are bluish- to dark-greenish-gray phyllitic amygdaloidal porphyritic metafelsites. Twinned, dusty albite phenoblasts (An^{-3}) are up to 3 mm long. Almond-shaped amygdules up to 1 mm in diameter are composed of fine-grained quartz, carbonate, and epidote. The groundmass in most specimens consists of subparallel twinned albite microlites(?) to 0.4 mm long in a field of finer grained albite, chlorite, carbonate, and magnetite. Carbonate veinlets and pods cut the rocks. The metakeratophyre is quite similar to tuffaceous schist (Wg), but the rather well-crystallized subparallel albite microlites(?) in the groundmass and the presence of amygdules indicate a volcanic flow origin.

Metaspillite flows and tuff(?) (not indicated on plate 1) are exposed on Sukkwan Strait west of Eek Point and on the east side of Hetta Inlet near the Copper City mine (pl. 1). About 1 km west of Eek Point metaspillite flows crop out over a width of 100 m and consist of bluish-gray fine-grained rock and flowage bands, 1/2- to 2-1/2-cm-long almond-shaped amygdules, and irregular metaspillite bombs up to 1 m long. The metaspillites in thin section (fig. 9) contain carlsbad-albite twinned albite and actinolite phenocrysts(?) to 1 mm long in a groundmass of divergent albite, chlorite, epidote, acicular actinolite, and tiny opaque grains. The bombs are composed of epidote, acicular tremolite, and quartz. Thin metaspillite tuff(?) beds outcropping at and near the Copper City mine are chlorite schists that contain patches of felsite and granoblastic quartz-albite in a rock largely composed of chlorite, epidote, sericite, and magnetite.

According to Dickenson (1962), "Quartz keratophyre

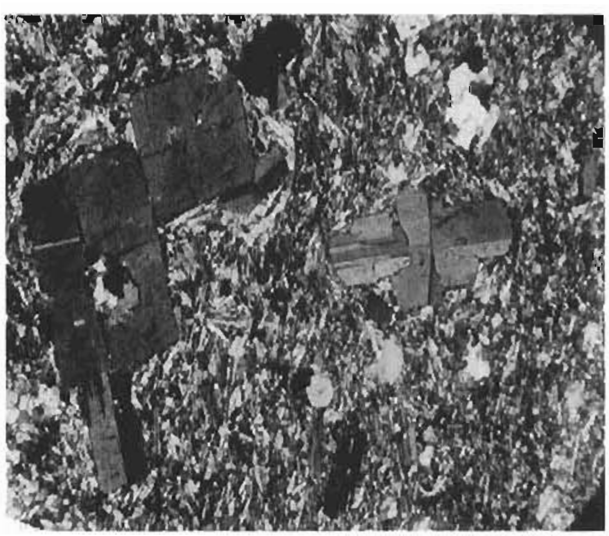

Figure 7. Photomicrograph of metakeratophyre tuff(?) from bed about 30 cm thick shown in fig. 6 (crossed nicols).

Figure 8. Photomicrograph of metakeratophyre crystal(?) tuff from south shore of Deer Bay (crossed nicols).

may be defined as felsite or felsophyre composed dominantly of albite and quartz forming an interlocking groundmass mosaic of microscopic anhedral and subhedral crystals. Most quartz keratophyres that have been described carry phenocrysts of quartz and albite as well."

This description fits the metakeratophyres in the Wales Group, except that the original quartz phenocrysts may now be represented as composite groups of quartz anhedra. In addition, albite phenocrysts are more abundant than quartz in the Wales Group metakeratophyres.

Most of the albite phenocrysts found in the metafelsitic and metabasaltic rocks previously described are believed to be igneous. Albite veinlets do not cut Wales Group metakeratophyres, and albite rims on the more calcic plagioclase are usually lacking. According to universal stage measurements made on 4 grains of albite from a metakeratophyre tuff(?) near Nutkwa Inlet and from 12 grains of albite from a similar locality west of Eek Point, the albite is An $2(\pm 2)$, between a high- and low-temperature state: $2V_z$ on two grains of albite from the Nutkwa Inlet locality is 87-88° (fig. 10), which also suggests an intermediate thermal state. According to Donnelly (1963), these properties are typical of albite phenocrysts that crystallized in a quartz-keratophyre melt rather than by later albitization.

Chemical analyses of five Wales Group metakeratophyre tuff(?) samples and a metaspillite tuff(?) show the distinctive sodic-rich nature (Na_2O of 4.95-6.77 percent) of the Wales Group metakeratophyre and metaspillitic volcanic rocks. In addition, the metakeratophyres range from intermediate to felsic compositions. Peek (1975) reported similar chemical oxide analyses from Wales Group(?) metavolcanic tuffs at Niblack Anchorage, which show Na-rich compositions. A plot of the analyses on an alkali-F-M diagram (p. 28) suggests that the Wales Group metavolcanic rocks may be part of a differentiated tholeittic suite (Carmichael and others, 1974). However, dark-greenish-gray metasedimentary phyllites and greenschists on Hetta Inlet and west of Eek Point often contain uniformly distributed albite grains in their muddy matrixes, which indicates secondary albitization during metamorphism. Also, some of the phenocrysts in the metaspillites and metakeratophyre probably have been albitized. Evidently there are both metamorphic and igneous albite in rocks of the Wales Group.

QUARTZ SERICITE SCHIST (Ws)

A 300-m-thick section of dark-gray quartz sericite schist (Ws) underlies Wales Group green tuffaceous(?) schist (Wg) on Hetta Inlet. This rock unit is well

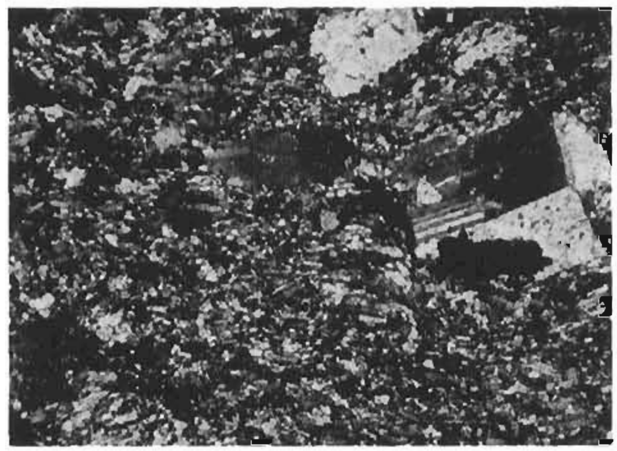

Figure 9. Photomicrograph of schistose metaspillite tuff, 1.4 km west of Eek Point. Colorless tremolite overgrowths on actinolite seen in grains in central and left-central parts of section (crossed nicols).

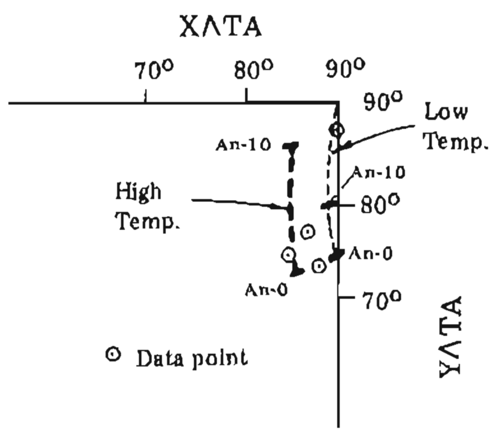

Figure 10. Photomicrograph of metakeratophyre tuff(?), 0.5 km north of Nutkwa Inlet. Universal stage data on four grains in this section of albite are also shown. The albite twin axis measurements are plotted according to Slemmons (1962, plate 2).

foliated and crenulated. Locally in the schist there are marble bands a few centimeters thick. Quartz veins, many of which are less than 5 cm thick, parallel and crosscut foliation, and many are stretched and folded with enlargements in the hinge zones. Quartz sericite schist (Ws) on Hetta Inlet south of the mouth of Jumbo Creek is somewhat gradational with the overlying Wales Group green tuffaceous schist (Wg).

In thin section the rock is primarily fine-grained granoblastic quartz and minor albite, with trains and scattered aligned shreds of sericite and chlorite and masses of carbonate; synkinematic biotite grains to 0.2 mm in diameter make up about 2 percent of the rock. There are a few fairly large partly sericitized albite crystals in typical rock samples. These crystals are up to 0.5 mm in diameter, have albite twinning, and may be related to the albite found in Wales Group metavolcanic rocks. The quartz-sericite schist may be a tuffaceous equivalent of some metakeratophyre flow rocks previously described. Some quartz-sericite schist zones are evidently associated with sulfide mineralization at Niblack Anchorage (Herreid, 1964; Peek, 1975) and in the study area (p. 36).

SILICIFIED SCHIST (Wss)

Mappable zones of greenish gray to gray quartzose schist are found throughout the area, particularly near Cholmondeley Sound and Copper Mountain. Quartz appears as veinlets and boudins that make up to 50 percent of the rock. Zones associated with sulfide mineralization are discussed in the Mineral Deposits section of the report.

PHYLLITE AND LIMESTONE (Wpl)

A carbonate unit less metamorphosed than the Wales Group marble (Wm) is present at the south end of Divide Head. It consists of thin-bedded, medium- to dark-gray, fine- to medium-grained limestone interbanded with dark-gray slaty phyllite, crenulated greenish-gray phyllite, and greenish-gray graywacke. Calcite veinlets, irregular quartz lenses, and dolomitized areas crosscut bedding in the unit. The Wpl unit displays distinctive granular weathering in the limestone in beach outcrops, a contrast with the hackly, pitted Wales Group marble. The phyllite beds have a more roughly weathered surface than the Wales Group green tuffaceous schist. Macroscopic folds are locally abundant in this unit.

MIGMATITIC GNEISS (Wgm)

A banded migmatite gneiss unit is exposed along the northeast shore of Sunny Cove on the West Arm of Cholmondeley Sound. It ranges in texture from banded quartz diorite gneiss to decussate amphibolite and fine-grained well-foliated schist. The unit is cut by irregular feldspar veins (fig. 11). The schist has kink bands geometrically identical to those in the enclosing Wales Group schists.

In thin section, the rock is seen to consist of fine-grained granoblastic albite-twinned andesine, quartz, garnet, scattered magnetite grains, and large ragged hornblende grains with many unreplaced quartz inclusions. The hornblende is partly altered to chlorite and the feldspar is partly altered to epidote and sericite. Knotted schist 0.8 km from the head of Sunny Cove contains rolled, dark-green to yellow actinolite and albite augen in a fine-grained greenschist composed of quartz, albite, chlorite, epidote, actinolite, and magnetite.

The migmatitic gneiss is in intrusive(?) contact with Wales Group schist along its southeast margin. Exposures show a sharp, planar, vertical contact without shearing that crosscuts foliation in gneiss and Wales Group greenschist. The Wgm unit may represent a metasubvolcanic plug intrusion into green schist (Wg) related to the Wales Group volcanism. At Sunny Cove there is no contact-metamorphosed aureole around the body of migmatitic gneiss.

AGE OF THE WALES GROUP

Published K-Ar data (Turner and others, 1977) indicate that the Wales Group was involved in a regional

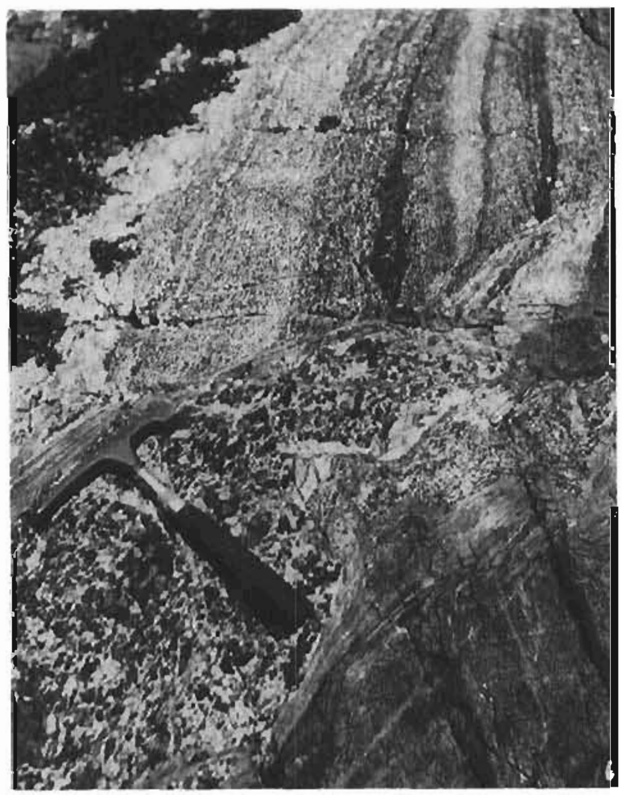

Figure 11. Migmatitic gneiss on northeast side of Sunny Cove, 2 km northwest of Sunny Point. The dark grains and streaks are hornblende.

thermal event that cooled to argon-blocking temperatures about 475 m.y. ago. The evidence for this conclusion is shown on $^{40}K^{40}Ar^{rad}$ isochron diagram, on which are plotted hornblende and tremolite data from two actinolite schists on Hetta Inlet near Eek Point, from a whole-rock metakeratophyre from the west side of Hetta Inlet, and from a migmatitic gneiss intruding the Wales Group on the West Arm of Cholmondeley Sound.

The two dated actinolite schists contain broken and rotated relict crystals of actinolite in a matrix of chlorite, albite and tremolite. The actinolites show incipient overgrowths of tremolite. These textural relationships and the presence of interbedded metakeratophyres indicate that the dated schists represent original volcanic ash layers in the Wales Group and that the relict hornblende represents a primary volcanic mineral that has partially altered to tremolite during greenschist-facies metamorphism (Turner and others, 1977).

On the basis of a preliminary Pb-U zircon age by Saleeby, Churkin and Eberlein (1977) have reported that metamorphic rocks of the Wales Group at Ruth Bay are intruded by an undeformed trondhjemite body that is believed to have crystallized at least 730 m.y. ago. Assuming that this age will be confirmed by additional Pb-U dating, these workers have proposed that a greenschist-facies metamorphism in the Wales Group preceded the intrusion sometime during the Precambrian. Churkin and Eberlein's zircon Pb-U age was apparently unaffected by the event that reset the K-Ar system to the isochron age of 475 m.y. The radiometric age data reported by Turner and others (1977) is not inconsistent with a Precambrian assignment to the Wales Group. If Churkin and Eberlein's conclusions are correct, the K-Ar data indicate that a second thermal event affected the Wales Group after a Precambrian(?) metamorphic event.

Eberlein (pers. comm.) found cobbles of green schist he believes to be of Wales Group origin in the Lower Ordovician Descon Formation sedimentary rocks west of the map area. During this study metakeratophyre(?) clasts were found in Descon Formation sedimentary rocks on Klakas Inlet. No fossils have been found in Wales Group rocks thus far and we are tentatively assigning the entire group to the Precambrian, although it may be a geologic unit that extends into the early Paleozoic.

DESCON FORMATION

INTRODUCTION

The Descon Formation along the west side of Prince of Wales Island consists of "a thick sequence of coarse- and fine-grained marine rocks, predominantly graywacke type with interbedded basaltic volcanics and minor limestone" (Eberlein and Churkin, 1970). According to Eberlein (pers. comm., 1972), the rocks on the north shore of Sukkwan Strait west of the map area are similar to the Descon Formation and are mainly andesitic mudstone, probably Middle or Late Ordovician, as shown by fossil evidence several kilometers to the north.

Along Klakas Inlet there is a section of unmetamorphosed Descon(?) Formation about 6,500 m thick, truncated at the base by the Keete Inlet underthrust and at the top by an angular unconformity. The oldest sedimentary rocks exposed are a sequence of about 1,000 m of strongly sheared but thermally unmetamorphosed flysch(?) deposits that consist of conglomeratic graywacke, siltstone, and argillite interbedded with basic volcanics rocks and marble. Overlying this sequence is about 3,500 m of unsheared graywacke and banded mudstone that is overlain by about 1,500 m of pillow basalt, which has been intruded by Silurian or older (probably Late Ordivician) granodiorite and alaskite. The graywacke and banded mudstone unit is correlated with the Descon Formation graywacke described by Eberlein and Churkin (1970).

Graywackes, volcanic, and associated rocks on South Arm (Ods, Odv) are tentatively classified with the Descon Formation. They are lithologically similar to the Descon(?) Formation on upper Klakas Inlet, although penetrative deformation is lacking in the section on South Arm. The unit is largely made up of massive medium-gray argillite with local thin-bedded mudstone, pebble conglomerate, spilite, and rhyolite tuff(?). A 30-m-thick unit of gray limestone is present in the section.

Clasts in Descon Formation graywackes and siltstones on South Arm suggest deposition by mudslides or turbidity currents. Sharp local folding in interfingering siltstone and pebble conglomerate indicates that slumping occurred shortly after the time of deposition.

SPILITE(?) (Ods) AND MIXED VOLCANIC ROCKS (Odv)

Spilite(?) (Ods) crops out in two areas along South Arm. It is dark-greenish-gray, nonfoliated, and abundantly porphyritic, with albite phenocrysts to 4 mm long in a less abundant matrix of chlorite masses with fibrous zeolite(?) cores, leucoxene, and carbonate. The albite phenocrysts are not cored by more calcic plagioclase and one chemical analysis (table 2, No. 11) shows spilitic affinities for this mafic volcanic unit (Ods).

Mixed volcanic rocks (Odv) including andesite flows and rhyolitic pyroclastic rocks are exposed adjacent to the spilite(?) (Ods) along the east side of South Arm. The andesite is medium to greenish gray and aphanitic, often showing pillow structures. Pillows in the andesites are 1 to 2 m in diameter and appear right-side up. Rhyolitic pyroclastic rocks are made up of fine lithic grains (to 0.3 mm long) of rhyolite(?) in a matrix of glass, dusty iron opaques, and secondary carbonate. The rhyolite grains are felsite with albite microlites not unlike the metakeratophyre found in the Wales Group.

Because both the spilite(?) (Ods) and mixed volcanic rocks (Odv) lack penetrative deformation and are apparently interbedded with Descon Formation mudstones (Odm), they have been tentatively assigned to the Descon Formation. Complex faulting, however, has separated them from the Wales Group schists to the north and the major Descon Formation sedimentary units to the south.

SHEARED CONGLOMERATIC GRAYWACKE (Odsg)

The sheared, unfoliated conglomerates, graywacke, siltstone, argillite, limestone, and minor mafic volcanics of the Odsg unit occur at the base of the Descon Formation on upper Klakas Inlet and at the end of South Arm. The conglomeratic rocks vary greatly in composition and texture. Some of the argillite has slaty cleavage, whereas the volcanic rocks and graywackes usually have none.

Typical intraformational conglomerate at the north end of Klakas Inlet contains rounded, unstretched clasts of fresh porphyritic andesite and grayish-red argillite in a grayish-red slate matrix. At other localities in the Odsg unit, greenish-gray conglomeratic graywacke interbedded with grayish-red argillite contains floating angular andesite clasts. Figure 12 shows a typical Odsg conglomerate from the northwest shore of Klakas Inlet.

Some conglomerates contain very large clasts. Along the west shore of Klakas Inlet, slaggy-weathered conglomeratic beds with a limy matrix contain rounded basalt and marble boulders up to 1.5 m in diameter. Conglomeratic rocks in the Odsg unit evidently formed in a high-energy environment, perhaps on a steep submarine slope.

The interbedded graywacke beds are massive, unsheared, greenish gray, up to 5 m thick, and range from silt to sand. They usually contain a subordinate amount of pebble- to cobble-sized clasts of chert, mudstone, and metavolcanic rocks.

Minor but distinctive argillite and siltstone beds are intercalated with graywacke and conglomerates throughout the Odsg section. They are typically greenish gray to dark gray with bands from 1 to 20 cm thick. Bedding-plane shear is very common, and much of the rock is often composed of sheared lenses differing slightly in grain size and composition. A distinctive argillite variant in the Odsg section is the grayish-red beds, 1/4 to 1 m thick, exposed at the north end of Klakas Inlet and on South Arm. These beds served as markers for mapping the Odsg section. Distinctive reddish-gray oxidized zones derived from nearly in-place float boulders of reddish-gray argillite are found along the northern shores of Klakas Inlet at intervals of 50 to 80 m.

A few fragmental basalt flows both with clasts in an aphanitic matrix and without clasts are present in the Odsg unit, particularly near the top of the section. Some basalt examined in thin section contains calcic plagioclase (An 50-70), but in others the plagioclase has apparently been albitized.

Interbedded conglomerate and marble beds are common in the upper 600 m of the Odsg section. At one locality a detrital marble bed contains angular basalt clasts.

The Odsg unit appears rightside up. A faulted sedimentary(?) contact separates Odsg from the overlying Odm unit.

BANDED MUDSTONE (Odm)

Units of flyschlike banded mudstone, ranging from 10 cm to 300 m thick, are interlayered with graywacke for about 8 km along Klakas Inlet. These well-bedded unsheared rocks are in sharp contrast to the underlying, pervasively sheared, poorly bedded Odsg unit.

The banded mudstone unit is composed of thin rhythmic beds of siltstone and argillite 0.5 to 10 cm thick, with occasional thicker beds of graywacke. Silt-

Figure 12. Descon Formation sheared conglomerate of the Odsg unit with red argillite and graywacke pebbles in a sheared argillaceous matrix. West shore of Klakas Inlet, 2.5 km from its head.

stone beds as thin as 1 cm grade from coarse at the base to fine at the top. They have sharp bottom contacts that are irregular in places because of the scouring of the underlying argillite. Contacts of siltstone beds with the overlying argillite beds may be sharp or gradational, planar or interfingering. Wisps of argillite are found in the siltstone. By use of these features, the tops of beds can usually be determined. Minor folds and crenulations are not found. Except for a large area of slaty cleavage and quartz veining east of Klakas Lake, cleavage was generally absent.

Graywacke beds from 1 to 3 m thick are common in the Odm unit. On the north shore of the bay west of Klakas Lake, a 1-m-thick graywacke bed interbedded with mudstone contains intraformational clasts of thin-bedded mudstone floating in the central portion (fig. 13). The graywacke and intraformational clasts were likely emplaced simultaneously as a turbid mudflow. The thin, graded mudstone beds were probably deposited at the outer margins of turbid mudflows. The argillite beds that are not the graded tops of mudstone beds probably originated as abyssal mud.

Limy rocks are nearly lacking, but two beds of slag-weathered, limy matrix conglomerate similar to those in the underlying Odsg unit are present near the base of the unit. These support the interpretation that the Odsg and Odm units are conformable, despite the presence of shearing along the contact.

GRAYWACKE (Odg)

Graywacke beds are massive, greenish gray, 1 to 5 m thick, and range in size from silt to sand. Individual beds are not banded and do not vary in grain size. Pebbles and occasionally larger clasts of chert or banded mudstone floating in the central portions of beds indicate an origin as submarine mud flows or turbidity currents. Commonly, thin-banded mudstone layers less than 30 cm thick are interbedded with the graywacke at stratigraphic intervals of 3 to 30 m. These mudstones are identical with those found in the Odm unit.

Albite grains are visible in some outcrops and a thin section of conglomeratic graywacke on the west shore of Klakas Inlet, 40 km from its head, reveals closely packed subangular clasts of metakeratophyre(?) (quartz-albite metafelsite containing albite phenocrysts). A similar outcrop, although chloritized, is present on the ridge 3 km southwest of the extreme head of the inlet. The presence of metakeratophyre(?) as clasts in the Odg unit suggests that source rock of at least part of the Descon Formation is the Wales Group.

ARGILLITE (Oda)

Near the top of the banded mudstone-graywacke sequence (Odm) on the east shore of Klakas Inlet are two sections of argillite (Oda) up to 100 m thick (or one section, repeated by faulting). The unit is dark gray, with thin bands of a very dark gray slate and a few limestone concretions up to 1 m in diameter.

BASALT (Odb)

Mafic volcanic rocks at the top of the Descon(?) Formation section on Klakas Inlet are at least 1,200 m thick. The rocks are greenish gray and form steep, rocky shorelines. Most of the rock unit (Odb) is massive, jointed, and lacks pillow structure. (Locally isolated pillows in fragmental rocks or angular blocks occur in a flow-rock matrix.) A typical outcrop has angular 2- to 10-cm-long fragments of limy, light-greenish-gray aphanitic basalt that stand out on weathered surfaces above the background of the same rock. In thin section the rock is seen to have an interstitial texture. There are dusty-albitized(?) plagioclase laths (0.2 mm long) in a dark matrix of devitrified glass that contains chlorite and epidote and amygdules of calcite and quartz epidote. Thin sections with plagioclase fresh enough for the determination of composition show albite-rich basalt or spilite, which indicates albitization of more calcium-rich plagioclase.

Figure 13. Descon Formation banded mudstone and graywacke with floating mudstone fragment (part of Odm unit), east shore of Klakas Inlet near outlet from Klakas Lake.

Two chemical analyses (table 2, Nos. 6, 12) and alkali-silica diagram (p. 28) show the alkaline nature of these Descon basalts.

AGE OF THE DESCON FORMATION

The age of the Descon Formation has been established as Middle Ordovician to Silurian on the basis of fossil collections made on the west side of Sukkwan Island (Eberlein, pers. comm.). More recent graptolite collections made on Klakas Inlet (Eberlein, pers. comm.) generally confirm the assignment of the rock units to the Descon Formation. Although the volcanic and sedimentary units on South Arm (Ods and Odv) could be part of the Wales Group, they are assigned to the Descon Formation.

SILURIAN(?) IGNEOUS ROCKS

ALTERED GRANODIORITE (Sgd)

Saussuritized granodiorite and alaskite are present along the northern edge of Max Cove. This is probably the southwest edge of a large pluton that forms the mountain northeast of Max Cove, which corresponds with the location of a prominent aeromagnetic high (Rossman and others, 1956). The rock is an albitized granodiorite breccia with fragments cemented by alaskite.

In thin section some of the dark breccia blocks are seen to be made up of saussuritized feldspar and fresh poikilitic hornblende with ragged borders. In coarser grained rock the dark breccia fragments are albitized granodiorite. There are fresh, euhedral, green hornblende crystals, tabular crystals of saussuritized albite with albite twinning, and irregular grains of potassium feldspar and quartz. The alteration of the plagioclase feldspar was probably deuteric. A chemical analysis of a sample (table 2, No. 16) from this pluton shows it to have calc-alkaline affinities, as do Paleozoic intrusive rocks at Bokan Mountain (MacKevett, 1957).

Potassium-argon dating reported by Turner and others (1977) of hornblende in deuterically altered granodiorite on the north shore of Max Cove gives a minimum age of 421 m.y. (mid-Silurian or older). This rock type may be part of the same suite of intrusives as the quartz diorite and quartz monzonite complexes near Bokan Mountain, 15 km to the east, which have potassium-argon ages of 432 $\pm$ 13 and 440 $\pm$ 13 m.y., respectively (Lanphere and others, 1964).

ALASKITE (Sa)

Alaskite, which has a distinctive micrographic texture, forms a long, eliptical plutonic body on both sides of Klakas Inlet, where it intrudes(?) into the Descon Formation. The alaskite is medium grained and commonly weathers to a pale yellow. In many outcrops the rock is crackled into 2- to 8-cm-wide blocks that are cemented by thin dolomite-sericite-magnetite seams (fig. 14). Feldspar phenocrysts are visible in some localities. There are no mafic minerals. In thin section the rock is mainly subhedral grains of perthite and albite, with some quartz. The feldspars have been extensively sericitized and their margins are embayed by quartz. In their central portions partial replacement by quartz formed lacy micrographic intergrowths of quartz albite and quartz perthite. The rock has been cut by younger dolomite-sericite-magnetite-chlorite veinlets. The alaskite contains about 30 percent perthite.

The alaskites on both sides of Klakas Inlet appear similar, and are probably related to a common pluton. The micrographic intergrowths are similar and both areas are cut by carbonate-sericite-magnetite-leucoxene veinlets.

The age of the alaskite is believed to be the same as the dated granodiorite (Sgd) described above. Alaskite is found as a cement in a granodiorite (Sgd) breccia at Max Cove.

Figure 14. Silurian crackled alaskite cemented by dolomite. Boulder on eastern shore of Klakas Inlet, near Max Cove.

KERATOPHYRE(?) (Sk)

Sills and dikes of keratophyre(?) cut Descon Formation rocks on Klakas Inlet. The rock is light-gray felsite that weathers to coarse, grayish-orange rubble in beach exposures. Some bodies are aphanitic near the central portions and contain visible feldspar laths near the contacts with the country rock.

In thin section the rock displays euhedral twinned albite laths up to 2 mm in a fine-grained granoblastic matrix composed mostly of equant albite and quartz grains with minor sericite. Twinned plagioclase microlites are not as common as in the groundmasses of Wales Group metakeratophyre on Hetta Inlet, but otherwise the rocks are similar. No chemical analyses of this rock type are available, and assignment as keratophyre is based on mineralogy.

The keratophyre(?) sills postdate the Middle Ordovician and are probably Silurian. They cut the Descon Formation on Klakas Inlet and are peripheral to Silurian plutons. However, they also could be related to the Cretaceous plutons in the area.

DEVONIAN BEDDED ROCK UNITS

INTRODUCTION

Devonian bedded rocks are represented by a 2,000-m-thick section of unfoliated dark-gray argillites and siltstones, greenish- to medium-gray siltstones and graywacke, and conglomerate. There is a 'basal' conglomerate near the base of the section. Andesitic volcanic rocks capping the sediments could be younger than the Devonian. Figure 15 is an approximate section of the Devonian rocks between Klakas and Keete Inlets.

BASAL CONGLOMERATE AND RED BEDS (Dbc, Dar)

Devonian rocks are separated from the underlying Descon Formation by a transgressive unconformity. The contact is marked by an unsheared basal conglomerate containing clasts derived locally from the underlying rocks. Progressing northward the most abundant clasts change from granodiorite to dark-gray argillite to grayish-red argillite.

The basal conglomerate (Dbc) is coarsest on the north shore of Max Cove, where it contains cobbles, gravels, and boulder conglomerate with granodiorite clasts up to 3 m across. These clasts are similar to the nearby dated pluton that intrudes the Descon Formation. Other clasts include basalt, felsite, red argillite, and black slate. The gravels interfinger with overlying fossiliferous limestone.

On the west shore of Klakas Inlet, the Devonian basal conglomerate (Dbc) overlies alaskite (Sa) and contains fragments of that rock up to 12 cm across in a graywacke matrix.

North of the alaskite (Sa) pluton the Devonian basal conglomerate beds are less coarse grained and contain no granitoid clasts. The basal rocks (Dar) are typically medium reddish-gray graywacke or siltstone and distinctive purple to grayish-red argillite, with scattered angular to subangular 1- to 5-cm clasts of white-weathering, dark-gray argillite and greenish-gray siltstone. At the north limit of the basal conglomerate beds, in the Keete Inlet drainage, the grayish-red beds (Dar) and pebbles in graywacke derived from the Descon Formation are common.

Some of the beds in the lower part of the Devonian section—particularly the graywacke, mudstone, and red argillite beds are identical in composition and texture to rocks in the Descon Formation below the unconformity and could be tectonic slices of the Descon Formation.

ARGILLITE-SILTSTONE (Da), SILTSTONE-GRAYWACKE (Dsg), PEBBLE-CONGLOMERATE (Dpc), LIMESTONE (Dl), AND FELSITE PEBBLE CONGLOMERATE (Dkpc)

Above the basal conglomerate the Devonian bedded rocks, for the most part, become finer grained and consist mainly of argillite, siltstone, limestone, and minor pebble conglomerate (fig. 15). This 1,800-m-thick section is capped by andesite breccias, flows, and volcaniclastic rocks.

The predominant rock type is a heterogeneous unit of dark-gray siltstone and dark-gray argillite (Da) (fig. 16). Directly above the basal conglomerate (Dbc), the Da unit consists of about 600 m of dark-gray siltstones and subordinate dark-gray argillite. Within the lower 100 m of this Da section are subordinate but distinctive dolomitic concretions, usually 0.1 to 3 m thick and a few meters long (fig. 15). The concretions are faintly banded and usually parallel the siltstone beds. Some banding in the concretions is oriented slightly oblique to the sedimentary layering within the Da unit. These dolomitic concretions may represent open space fillings with bands being successive water levels during filling. Some evidently filled while the beds were horizontal, others during tilting. In the upper 1,200 m of the Devonian-sedimentary section the Da unit becomes finer grained and consists of dark-gray argillite and subordinate siltstone.

Within the Da unit are subordinate but mappable beds of intraformational pebble conglomerate (Dpc), siltstone and graywacke (Dsg), and locally fossiliferous (e.g. Max Cove) limestone (Dl). These subordinate units are generally less than 20 m thick and lense out along strike. Pebbles in the Dpc unit consist of argillite, siltstone, and graywacke, some possibly derived from the underlying basal conglomerate (Dbc) unit. A typical exposure of the Dsg unit contains a series of 15-cm-thick greenish-gray beds that grade from graywacke at the base to siltstone at the top and are separated by 1-cm partings of argillite. Limestone (Dl) at Max Cove is light gray, essentially nonbanded, and very finely re-

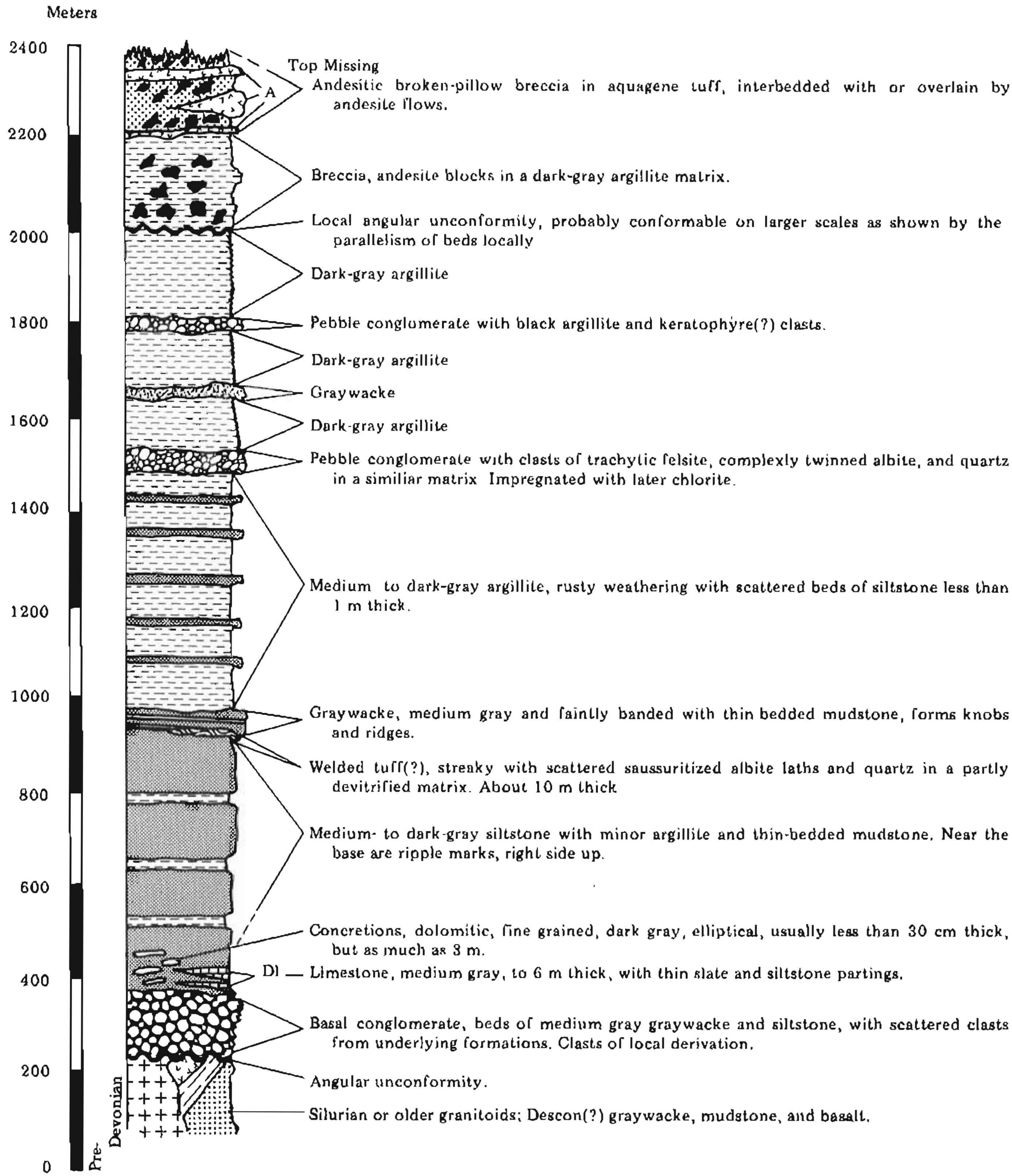

Figure 15. Devonian stratigraphic section between Klakas and Keete Inlets (thicknesses are approximate).

crystallized and contains small dolomitic inclusions.

In the upper part of the Devonian sedimentary section (fig. 15), the Da unit is interbedded with 10- to 30-m-thick beds of greenish-gray clastic rocks (Dkpc) derived from a felsite(?) that consists of twinned plagioclase and quartz grains. Interbedded with the conglomerates are subordinate greenish-gray argillite and siltstone.

AGE

Churkin and others (1970) have identified graptolites in the Da unit that are latest Lower Devonian or earliest Middle Devonian. They found fossils at four localities in Klakas and Kassa Inlets in black slate, apparently in the upper beds of the dark-gray argillite unit. The diagnostic fossil is a graptolite *Mongraptus pacificus*, of 'Praguian' or possibly a slightly younger horizon that extends into the Middle Devonian.

A coral reef located in the Dl unit above the unconformity at the base of the Devonian section on the north shore of Max Cove (pl. 1) was first reported by Buddington and Chapin (1929). According to Churkin and others (1970), it is "limestone rich with tabulate corals and stromatoporoids...apparently long-ranging species that cannot be assigned to any specific part of the Devonian."

ANDESITE(?) (Dand)

Devonian(?) andesite forms an outcrop band of submarine andesitic tuff, flows, and sedimentary breccia that extends from Keete Inlet south to the edge of the map area, east of Kassa Inlet. On Kassa Inlet this unit crops out as shoreline cliffs of distinctive unfoliated greenish-gray, blocky, locally amygdaloidal, aphanitic andesite flows and tuff. In the flows, calcite stringers that cut the rock weather to give the surface a blocky crackled appearance with blocks about 3 cm in diameter. The flows in thin section show devitrified glass with diffuse carbonate patches and tiny magnetite grains. Elsewhere the rock is a slightly foliated, aphanitic tuff with 6-cm-long andesitic fragments. Pillows were not recognized on Kassa Inlet. Northeast of the head of Kassa Inlet the andesite is amygdaloidal welded(?) tuff with a streaky appearance in outcrop and contains shard-shaped chlorite masses. In upland areas east of the head of Kassa Inlet the rock is mainly conglomerate, made up of rounded to angular andesitic clasts to 30 cm long in a matrix of black slate and thin-bedded siltstone pebbles.

Along the south shore of Keete Inlet, nearest the thrust fault (pl. 1), the unit is believed to be a hyaloclastite broken pillow breccia (Carlysle, 1963). It has irregular, rounded andesite pillows with chilled borders in a matrix of darker, grit-sized porphyry fragments. This is cut by similar andesite dikes with chilled borders. Nearby, there is andesite composed of angular 1-cm fragments. Farther east, the rock is a sedimentary breccia made up of angular andesite and thin-banded mudstone blocks in a dark-gray argillite matrix. This sequence of tuff on the west and the sedimentary breccia on the east at Kassa and Keete Inlets may not hold true for the mass of the unit in between.

The Devonian(?) andesite (Dand) unit generally parallels and is roughly conformable with the underlying Devonian argillite (Da) unit, but local unconformities do exist between the two units. Devonian(?) andesite (Dand) is the youngest bedded deposit in the map area. It is tentatively considered to be Devonian on the basis of regional correlation with the Devonian St. Joseph volcanic rocks on the west coast of Prince of Wales Island (Eberlein and Churkin, 1970).

PALEOZOIC(?) DIKES (Pdk)

INTRODUCTION

Dikes in the study area vary in composition, texture, age, and orientation. They are andesitic and basaltic, fine-grained and diabasic and intrude along joint sets.

Figure 16. Devonian argillite and siltstone (Da). Keete and Nutkwa Inlets in background.

There are a few felsic dikes related to nearby plutonic bodies. Compositions categorized in this section are based on hand-specimen and thin-section examination. Because of their small size, most dikes are not shown on plate 1.

FELSITE DIKES

Several quartz-albite-felsite dikes in the Klakas Inlet area near Max Cove are probably related to the nearby early Paleozoic(?) granodiorite pluton (Sgd) on Max Cove.

AMYGDALOIDAL PORPHYRITIC BASALTIC ANDESITE DIKES

Dikes of basaltic andesite along Hetta Inlet and Sukkwan Strait cut both the Wales Group and the Descon Formation rock units. They have chilled borders, are conspiciously greenish black, and are made up of fine-grained, randomly oriented, rather sericitized andesine-to-labrodorite laths with intersitial clinopyroxene, basaltic hornblende, and magnetite grains. Pyroxene and plagioclase phenocrysts are 2 mm long. Olivine is locally psuedomorphosed by patches of carbonate, chlorite, and opaques. Many dikes, but not all, contain amygdules of carbonate fringed with chlorite. Lamprophyre(?) inclusions were observed in one dike.

PORPHYRITIC DIABASE DIKES

Diabase dikes are the most common type in the map area. Their textures range from that of coarse-grained basalt or andesite to diabase and often have chilled borders, and their composition ranges from basic andesite to basalt. Groundmass plagioclase laths are albite twinned. The albites range in length from 0.7 to 2.0 mm and vary from An-40 to An-60. Between the plagioclase laths are smaller grains of fresh pyroxene and magnetite(?) with patches of chlorite and carbonate. Chlorite makes up 5 to 20 percent of the rock. Some rocks have a trace of brown biotite in the groundmass.

Porphyritic basaltic diabase follows a fault with a meter or so of left lateral offset at Copper City (p. 42). This dike is 4 m wide, vertical, and strikes N. 35° W. It has chilled borders and contains rounded clusters of mafic minerals up to 2 mm in diameter. In thin section the rounded clusters are composed of serpentine and iron opaques, pseudomorphic after olivine, in a diabasic matrix. The diabasic matrix is made up of slim, divergent, albite-twinned labradorite laths (An-60) up to 2 mm long with interstitial grains of fresh clinopyroxene, iron opaques, patches of chlorite, and brown hornblende.

Porphyritic diabase of andesitic composition cuts Wales Group metakeratophyre tuff on the east shore of Nutkwa Inlet. This dike is similar to the diabase described above, except that the plagioclase is An-45, brown biotite replaces brown hornblende, and the plagioclase laths are shorter (up to 1 mm long). There are phenocrysts of sericitized plagioclase up to 5 mm long, fresh clinopyroxene(?), and serpentine-iron opaques pseudomorphic after olivine.

AMYGDALOIDAL PORPHYRITIC ANDESITE DIKES

These dikes and small sills are up to 3 m thick and have chilled borders. A typical example is a sill on the west coast of Nutkwa Inlet, which is made up of fine-grained, randomly oriented, much sericitized and leucoxenized albite-twinned andesine laths separated by patches of chlorite, carbonate, and leucoxene. Phenocrysts are sericitized and leucoxenized plagioclase up to 5 mm long. Amygdules are calcite rimmed by chlorite. These altered rocks contain no pyroxene.

THERMALLY METAMORPHOSED DIKES

Thermally metamorphosed dikes of variable composition are common in the hornfels aureole around Copper Mountain and on the north shore of West Arm. Some of these dikes, because of their large euhedral hornblende phenocrysts in a saccharoidal plagioclase and hornblende matrix, have the appearance of lamprophyre dikes. A thin section from a 1-m-thick dike on the west end of Gould Island shows it to be a partly recrystallized porphyry dike with late poikilitic hornblende and altered relict plagioclase phenocrysts. This groundmass is made up of irregular-shaped hornblende and zoned plagioclase microlites (cores, An-45; rims, An-30). Zoning is believed to be the result of partial decalcification during contact metamorphism.

A typical andesite dike that has been thermally metamorphosed in the hornfels zone southwest of Gould Island has zoned feldspar microlites with blurred margins probably due to extensive recrystallization. The feldspar cores are An-55 and the rims are An-40. Chlorite grains are larger and more distinctive than other less thermally metamorphosed dikes. Another dike nearer the intrusive shows chlorite replaced by diopside. The plagioclase grains (An-45) retain albite twinning but their margins are blurred because of recrystallization.

STRUCTURE

None of the Paleozoic(?) dikes are foliated and most that intrude the Wales Group have chilled borders with the enclosing schist. Most dikes are steeply dipping and have two preferred orientations across the map area. The most frequent width of dikes is 0.6 m on Hetta Inlet and 0.3 m on Chomondeley Sound (fig. 17). There are from 10 to 50 dikes per km^2 along Hetta Inlet north of Hetta Point (versus 5 to 15 per km^2 throughout the rest of the map area).

Most of the dikes dip more than 70°. The steepness and two-directional orientation of dikes is illustrated in

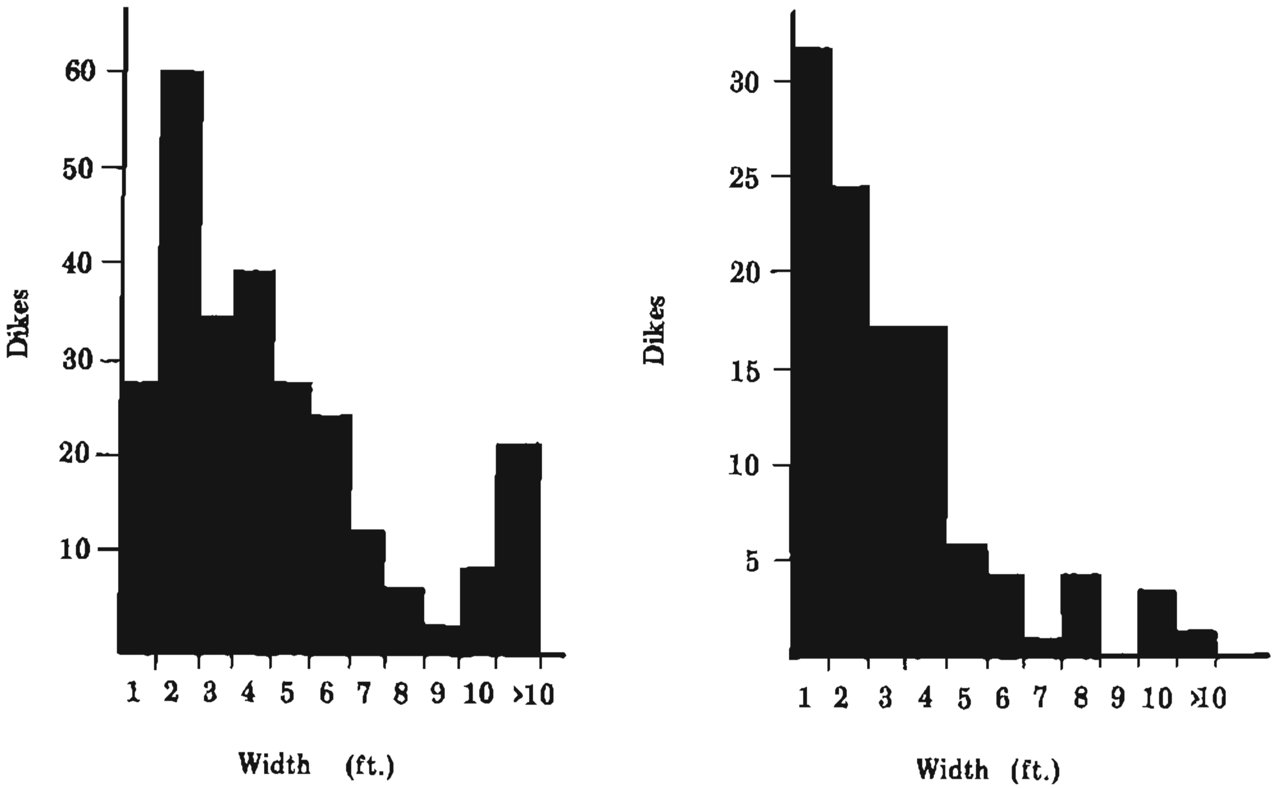

Figure 17. Dike measurements in Hetta Inlet and Cholmondeley Sound. Paleozoic(?) mafic dikes intrude the Wales Group, Descon Formation, and Devonian sedimentary and volcanic rock units. Left - Hetta Inlet dikes (246 measurements). Right - West and South Arms, Cholmondeley Sound (108 measurements).

figures 18 and 19, which record 400 dike orientations in the map area. The most frequent dike direction along Hetta Inlet, N. 60° W., is at roughly a 120° angle to the most frequent dike direction along the South and West Arms of Cholmondeley Sound, which is N. 60° E. A similar conjugate system of mafic dikes is present at McLean Arm, 50 km to the southeast (Forgeron and LeRoy, 1971).

AGE

Andesite and basalt dikes of a conjugate system intrude the Wales Group and Descon Formation throughout the map area as well as the Middle Devonian rocks on Klakas and Kassa Inlets, but do not clearly cut Cretaceous igneous bodies. Some of these dikes may be related to volcanism found in the various rock sequences. Leavens (1967) believes the altered mafic dikes within the Copper Mountain skarn zone are related to epidote mineralization; if this is true, some mafic dikes could be of Cretaceous age. A few keratophyre(?) and felsite dikes related to the Silurian plutons on Klakas Inlet are probably of Silurian age.

CRETACEOUS INTRUSIVE ROCKS

ALTERED PORPHYRITIC DIORITE (Kdlp)

Small plutonic bodies averaging 2 km^2 of altered porphyritic diorite intrude the Wales Group, the Descon Formation, and Lower Devonian rock sections in the south-central part of the map area (pl. 1). Thin sections from nine different bodies showed mineralogical compositions ranging from syenite to diorite. Textures are prophyritic to seriate with plagioclase phenocrysts ranging up to 5 mm long. Plagioclase phenocrysts are twinned, unzoned, and lath shaped, and have been altered to albite. All bodies contain pyroxene, often partly altered to chlorite, and some contain biotite; none have hornblende. Perthite content ranges from 0 to about 55 percent. Accessories are sphene, leucoxene, ilmenite, and apatite. Alteration by saussuritization of originally calcic-plagioclase produced albite, epidote, and sericite. Partial chloritization of the pyroxene and biotite has also taken place.

A Kdip pluton that intrudes the Wales Group on the south side of Keete Inlet is composed mainly of lacy intergrowths of quartz and albite without mafic minerals and could be called an alaskite. The rock is cut by chlorite, sericite, magnetite, and carbonate veinlets. The Kdip pluton at the east side of Keete Inlet in-

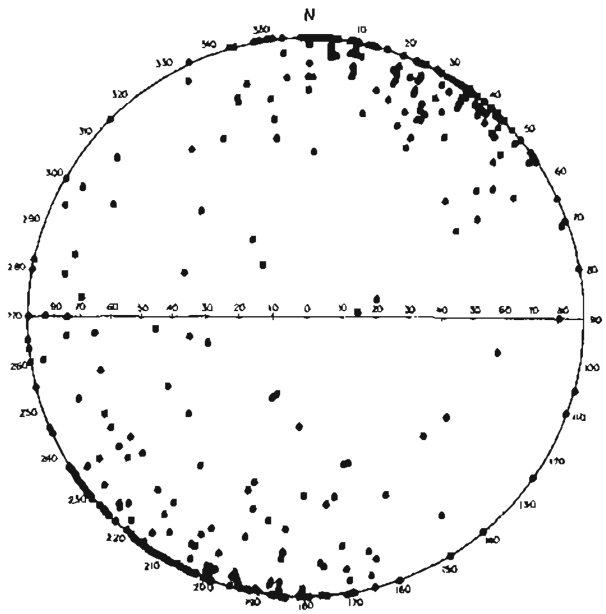

Figure 18. Attitudes of 292 dikes along shoreline of Hetta Inlet north of Hetta Cove.

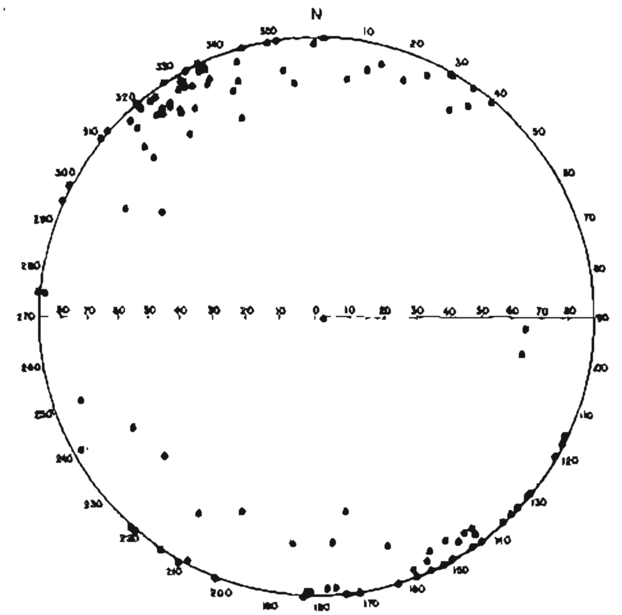

Figure 19. Attitudes of 108 dikes along South and West Arms, Cholmondeley Sound.

trudes into Devonian sediments. Here it is slightly crackled and made up of medium-grained perthite with small amounts of interstitial fine-grained quartz, carbonate, and chlorite veinlets.

GRANODIORITE (Kgdl)

The Copper Mountain pluton is a heterogeneous intrusive body with many roof pendants and satellite bodies and is surrounded by a wide-contact metamorphic aureole. The mineral deposits and crystal localities that have made the district famous are in this aureole, particularly where the pluton intrudes Wales Group calcareous rocks.

The central part of the Copper Mountain pluton is mostly granodiorite, whereas its margins and other granodiorite plutons are varied. Kennedy (1953) noted compositional changes from syenite to gabbro over a few hundred meters within the border phase of the Copper Mountain intrusive. Locally, dark early intrusive rock is cut by lighter colored intrusive rock. At other localities epidote veins and other skarn minerals replace the igneous rock.

A marginal mixed zone of inclusion-charged hornblende gabbro separates the Gould Island and Copper Mountain plutons along the narrow channel south of Gould Island. The inclusions are angular to rounded epidotized gabbro, amphibolite, and fine-grained mafic rock. Near the contact are patches of coarse-grained metasomatic(?) amphibolite with hornblende crystals up to 15 cm long (fig. 20). The rock is cut by inclusion-free granodiorite dikes that are probably the same age as the central Copper Mountain intrusive. In some places these septa are gabbro breccia cemented by granodiorite.

Farther east, on the south shore of Portage Bay, the marginal zone is composed of faulted skarn, marble, gabbro, and hornfels cut by inclusion-free granodiorite dikes and aplite veins. These contact areas show the vigorous nature of emplacement of the plutons. On the ridge north of Copper Harbor, the granodiorite is partly transformed to skarn along its west contact (pl. 1 and p. 37-38).

The Copper Mountain pluton is mainly granodiorite with some monzonite, quartz monzonite, and diorite (table 1). It has large poikilitic potassium feldspars with abundant inclusions of plagioclase and mafic minerals. In thin section, plagioclase is subhedral and normally zoned with cores ranging from An-20 to An-40 (rims were not determined). Mafic minerals are strongly pleochroic green to straw-yellow hornblende, slightly greenish pyroxene, and minor amounts of brown biotite. The granodiorite usually contains 0.3 to 2.0 percent magnetite. Apatite is an abundant accessory. The large anhedral potassium feldspars are up to 5 mm in diameter and were the last mineral to crystallize in the magma, perhaps before intrusion into the present crustal level. Potassium feldspar veinlets also cut the rock, indicating postcrystallization potassium enrichment. Chemical analyses of the two Copper Mountain pluton samples show quartz monzonite and diorite composition (table 2, Nos. 18, 19).

EPIDOTIZED GABBRO AND DIORITE (Keg)

Epidotized gabbro and diorite make up the small (3 km^2) pluton on the north side of Green Monster

Table 1. *Modes of selected granodiorite and related rocks (Kgdi) (based on 1000 points counted per stained slab)—in percent.*[1]

Type[2]	Unit	Sample	Quartz	Plagioclase	K feldspar	Mafic minerals	Accessory minerals	Alteration	Location	Remarks
Granodiorite	Hetta Lake pluton	70C 110	21	57 normal zoning, An-40	7	14 biotite & horn-blende	1.1 magnetite apatite sphene	Fresh	West end Hetta Lake	More biotite than average. K-Ar average age—hbde. 103 m.y., biotite 105m.y.
Granodiorite	Copper Mtn. pluton	70C 194	18	48 zoned, An-35	18 poi-kilitic perthite	14 horn-blende	1.2 magnetite apatite sphene	Plagioclase flecked by sericite	Summit Lake, south side, near out-let	Honey-yellow apatite.
Granodiorite	Copper Mtn. pluton	70C 197	17	56 zoned (2 mm), An-40	10 poi-kilitic large	15 horn-blende & biotite	1.3 magnetite apatite sphene fluorite(?)	Fresh	Summit Lake, south side, 1.4 km from out-let	
Quartz dio-rite	Copper Mtn. pluton	70C 198	17	50, An-25	2.3 poi-kilitic large with plagio-clase in-clusions	18 biotite, 12 horn-blende	0.3 magnetite sphene leucoxene	Partly sericitized	Summit Lake, south side, 1.6 km from outlet.	
Diorite	Copper Mtn. pluton	70C 426	4	60, An-35	4	28 pyro-xene minor horn-blende biotite	1.9 magnetite 2.4 pyrite	Fresh, cut by sericite veinlets	Portage Bay, south shore, 1.0 km from Gould I.	Border phase brecciated & intruded by granodiorite chemical analyses in table 2, No. 19.

[1]Counted by T.K. Bundtzen; all rocks medium grained with subhedral granular texture.
[2]Initially based on hand-specimen and thin-section examinations.

Mountain and a few areas near the margins of the Copper Mountain pluton. This rock is olive green and forms bold outcrops that are darker, more rounded, and rougher than the average rock of the Copper Mountain pluton. Epidote has replaced gabbro in irregular, rather angular masses that range from a few millimeters to several meters in diameter. Few epidote veinlets cut the rock. Enlarged masses along the veinlets are believed to be feeders for the epidotization of the gabbro (fig. 21). In thin section the replacement origin of the epidote masses is clearly shown by the gradational embayed contacts with the gabbro. The gabbro is made up of medium-sized subhedral crystals of labradorite (An-55-5), smaller amounts of hornblende and pyroxene, and minor ilmenite(?), sphene, and apatite. Much of the plagioclase has been slightly sericitized. The epidote masses embay the surrounding gabbro and contain relict gabbro minerals in their outer portions.

The progressive alteration of accessory magnetite also demonstrates the replacement origin of the epidote masses. Magnetite grains are unaltered in fresh gabbro but have thin rims of sphene near epidote masses and are seamed with chlorite. In the outer 5 mm of the masses, the magnetite grains become progressively more chloritized. The resultant rock within the 5-mm transition zone is granular epidote with scattered, rounded, sphene-rimmed chlorite grains of the same irregular shape and size as the accessory magnetite in the fresh gabbro.

The gabbro and diorite were probably epidotized shortly after intrusion and solidification—about the same time that pyrometasomatism occurred in the surrounding bedded rocks. One chemical analysis of epidotized gabbro near Gould Island (table 1, No. 17) suggests that SiO_2 has left the system and CaO has entered it.

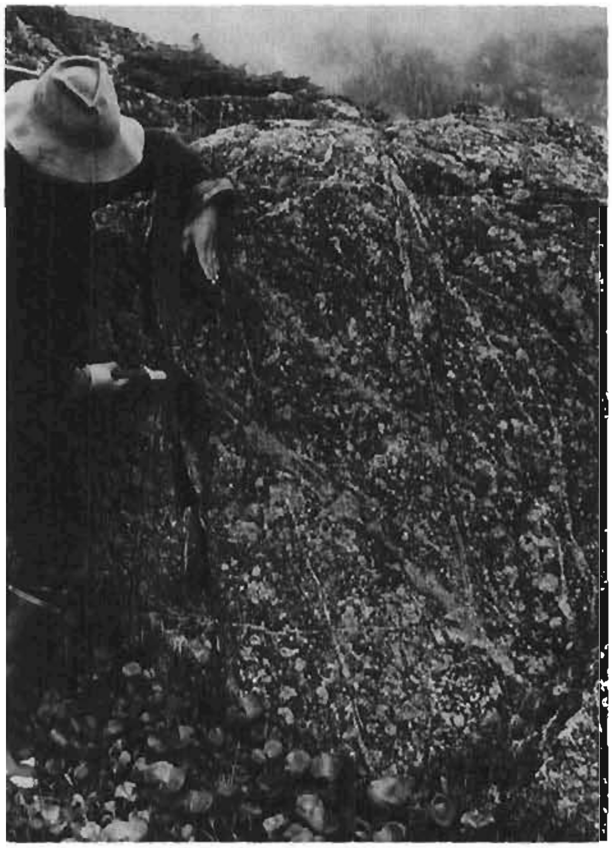

Figure 21. Epidotized gabbro on the ridge west of Lake Marge. Lighter colored masses are epidote. A few 0.5- to 25-cm-thick feldspar quartz veins with miniscule amounts of chalcopyrite are present along this ridge.

Figure 20. Migmatite from the marginal zone of the Copper Mountain pluton. Beach boulders nearly in place on the southwest shore of Gould Island show fine-grained diorite, coarse-grained amphibolite, and aplite veins.

BRECCIA DIKES (Kbd)

Fragmental dikes, 15 cm to 60 m thick, occur on Klakas Inlet near small porphyritic diorite plutons (Kdip) and intrude dark-gray Devonian siltstone and argillite (Da). Clasts are rounded to angular, usually 2 to 6 cm in diameter, but range from sand size to 30 cm long. The clasts are syenitic felsite, porphyrytic alaskite, dark-gray slate, and massive fine-grained pyrite. They fit compactly in a sparce chlorite matrix and are veined and partly replaced by carbonate; there is no quartz or pyrite veining. Although the breccia dikes in the Devonian sediments have not deformed thin siltstone beds, larger clasts have deformed the walls in a few places.

The breccia dikes were probably emplaced by surges of high-pressure CO_2-rich gas charged with rock fragments from bedrock at depth. Such an origin is compatible with the rounded to angular shape and lace of sorting of the fragments, the lack of quartz veining, and the presence of carbonate alteration. The alaskite and syenitic felsite are probably derived from Silurian or older alaskite and granitic rocks (Sgd, Sa) below the pre-Devonian unconformity.

AGE

Six hornblende and biotite separates of the granodiorite (Kgdi) plutons throughout the Craig A-2 quadrangle yield concordant ages averaging 102 m.y. This age is believed to approximate the time and emplacement and crystallization of the plutons (Turner and others, 1977). Contact relationships suggest that the Keg plutons intruded before the main Kgdi intrusive event.

Altered porphyritic diorite (Kdip) is younger than the Lower Devonian and, judging from its lithologic affinities to the Kgdi plutons, probably represents an early manifestation of Cretaceous magma generation. These rocks, however, are too altered to be suitable for the ^{40}K-^{40}Ar age-dating method. Breccia dikes (Kbd) are thought to be Cretaceous for the same reason.

THERMALLY METAMORPHOSED ROCKS

HORNFELS (Kh)

An aureole of hornfels surrounds the Copper Mountain pluton (Kgdi) and its outliers at Hetta Lake, Gould Island, and north of Portage Bay. Hornfels aureoles also surround epidotized gabbro (Keg) and the granodiorite (Kgdi) pluton at 2546 mountain near the Keete Inlet thrust. Near the intrusive the aureole is garnet-bearing hornblende hornfels grading into albite-epidote hornfels away from the plutonic body.

Metalliferous skarns derived from calcareous and igneous rocks have been discussed in detail by Wright (1915) and Kennedy (1953); some are described in the mineral deposits section (p. 32-46).

The hornfels aureole is well exposed at the west end of Gould Island. Here, at the outer edge, the intrusive is gabbro with epidote clots and pyrometasomatic acicular hornblende crystals up to 15 cm long.

Near the contact with the gabbro, the hornfels is greenish black and composed of fine, nondirectional grains of biotite, magnetite, and apatite in a turbid granoblastic quartz-andesine matrix. This rock is cut by numerous irregular quartz veins. These have margins of granoblastic quartz and irregular cores of sieve-textured diopside(?), garnet, and hornblende. The garnet-cored veins are ubiquitous near the intrusives and indicate that the inner aureole belongs to the hornblende-hornfels metamorphic facies. In the field the reddish garnet-cored veins with white margins mark this facies clearly.

At the west end of Gould Island, the inner zone of hornblende-hornfels gives way to an outer zone of albite-epidote hornfels at distances of 150 to 600 m from the contact. The albite-epidote hornfels is a fine-grained, dark-gray to greenish-black rock composed of randomly oriented biotite in a fine-grained matrix of quartz and feldspar. Scattered relict albite phenocrysts suggest the original rock was green tuffaceous schist (Wg) of the Wales Group. In the outer part of the albite-epidote hornfels zone, near the northwest end of Gould Island, the original fine-grained green tuffaceous(?) schist is largely replaced by chlorite and magnetite and the rock is cut by epidote veinlets.

The outer margin of the aureole is well exposed on the coast of Hetta Inlet, just 100 m east of Dell Island, where green tuffaceous(?) schist is silicified, has rusty pyritized zones, epidote veinlets and patches, and seams of sericite, magnetite(?), and chlorite that parallel foliation. The relict albite phenocrysts(?) are cloudy, poorly twinned, and were not noticed in outcrop. On Dell Island itself the green tuffaceous(?) schist is fresh appearing and has 5 percent twinned macroscopic albite. The felsic groundmass is about the same in the two rocks.

The depth of formation of the hornfels is probably 3 km or less; this estimation is based on the contact metamorphic mineral assembledges on Green Monster Mountain, where there is a 30-m-wide band of monticellite, calcite, chlorite, and sericite skarn along the east contact of the epidotized gabbro. According to Winkler (1967, p. 44) "at temperatures realized in nature, montecellite can form only at very low CO_2 pressures, at most, a few hundred bars." A depth of 1 km in average rock is equal to a geostatic pressure of 250 bars.

The geometry of the hornfels at Copper Mountain and mountain 2525 plutons suggest that these intrusions may have angled up from depth at a northwest-southeast plunge (pl. 1). The hornfels zones are wide (up to 6 km) on the southeast edges of the plutons and narrow (<1 km) on the northwest edges.

The porphyritic diorite plutons (Kdip) have minor irregular hornfels zones, sometimes only a few meters thick. In some areas hornfels are near (but not along) the igneous contact. These bodies were apparently intruded to very shallow depths, as indicated by the breccia dikes (Kbd) along Klakas Inlet west of Max Cove, where very little thermal alteration of country rock occurred during intrusion and where little (if any) hornfels was formed.

ACTINOLITIC HORNFELS (Kah)

A sheet of hornfels up to 150 m thick caps the ridge northeast of Hetta Lake. The hornfels (Kah) is a fine- to medium-grained, nearly unfoliated, and unbanded dark-greenish-gray rock composed of unoriented acicular actinolite, albite, epidote, and leucoxene-ilmenite mineralogy. Along the western and northern edges, the gently dipping sheet is distinctly different from the underlying thick-bedded and steeply dipping sequences of hornfels and marble (pl. 1). The edge of the sheet, which is thin and underlain by marble, is much broken by solution pits in the marble. Many of these pits have marble on the bottom and amphibolite on the rim. The surface of the underlying rock was uneven when the overlying sheet was emplaced. In the exposures at the north end of the sheet, the actinolitic hornfels is a massive metabasite either in thrust contact with or unconformably overlying older bedded rocks. The sheet recrystallized without developing much foliation because of the lack of shearing in the massive unit. Along the eastern contact with the Wales Group, the actinolite hornfels becomes banded with quartzose layers and is difficult to distinguish from the normal Wales Group green schist.

AGE

Hornfels (Kh) is believed to have formed at the same time or after the crystallization of the Copper Mountain pluton (Cretaceous). A ^{40}K-^{40}Ar radiometric age of actinolite in the actinolite hornfels (Kah) near Hetta Lake of 216 $\pm$ 4 m.y. (Turner and others, 1977) suggests that the Cretaceous Copper Mountain pluton has partially reset the radiometric age from the Middle Ordovician thermal event.

A sample of actinolite-bearing hornfels (Kh) from Dell Island gave an apparent age of 141 $\pm$ 4 m.y. (Turner and others, 1977) and is believed to represent a nearly complete resetting of the Wales Group metamorphic age by the emplacement of the Copper Mountain pluton.

A zone of biotite hornfels crops out for a short distance along the west side of Cholmondeley Sound. Biotite in the hornfelsed zone is discordant to foliation in the Wales Group schist country rock. This biotite was dated at 355 $\pm$ 11 m.y. (Turner and others, 1977). There is no exposed intrusive body in the area that could account for the hornfels. The apparent age represents either 1) a partial resetting of the 475-m.y.-old Wales Group metamorphic age or 2) the thermal manifestations of a buried Paleozoic intrusive.

STRUCTURE

SMALL-SCALE FEATURES ASSOCIATED WITH PENETRATIVE DEFORMATION

FOLIATION

Foliation occurs pervasively in the Wales Group but is rarely found in the Descon Formation. The foliation in the Wales Group is due to parallel orientation of chlorite flakes that parallel composition layers in most outcrops. Only rarely does foliation cut compositional banding. In most localities the compositional layering in the Wales Group represents original bedding that ranges from vague color bands to well-defined beds of metakeratophyre, tuffaceous schist, and marble. Most of the Wales Group green schist (Wg) is made up of alternating thin quartzose and chloritic laminae.

CRENULATIONS

In much of the Wales Group are crenulations about 1 mm apart with axes parallel to nearby minor folds. In some outcrops two directions of crenulations are visible on different layers. Commonly there are chloritic streaks on foliation surfaces that parallel crenulations or define a second direction of lineation.

In many outcrops crenulations are deflected by later small folds or kink bands with axes parallel to the crenulations. The early (E) and late (L) linear features in figure 22 show that later small fold or kink bands deflect earlier crenulations. Apparently, there were two periods of penetrative deformation, with much wobble in axial direction.

MINOR FOLDS

Minor folds in the Wales Group are usually 2 to 15 cm in wavelength. Most are recumbent so that in profile, they are S or Z shaped, having formed during periods of penetrative rotational shear. The local direction of rotation is perpendicular to the fold axes. The folds (pl. 1), as seen looking down the plunge of the fold axis.

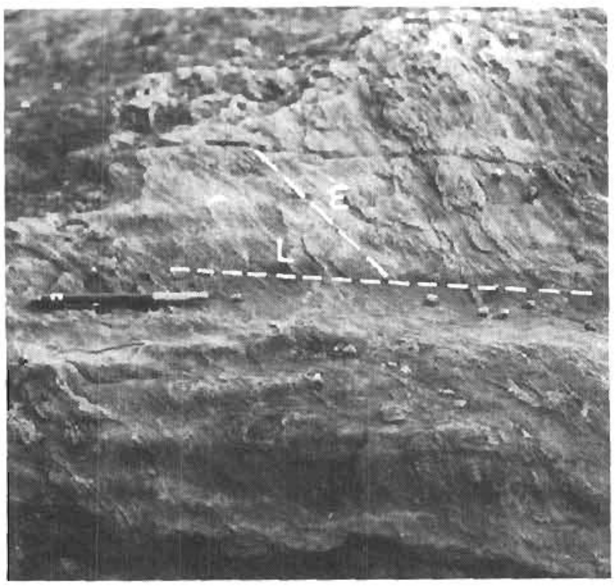

Figure 22. Foliation surface in Wales Group green schist. Earlier crenulations (E) are gently folded by later, nearly horizontal folds (L) at the northwest corner of Kassa Inlet.

Minor folds are a common feature of penetrative regional deformation. Minor folds in one outcrop are usually parallel to crenulations and chloritic streaking in nearby outcrops.

BOUDINAGE

Many dolomite and quartz layers in the Wales Group units show boudinage structure. This is well illustrated by dolomite layers on the north side of West Arm that have been pulled apart and show 'sucking-in' of the adjacent marble at necked parts and around the ends of the boudin. The boudins are up to 3 m thick and 20 m long. Their long axes are steep (S. 80° W., 85° plunge) and parallel the early fold axes.

KINK BANDS

The latest structural features in the Wales Group are crosscutting zones of kinking in the foliation that form bands a few centimeters thick. Both single and multiple bands that split and join are found. These kink bands occasionally grade into cleavage and secondary foliation (fig. 23). Axes of kink bands are shown on plate 1.

LARGE-SCALE FAULTS AND FOLDS

THRUST FAULTS

The Big River thrust sheet is a complexly folded and faulted sheet of Wales Group marble (Wm), dark-gray phyllite (Wp), and minor greenschist (Wg) that has been thrust over the Wales Group green schist (Wg) and quartz sericite schist (Ws) at the time of or before regional folding. Thrusting has been definitely identified only near Big River. In other places foliation and bedding in the thrust sheet are more or less parallel to foliation in the rock units, although the thrust contact shows extreme shearing in these localities.

On the slope southwest of the mouth of Big River (pl. 1), the thrust surface truncates Wales Group units below it at an angle of 40°. A greenschist layer in the Wales Group marble (Wm) above the thrust is also truncated. Two km to the south, two thick marble beds (Wm) in the lower plate strike into the thrust and are apparently truncated.

A thrust system crosses the east shoreline of Hetta Inlet south of Jumbo Creek in an area of unusually abundant folds. These folds are parallel to the earlier

Figure 23. Silicious Wales Group Schist near Summit Lake. Drag-folded quartz is cut by younger cleavage.

minor fold direction nearby, which suggests that the thrusting occurred at the same time as the penetrative deformation (synkinematic thrusting). The folds are overturned to the east.

Thick sections of interbedded marble and hornfels (Kh) east of Summit Lake, northeast of Hetta Lake, and at Hetta Mountain may be faulted parts of the Big River thrust sheet. The well-defined hornfels sheet (Kah) northeast of Hetta Lake rests partly on the Big River thrust sheet.

At the west end of West Arm, marble fault blocks (pl. 1) are interpreted as part of the Big River thrust sheet dropped down along normal faults. These faults are about vertical and cut across bedding in the marble. Farther east, at Divide Head and across on the north shore of West Arm, horst and graben normal faulting dies out and the Big River thrust fault is exposed. The thrust sheet here has been folded into a syncline. The marble is parallel with the underlying schist and partly dolomitized.

The Keete Inlet thrust brings Wales Group schist under unmetamorphosed Lower Devonian and Descon Formation rocks. The nature of the fault movement is based on the following observations: 1) the fault, where measureable, dips under the sediments and away from the Wales Group rock units at roughly 25-40^{o}, 2) its strong curvature, which causes a 90^{o} change in direction in 14 km, indicates that it is a shallow-dipping fault, and 3) both the pervasive shearing of the Wales Group green schist for up to 450 m from the fault and the lack of shearing in the sediments on Keete Inlet indicate that the dip-slip movement was thrusting and that the green schist was an active agent.

AGE OF THRUSTING

The Big River thrust sheet probably moved contemporaneous with the latest major folding episode in the layered rock section. This is suggested by the parallelism of larger scale folds in the thrust sheet with those in the underlying rocks. In addition the thrust is folded into a syncline near Big River. Movement on the thrust sheet northeast of Hetta Lake evidently ceased before Cretaceous plutonism.

The Keete Inlet thrust clearly cuts Middle Devonian sedimentary rocks but is intruded by a Cretaceous granodiorite (Kgdi). Thus the age of thrusting in the map area is believed to have taken place during a post-Middle Devonian—pre-Cretaceous interval. Some minor low-angle movement along older thrust faults may have occurred during intrusion of the Copper Mountain pluton.

HIGH-ANGLE FAULTS

The map area is cut by north and northwest-trending steep faults. The Klakas Inlet fault is the clearest example of a north-trending fault. A left-lateral strike-slip movement of 2-1/2 km is shown by offset of the lower sheet of the Keete Inlet thrust. On the divide between Klakas Inlet and South Arm, the fault has a vertical shear zone 1 m wide that trends north from Klakas Inlet to the south half of South Arm and is probably offset by a northwest-trending cross fault at West Arm near Cholmondeley Sound. It apparently does not extend across West Arm.

Prominent northwest-trending lineaments extend through the southern part of Prince of Wales Island. Several major northwest-trending fault zones that extend for a number of kilometers in the map area include the East Finger, Deer Bay, and West Arm faults.

The north-trending high-angle faults are generally cut by the more prominent northwest-trending fracture series. Neither set appears to have significant stratigraphic displacement, although both sets produced offsets of up to 5 km. Radial high-angle faulting adjacent to the Copper Mountain pluton likely resulted from stress created by the intrusive episode in Cretaceous time.

FOLDS

The Wales Group has undergone two periods of folding, the latter of which warped the Wales Group, the Descon Formation, and the Middle Devonian rocks into rather broad northwest-trending fold structures. A regional anticline, possibly the Dolomi-Sulzer anticline (Peek, 1975), may be the axis of a broad northwest-plunging anticlinorium that shapes the present configuration of Wales Group rocks in the map area (pl. 1). These larger fold structures have been complicated by several periods of thrust faulting and high-angle fracturing.

WHOLE-ROCK MAJOR OXIDE ANALYSES OF IGNEOUS ROCKS

Whole-rock chemical analyses of 12 plutonic, volcanic, and metavolcanic rocks are given (table 2) and shown on triangular alkali-F-M diagrams and an alkali silica diagram (fig. 24-27). The results of the analyses have been discussed individually in the rock-unit sections of the text.

ELEMENTAL GEOCHEMISTRY

The geochemical sampling and trace-elements analysis program was aimed at determining the metal content of the Wales Group rocks and defining mineralized zones within the map area. In an area of about 740 km^2, 1,130 stream-sediment and soil samples (table 3)[4] and 140 rock samples (table 4)[4] were taken for 30-element analysis. Rock samples were composite chip samples taken of shoreline outcrops of Wales Group rocks and channel samples from mineralized zones and prospects.

[4]Tables in back-cover pocket.

Table 2. *Bulk chemical analyses of 12 plutonic, volcanic, and metavolcanic rocks from the Craig A-2 quadrangle and vicinity, and 13 examples from literature*

	1[1,2]	2[1]	3[1]	4[1]	5[1]	6[1]	7	8	9	10,13	11[1]	12[1]	14	15	16[1]	17[1]
	Wales Group meta-kerato-phyre (Wk)	Wales Group meta-spilite	Wales Group meta-spilite tuff(?)	Wales Group tuff-aceous green-schist	Wales Group meta-kerato-phyre tuff(?)	Descon Fm alkaline basalt	Quartz kerato-phyre (Gil-luly, 1935)	Quartz kerato-phyre (Dick-enson, 1962)	Magne-tite kerato-phyre (Ben-sen, 1915)	Avg spilite (Sun-dium, 1930)	Descon Fm basalt	Descon Fm basalt	Avg oceanic tholei-ite (Engel, 1965)	Avg andesite (Nock-olds, 1954)	Max Cove granite (Sgd)	Green M'ster Mtn epido-tized gab-bro (Keg)
SiO_2	63.12	47.66	50.32	76.87	69.69	43.65	75.04	74.40	56.95	51.22	50.08	40.78	49.94	54.20	76.70	38.14
TiO_2	0.55	0.77	0.53	0.22	0.47	0.42	0.10	0.32	0.89	3.32	1.55	0.71	1.51	1.31	0.18	1.04
Al_2O_3	14.55	16.24	16.30	12.61	12.19	10.25	13.39	13.50	17.87	13.66	18.42	14.91	17.25	17.17	12.97	19.97
Fe_2O_3	2.34	7.73	3.78	1.40	3.33	2.49	1.61	1.50	4.49	2.84	2.56	3.63	2.01	3.48	0.96	10.25
FeO	4.64	2.83	4.05	0.63	2.64	7.49	0.37	0.26	6.00	9.20	6.00	5.59	6.90	5.49	0.52	2.11
MnO	0.11	0.13	0.14	0.03	0.07	0.20	0.05	0.02	0.08	0.25	0.12	0.71	0.17	0.15	0.03	0.16
MgO	3.76	4.37	3.52	0.57	2.14	15.80	0.18	0.11	0.93	4.55	6.02	8.05	7.28	4.36	0.45	3.40
CaO	0.96	7.80	6.49	0.11	1.11	9.95	0.40	0.74	2.30	6.89	3.74	13.38	11.86	7.92	0.57	21.95
Na_2O	4.95	6.76	7.12	6.77	5.77	1.79	6.36	7.70	8.80	4.93	4.26	2.91	2.76	3.67	3.64	0.12
K_2O	1.65	0.56	0.06	0.03	0.14	0.12	0.83	0.36	0.38	0.75	1.48	0.18	0.16	1.11	1.85	0.04
$H_2O(-)$	0.38	0.73	0.87	0.24	0.51	0.86	0.24	---	0.38	---	0.99	0.98	---	---	0.60	0.46
$H_2O(+)$	---	---	---	---	---	---	1.07	---	0.71	---	---	---	---	0.86	---	
	97.01[3]	95.58	93.18	99.48	98.06	93.02	99.64	99.09	99.78	97.61	95.22	91.29	99.84	99.72	98.47	97.64

CIPW Norms

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
QZ =	16.87	0.0	0.0	33.72	27.98	0.0	31.67	24.29	0.0	0.0	0.0	0.0	0.0	2.55	44.76	0.0
OR =	10.05	3.42	0.37	0.18	0.85	0.75	4.97	2.12	5.23	4.58	9.15	1.16	0.95	6.66	11.35	0.0
AB =	45.81	29.80	46.19	60.97	53.31	9.87	57.87	68.95	72.43	44.16	40.04	6.49	24.81	33.48	33.93	0.0
AN =	4.91	12.74	13.02	0.55	5.67	20.69	2.01	1.21	8.10	13.35	19.43	29.66	34.25	27.53	2.94	57.59
NE =	0.0	19.80	12.74	0.0	0.0	4.27	0.0	0.0	3.70	0.93	0.0	13.26	0.0	0.0	0.0	0.69
CO =	3.24	0.0	0.0	1.36	0.59	0.0	1.44	0.0	0.0	0.0	3.44	0.0	0.0	0.0	4.47	0.0
DI =	0.0	10.92	8.38	0.0	0.0	12.59	0.0	1.27	1.30	8.78	0.0	34.41	9.86	4.96	0.0	20.08
HY =	15.82	0.0	0.0	1.58	7.34	0.0	0.50	0.0	0.0	0.0	21.88	0.0	1.20	16.79	1.29	0.0
OL =	0.0	9.36	10.16	0.0	0.0	42.17	0.0	0.0	5.68	15.96	0.99	9.78	19.79	0.0	0.0	0.0
MT =	2.52	5.45	4.17	1.08	3.58	2.75	0.78	0.0	4.67	3.07	2.80	4.15	2.10	3.70	0.94	3.32
IL =	0.79	1.11	0.78	0.31	0.67	0.62	0.14	0.43	1.23	4.78	2.26	1.08	2.11	1.85	0.26	1.55
AP =	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HT =	0.0	1.94	0.0	0.26	0.0	0.0	0.62	1.04	0.0	0.0	0.0	0.0	0.0	0.0	0.07	5.43
WO =	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.98
EN =	10.72	0.0	0.0	1.58	6.08	0.0	0.50	0.0	0.0	0.0	16.41	0.0	0.87	12.23	1.29	0.0
FS =	5.12	0.0)	0.0	0.0)	1.26	0.0	0.0	0.0	0.0	0.0	5.47	0.0	0.32	4.56	0.0	0.0
FO =	0.0	9.36	7.69	0.0	0.0	34.57	0.0	0.0	1.92	9.73	0.74	7.87	14.44	0.0	0.0	0.0
FA =	0.0	0.0	2.47	0.0	0.0	7.60	0.0	0.0	3.77	6.23	0.25	1.91	5.35	0.0	0.0	0.0
	100.01	94.54	95.81	100.01	99.99	93.71	100.00	99.98	99.34	95.61	99.99	99.99	95.07	97.56	100.01	92.64

	18[1]	19[1]	20	21	22	23	24	25	26
	Mount Jumbo grano-diorite (Kgdi)	Copper Mtn diorite (Kgdi)	Avg horn-blende gabbro (Nock-olds, 1954)	Avg diorite (Nock-olds, 1954)	Avg horn-blende biotite diorite (Nock-olds, 1954)	Avg monzon-ite (Nock-olds, 1954)	Avg grano-diorite (Nock-olds, 1954)	Avg calc-alka line granite (Nock-olds, 1954)	Avg alka-line granite (Nock-1954)
SiO_2	60.66	47.70	48.36	51.86	52.97	55.36	66.88	72.08	73.86
TiO_2	0.62	0.97	1.32	1.50	1.60	1.12	0.57	0.37	0.20
Al_2O_3	16.59	17.98	16.84	16.40	18.19	16.58	15.66	13.86	13.75
Fe_2O_3	3.12	4.59	2.55	1.73	1.97	2.57	1.33	0.86	0.78
FeO	3.04	5.54	7.92	6.97	6.29	4.58	2.59	1.67	1.13
MnO	0.15	0.17	0.18	0.18	0.13	0.13	1.57	0.52	0.26
MgO	2.11	4.30	8.06	6.12	4.75	3.67	3.56	1.33	0.72
CaO	5.94	11.84	11.07	8.40	7.61	6.76	3.84	3.08	3.51
Na_2O	4.12	3.43	2.26	3.36	3.50	3.51	3.07	5.46	5.31
K_2O	3.03	1.19	0.56	1.33	1.65	4.68	---	---	---
$H_2O(-)$	0.24	0.48	---	---	---	---	---	---	---
$H_2O(+)$			0.64	0.80	1.00	0.60	0.65	0.53	0.47
	99.62	98.19	99.76	98.65	99.66	99.56	99.79	99.82	100.16
QZ=	10.01	0.0	0.0	0.0	0.0	0.0	20.21	27.19	29.48
OR=	18.05	7.22	3.34	8.01	9.87	27.87	18.39	32.88	30.78
AB=	37.31	23.42	20.50	30.75	31.83	28.84	34.95	28.19	32.01
AN=	17.98	30.97	34.51	26.24	29.43	15.79	16.65	6.73	3.63
NE=	0.0	4.93	0.0	0.0	0.0	1.75	0.0	0.0	0.0
CO=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.52	1.24
DI=	9.30	23.49	8.39	6.50	3.53	7.21	0.50	0.0	0.0
HY=	3.10	0.0	3.49	9.68	17.78	0.0	6.83	3.06	1.75
OL=	0.0	3.65	21.02	11.61	1.45	10.65	0.0	0.0	0.0
MT=	3.29	4.93	2.69	1.84	2.09	2.71	1.41	0.92	0.83
IL=	0.87	1.39	1.86	2.13	2.26	1.57	0.80	0.53	0.28
AP=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HT=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WO=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EN=	2.34	0.0	2.49	6.63	11.98	0.0	4.39	1.46	0.73
FS=	0.76	0.0	1.00	3.06	5.80	0.0	2.43	1.60	1.02
FO=	0.0	2.68	15.00	7.95	0.98	7.66	0.0	0.0	0.0
FA=	0.0	0.97	6.02	3.66	0.47	2.98	0.0	0.0	0.0
	100.00	100.00	95.8	96.76	98.24	96.39	99.74	100.02	100.00

[1]Analyses by Imai Shiro, Japan Analytical Chemistry Research Institute, Tokyo.
[2]Numbers are keyed to Alkali-F-M diagrams.
[3]Values have not been corrected to 100 percent. QZ= Quartz, OR= Orthoclase, AB= Albite, AN= Anorthite, NE= Nephaline, CO= Corundum, DI= Diopside, HY= Hyperstene, OL= Olivine, MT= Magnetite, IL= Ilmenite, AP= Apatite, WO= Wollastonite, EN= Enstatite, FS= Ferro-sillite, FO= Forsterite, FA= Fayalite.

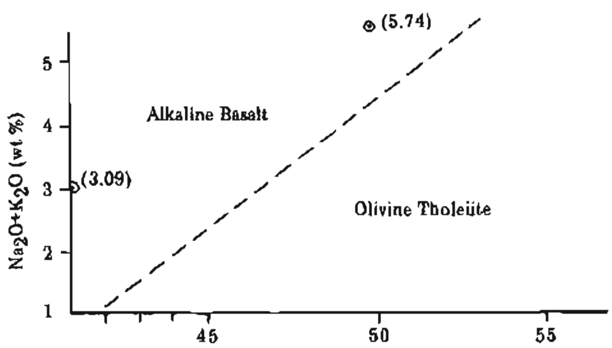

Figure 24. Alkali-silica diagram for Hawaiian basalts (after MacDonald and Katsura, 1964) and two analyses of Descon basalt (Odb) from Klakas Inlet.

ANALYTICAL TECHNIQUES

Elemental analyses were performed at the DGGS Mineral Analysis Laboratory. Soil and stream-sediment samples were screened to -80 mesh and rocks were pulverized. Atomic-absorption analysis was carried out

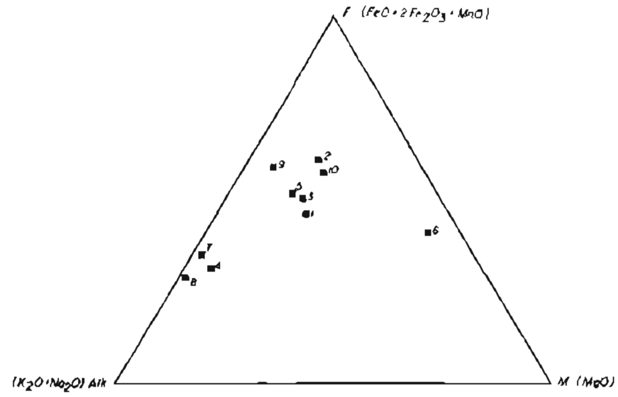

Figure 25. Alkali-F-M diagram of keratophyre tuff and spilite tuff in the Wales Group and from published information. Locations shown on plate 1. 1 - Wales Group keratophyre, Nutkwa Inlet (70C 218). 2 - Wales Group metaspilite tuff, Nutkwa Inlet (70C 276). 3 - Wales Group metaspilite tuff, South Arm (71C 165). 4 - Wales Group tuffaceous green schist, Hetta Inlet near Deer Bay (72C 174B). 5 - Wales Group metakeratophyre tuff, Sukkwan Strait (72C 202B). 6 - Wales Group spilite tuff, Sukkwan Strait (72C 202C). 7 - Quartz keratophyre (Guilluly, J., 1953, Amer. Jour. Sci., v. 229, p. 235). 8 - Quartz keratophyre (Dickenson, W.R., 1962, Amer. Jour. Sci., v. 260, p. 261). 9 - Magnetite keratophyre (Benson, N.W., 1915, Linnean Soc., N.S. Wales Proc., v. 40, p. 139). 10 - Average spilite, 19 analyses (Sundium, N., 1930, Geol. Mag., v. 67, p. 9).

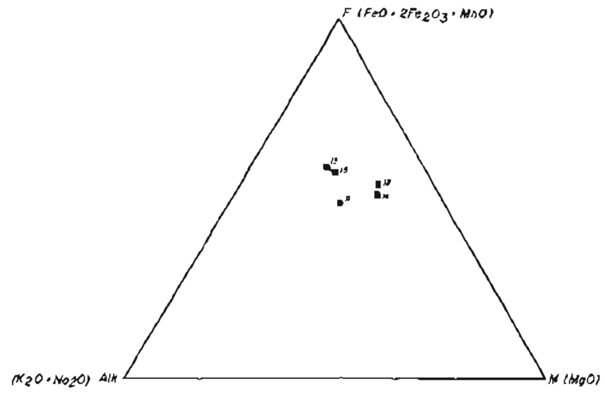

Figure 26. Alkali-F-M diagram of two basalts from the Descon Formation on Klakas Inlet and from published data. Locations shown on plate 1. 11 - Descon Formation basalt from east shore, Klakas Inlet (71C 122). 12 - Descon basalt from west shore, Klakas Inlet (71C 17). 13 - Average spilite, 19 analyses (Sundium, op. cit., p. 9). 14 - Average oceanic tholeiite, 10 analyses (Engel and others, 1965, Geol. Soc. America Bull., v. 76, p. 723). 15 - Average andesite (Nockolds, S.R., 1954, Geol. Soc. America Bull., v. 65, p. 1019).

by taking a 10-g sample and digesting it in an appropriate amount of aqua regia. The digestate was diluted to 100 mm with distilled water and centrifuged. The elements copper, lead, zinc, and silver were aspirated

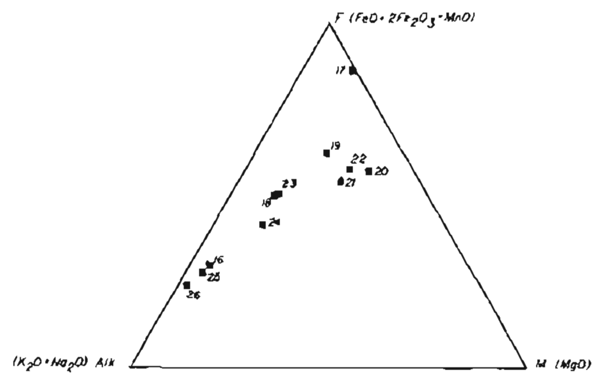

Figure 27. Alkali-F-M diagram of four granitoid rocks. Locations shown on plate 1. Others taken from literature. 16 - Calc-alkaline granite (Sgd) from west shore, Klakas Inlet near Max Cove (71C 23). 17 - Epidotized gabbro (Keg) from Green Monster Mountain (72C 217). 18 - Quartz monzonite (Kgdi) from Mount Jumbo, Copper Mountain pluton (DT72 61A). 19 - Diorite (Kgdi) from south shore of Portage Bay, border phase of Copper Mountain pluton (71C 426). 20 - Average hornblende gabbro (Nockolds, op. cit., p. 1020). 21 - Average diorite (Nockolds, op. cit., p. 1019). 23 - Average monzonite (Nockolds, op. cit., p. 1017). 24 - Average granodiorite (Nockolds, op. cit., p. 1014). 25 - Average calc-alkaline granite (Nockolds, op. cit., p. 1012). 26 - Average alkaline granite (Nockolds, op. cit., p. 1012).

directly into the air-acetylene flame; gold was determined following a DIBK-Aliquat 336 solvent-solvent extraction.

Emission spectrographic analyses are reported in a three-step series 1, 2, 5, 10, 20, 50, 100, 200, etc. in ppm or percentage. A reported value of 100 ppm identifies the concentration as nearer 100 ppm than 50 or 200 ppm. Approximately 95 percent of the values fall within a ± 1 reporting interval.

Cumulative frequency plots (figs. 28-30) of the copper, lead, and zinc analyses by atomic-absorption spectrophotometry for the stream sediments and soil samples were made by the method described by Lepeltier (1969). Straight parts of these curves indicate single populations of log-normally distributed sample values. Most of the curves show a positive break, indicating an excess of high values over the log-normal distribution sample values. Thresholds for copper, lead, and zinc anomalies have been taken as the lowest break in the slope of the curve. Anomalous values for elements other than copper, lead, and zinc were obtained by inspection.

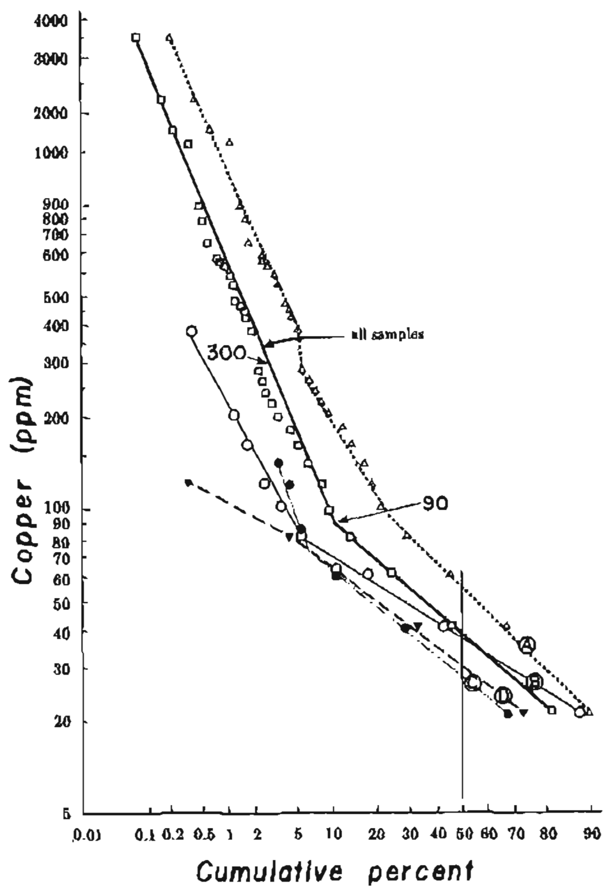

Figure 28. Cumulative frequency plot for copper in stream-sediment and soil samples. A - Copper Mountain subarea. B - Cholmondeley Sound subarea. C - Kassa Inlet subarea. D - Klakas Inlet subarea.

Cumulative frequencies were plotted for the entire area and the four subareas (Copper Mountain, Cholmondeley Sound, Kassa Inlet, Klakas Inlet) shown on plate 2. Three of these subareas are underlain by Wales Group rocks and the fourth includes all rocks south of the Keete Inlet thrust. The cumulative frequency plots show that the Copper Mountain subarea (plot A) has more copper and Cholmondeley Sound (plot B) has more lead and zinc than the rest of the map area.

Stream-sediment samples of the finest fraction available below the water line were taken on creeks at intervals of about 1/2 km. All creek-mouth samples draining into salt water were taken well above the high-tide line. Soil samples were usually taken in and around prospect areas and mineralized zones. Average depth of soils sampled was about 15 cm. An effort was made to exclude organic material in all samples.

Confidence in the reproducibility of the stream-sediment sampling is given by examining sample results from the mouth of Jumbo Creek and from an unnamed creek at the north end of Hetta Lake. At the latter site (No. 218, pl. 2), an area of low relief and fine sediment, three samples were taken 15 m apart. Each was divided into three splits and all nine samples were analyzed. The results (table 3) show that the variations between sample sites (55 ppm) and the splits of each sample (10-20 ppm) is fairly small compared to the average copper content of the samples (175 ppm). At the mouth of Jumbo Creek (No. 99, pl. 2), the copper content of two samples from the creek bed below water level taken by different samplers 2 years apart was 600 and 675 ppm.

An indication of the effect of location on copper values of these samples (analyzed by atomic absorption spectrophotometry) is shown by three sediment samples taken at site 99 (pl. 2). In the stream bed in 30 cm of water, 675 ppm Cu was recorded. In the bank at water level, 745 ppm Cu was recorded. In the bank 15 cm above water level, 675 ppm Cu was recorded. Other elements, notably scandium and molybdenum, show considerably more variability than the copper in these samples.

Mineralized zones, prospects, and old mines were sampled to obtain an indication of the relative grade of mineral deposits present in the map area. As part of the regional geochemistry program, random grab samples of representative Wales Group rock units were collected along the shores of Kessa, Keete, Hassiah, and Hetta Inlets and Cholmondeley Sound. Because they were analyzed along with the stream sediments, the results obtained from stream sediments and what is thought to be background metal content in the Wales Group can be compared.

All samples containing anomalous amounts of any of the analyzed metals are shown on plate 2 and described (tables 3 and 4). Background samples taken in 1970 and 1971 are not listed in this report, but can be found in DGGS Geochemical Reports 24 and 27, respectively (Herreid, 1971; Herreid and Trible, 1973).

ANOMALOUS AREAS

Peary Creek zinc and lead anomalies cover more than 5 km^2 near the Copper Mountain pluton in an area of north- and northwest-trending faults that cut marble and dark-gray phyllite bedrock. The anomalies may be partly due to a high background in the sheared quartz-vein-rich phyllite, but there may also be undiscovered mineral deposits in the Wales Group there.

Anomalous amounts of copper and other base metals are present in streams draining the pyrometasomatic skarn deposits on the west side of the Copper Mountain pluton. The Jumbo glory hole is near the upper part of Jumbo Creek, about 2.5 km from the beach. At the mouth of Jumbo Creek, stream sediments average 600 ppm copper. Bedrock for most of this distance is marble, which has not inhibited the transportation of copper in the stream. Samples from Wright Creek, where several small prospects are located, also contain anomalous copper values. In contrast to this, the small creek on the south side of Copper Harbor has no known copper prospects and its sediments are not anomalous at the mouth and only slightly so near its head. There are tungsten anomalies from streams draining the northern portion of the Copper Mountain pluton contact aureole.

Small copper deposits on the east side of the Copper

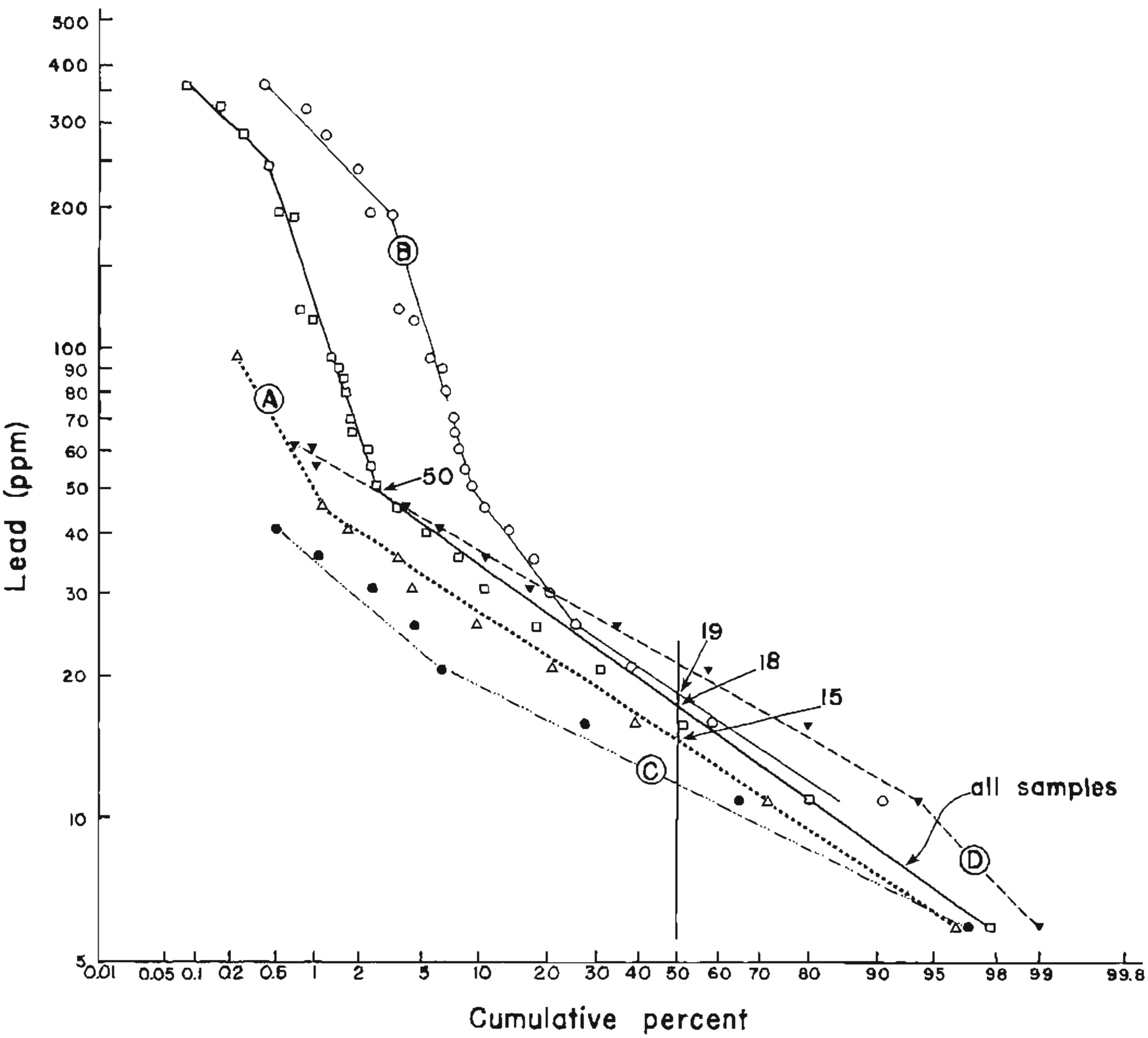

Figure 29. Cumulative frequency plot for lead. A - Copper Mountain subarea. B - Cholmondeley Sound subarea. C - Kassa Inlet subarea. D - Klakas Inlet subarea.

Mountain pluton are mirrored by anomalous copper contents in many of the small streams. The sediments in the 3-km-long creek draining into Hetta Lake from the north are anomalous in copper from head to mouth and in molybdenum near its head. Disseminated molybdenite is present in outcrops of skarn at the head of the creek directly west of Lake Marge. This creek would certainly lead the prospector from Hetta Lake to the Lake Marge mineralized area. However, it seems likely that there is more than one source of copper and molybdenum along

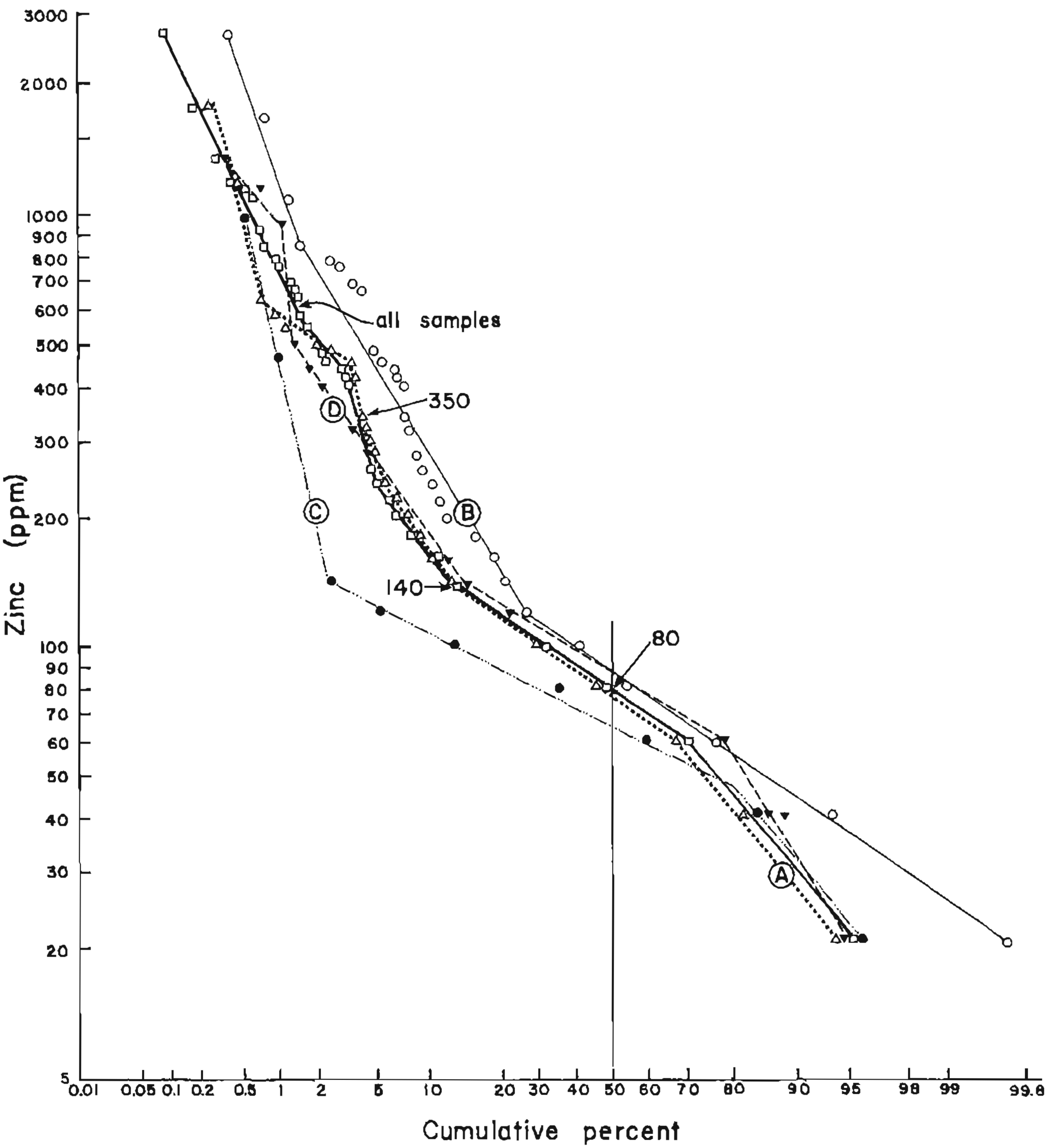

Figure 30. Cumulative frequency plot for zinc. A - Copper Mountain subarea. B - Cholmondeley Sound subarea. C - Kassa Inlet subarea. D - Klakas Inlet subarea.

the creek drainage and the actual distance of transport of the base metals down the creek may be less than 3 km.

High tin values from streams draining Beaver Mountain at the head of West Arm probably represent a high tin background for the granitic rocks to the north of the map area.

Antimony anomalies from sediments in streams draining the south shore of West Arm may indicate mineralization in the Wales Group there.

The creek at Chomly townsite on West Arm extends along a north-northeast-trending fault parallel to the Friendship fault. The indicated lead-zinc anomalies there may originate from the fault or in the Polymetal lode—Friendship silicified-zone area. Stream sediments and soil samples taken near the Friendship silicified zone on South Arm show anomalous amounts of copper, yttrium, and bismuth. Samples of residual soil draining the Polymetal lode (locality 22, pl. 1) on the west shore of South Arm are highly anomalous in lead, zinc, and silver. Threshold values for copper also were detected. On the east side of South Arm, the silicified zone is anomalous in zinc and yttrium. Farther east, beyond the area of geological mapping, stream sediments are conspicuously anomalous in beryllium and accompanied by threshold zinc values. The beryllium anomalies probably indicate an intrusion east of the map area. Joe Walper (pers. comm.) has found zirconium mineralization in dikes on Dora Bay, just east of South Arm. The mineral he discovered is eudialyte, a zirconium silicate, confirmed by geochemist N.C. Veach of the DGGS Laboratory.

Geochemical stream-sediment samples from streams draining the east slope of the Moonshine lead-zinc-silver deposit on South Arm (pl. 1) produced only background amounts of metals. Nearby silicified zones yield threshold values of zinc, yttrium, and vanadium.

The East Finger fault zone on South Arm may be responsible for a line of antimony anomalies and threshold copper values on both sides of the East Finger fault. These anomalies extend from sample locations 406 to 447 (pl. 2), a distance of 7 km.

Creeks near Klakas Inlet contain scattered threshold-to-anomalous copper, zinc, cobalt, manganese, tin, and tungsten values. Along Klakas Inlet west of Max Cove is a series of high zinc and threshold chromium, nickel, and antimony values that may be associated with a group of small porphyritic diorite (Kdip) plutons. The large creek draining into Max Cove from the north has a line of threshold zinc and anomalous antimony values, and the large Silurian(?) granodiorite (Sgd) stock there may have a mineral potential.

Threshold-to-anomalous zinc, zirconium, and rare-earth-element values show up in the stream sediments along the entire east side of Kassa Inlet. However, the rare-earth anomalies may mirror the bedrock composition of the Devonian(?) andesite (Dand) there and have no economic value.

MINERAL DEPOSITS

INTRODUCTION

Known mineral deposits in the Craig A-2 quadrangle and vicinity occur in metasomatic skarns, as massive sulfide lenses in Wales Group schists, as dolomitic replacements, and in fractures that clearly cut the bedded rocks. Most of the sulfide occurrences are hosted in the Wales Group. Table 5 is a summary listing of the known mineral deposits, which have been shown on plate 1.

Although the skarn-derived deposits and stratiform mineral occurrences along Hetta Inlet are obviously of different origin, both are very similar in metallic content (table 5). They include major copper and zinc with lesser but significant amounts of molybdenum, gold, silver, cadmium, antimony, and barium. Lead is conspicuously minor or absent. The stratiform mineralization at Lime Point, Keete, Copper City, and Corbin (localities 19, 20, 18, and 12, respectively) lie in the same approximate stratigraphic position in the Wales Group (pl. 1), which contains up to 15 percent metakeratophyre (Wkt) and related flow rock interbedded in green tuffaceous schist (Wg). Included in this rock package are several lense-shaped pyritic-quartz-sericite zones probably related to the known massive-sulfide deposits. Similar deposits occur within the Wales Group outside the study area at Khyham, Trocadero Bay, McLeod Bay, and Niblack Anchorage, all on Prince of Wales Island (Hawley, 1976; Herreid, 1964; Peek, 1975).

The Copper Mountain pluton, with its associated skarn-sulfide deposits, intrudes the same approximate stratigraphic sequence as the sections at Corbin, Copper City, and Lime Point. Thus, the metals in these skarn deposits may have been derived from the leaching of the metalliferous upper(?) section of the Wales Group.

The metallic content of mineral deposits along the South Arm of Cholmondeley Sound differs somewhat from those along Hetta Inlet to the west. They are high in lead, zinc, and silver and low in copper, molybdenum, and gold (table 5). Anomalous yttrium and bismuth occur in vein deposits. The Polymetal lode appears to be a stratiform deposit, whereas the Moonshine (locality 24), Friendship (locality 23), and associated deposits are structurally controlled veins that clearly crosscut foliation in the schist.

The stratigraphy and mineral deposits of the West Shasta mining district in northern California were compared with the Wales Group rocks and mineral deposits. Both areas are floored by volcanogenic-sedimentary piles. Geologic character of the stratiform deposits in both districts is similar (Kinkel and others, 1956), and both appear to have significant amounts of sodic volcanism associated with mineralization. However, the known deposits of the West Shasta district are larger than those of the Wales Group, and Wales Group volcanism is pre-Middle Ordovician and likely Precambrian (Churkin and Eberlein, 1977); the Balaklala rhyolite and associated rocks are considered Devonian (Kinkel and others, 1956).

DOLOMITE DEPOSITS (D)

Dolomite of several ages is common in the study area. The oldest dolomite occurrences are boudined lenses in Wales Group marble that are considered of primary origin. Veins and replacements along faults in the Wales Group at Kassa Inlet are associated with late minor folds. Veins and replacements in the Wales Group green schist at Nutkwa Inlet are along steep faults and are related to mafic dikes. Dolomite veins in steep faults cut the marble of the Big River thrust sheet. Late dolomite-bearing veins occur at the Friendship silicified zone and the Moonshine lead-zinc-silver-copper deposit. At the Green Monster Mountain prospect, a metasomatic dolomite deposit is associated with copper mineralization. In other localities dolomite and copper mineralization are associated along fault zones in the Wales Group. Dolomite deposits are conspicuously absent in the Descon Formation. Most of the dolomite in the map area, whether of primary or secondary origin, is found in the Wales Group.

Some dolomite-bearing veins contain sulfide mineralization. Dolomite-quartz veins on Kassa Inlet contain pyrite and slightly anomalous values of lead, silver, and gold (sample 549, pl. 2). A dolomite-quartz vein (sample 588, pl. 2) intruding the lower part of the Devonian bedded rocks on the west shore of Klakas Inlet contains minor malachite stain and background values of copper, lead, zinc, and silver. For 30 m on the west shore of Hetta Inlet, opposite Jumbo Island, three cross faults with slickensides have veins and replacements of dolomite accompanied with minor malachite stain. There is no mineralization along the fault itself; the copper carbonate is in the wall rock.

QUARTZ BOUDINS AND SILICIFIED ZONES

Quartz boudins and silicified or siliceous zones (where mappable, shown as Wss) are fairly common in Wales Group rocks. Types of occurrences are 1) silicification of schist, 2) folded quartz that parallels foliation, 3) folded quartz that crosscuts foliation, 4) isolated quartz lenses in fold hinges, 5) unfolded veins extending from faults, 6) tabular veins in faults and joints, and 7) sulfide-bearing veins in fractures.

Tabular quartz boudins more than 20 cm thick are uncommon in the Wales Group and Descon Formation schists and phyllites; when present they are commonly folded. The character of the quartz boudins throughout the area suggests that most of the quartz was emplaced before or during regional dynamothermal metamorphism and was probably 'sweated' out of the country rock. Tabular quartz veins less than 10 cm thick are fairly common. The quartz is believed to be deformed by gliding along the foliation planes (figs. 31, 32).

Some quartz bodies display little or no deformation, and many of the undeformed veinlets are obviously late.

Distinctive zones of silicification scattered in layers spaced up to 100 m apart throughout the Wales Group display no quartz boudins. Evidently, some of these 'silicified' zones must have been siliceous rock layers before metamorphism.

Only a few widely scattered quartz veins and boudins are present in the unfoliated Descon Formation(?) and Devonian rocks on Klakas, Kassa, and Keete Inlets, but 2 km east of Klakas Lake a large area of Descon Formation(?) mudstone (Odm) has been slightly sheared and a significant amount of unmineralized white-quartz stringers occurs throughout the rock.

Quartz in the Copper City, Corbin and Polymetal massive-sulfide deposits appears to be older than the last phase of regional metamorphism, which ended in Late Ordovician time. Axes of braids in the quartz veins are parallel to kink bands, which deflect earlier crenulations. Crosscutting quartz veinlets near the Copper City mineral deposit are deformed (p. 42). Postkinematic sulfide-quartz vein mineralization occurs north of West Arm, occurs as vein deposits on South Arm, and intrudes hornfels (Kh) around the periphery of the Copper Mountain pluton.

Several interesting pyrite-quartz-sericite zones within the quartz sericite schist (Ws) unit occur in the Wales

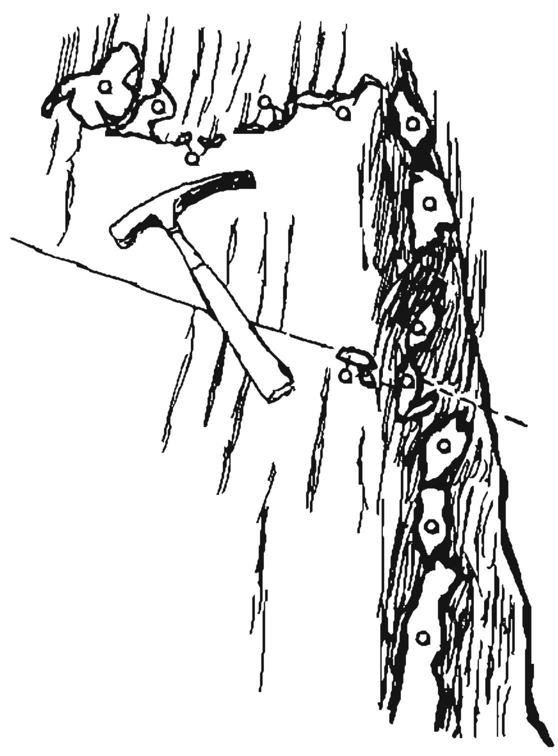

Figure 31. Parallel and crosscutting quartz deformed by gliding along foliation planes, South Arm, Cholmondeley Sound.

Table 5. *Summary listing of known mineral occurrences in the Craig A-2 quadrangle and vicinity.*

Occurrence	Name	Production record	Type of deposit	Major metals	Minor metals
1	Gould Island prospect	None recorded	Quartz vein in skarn zone north of Copper Mountain Inlet.	Pb-Zn-Ag, Cu	Mo
2[1]	Sultana Group (Wright, 1915)	None recorded	Skarn pods containing chalcopyrite-epidote-quartz veins in diorite pluton.	Cu-Fe	Ni(?)
3	Houghton or Cuprite Copper Company (Wright, 1915)	Small tonnages of 'high grade' shipped during 1906-11 (Bufvers, 1967)	Chalcopyrite-magnetite garnet-epidote-sphalerite-marcasite skarn deposit.	Cu-Zn-Ag	Pb-Cd
4	Billie Mtn.	None recorded	Epidote-garnet-sulfide skarn.	Cu-Zn	Ag-Nb-Sn-W
5	Campbell prospect	None recorded	Chalcopyrite-pyrrhotite garnet skarn deposit.	Cn-Zn-Fe	Pb-Ag
6	Mt. Jumbo prospect	None recorded	Chalcopyrite-pyrite-garnet epidote skarn deposit.	Cu-Zn-Ag, Fe	Pb
7	Magnetite Cliff deposit	Small tonnages of 'high-grade' ore added to Jumbo production.	Chalcopyrite-epidote garnet skarn deposit.	Fe	Cu-Ni(?)
8	Upper magnetite bodies	None recorded	Magnetite-chalcopyrite epidote skarn pods.	Fe-Cu	Zn-Ag-Au
9	Gonasson	None recorded	Magnetite-chalcopyrite epidote-diopside-garnet skarn.	Fe-Cu	Zn-Ag-Au
10	Jumbo deposits (Wright, 1915; Kennedy, 1953)	10,197,264 lb copper, 87,778 oz silver, 7,076 oz gold from 122,937 T ore	Chalcopyrite-pyrrhotite-pyrite molybdenite-sphalerite-epidote-diopside-garnet skarn deposits.	Cu-Zn-Ag-Zn-Mo	Pb
11a-c	Copper Mountain deposits	5,768 tons 'high-grade' ore smelted at Copper Harbor (Wolff and Heiner, 1971)	Malachite-azurite-chalcopyrite-epidote sphalerite-garnet skarn(?) deposits.	Cu-Zn-Ag-Au	Sb-Co-Mo
12	Corbin (Alaska Metals Mining Co.) (Wright, 1915)	Limited tonnage of massive-sulfide ore shipped to Tacoma 1906-1913	Pyrite-chalcopyrite sphalerite massive sulfide lense in Wales Group green schist.	Cu-Zn-Ag-Au	Mo
13a,b	Green Monster deposits	Museum-quality epidote crystals mined by Smithsonian Institute and other lessees 1930-present (Eskil-Anderson, pers. comm.).	Epidote quartz vugs in skarn zone, magnetite-actinolite-dolomite-limonite skarn deposit.	Fe-Cu	Zn-Ag-Sc
14	Summit Lake A	None recorded	Chalcopyrite-sphalerite covellite, epidote-garnet-quartz skarn.	Cu-Ag-Fe	Zn
15	Summit Lake B	None recorded; several tons of 'high grade' sacked and stockpiled.	Magnetite-chalcopyrite epidote-garnet diopside skarn.	Not assayed	Not assayed

Table 5. *(Cont.)*

Occurrence	Name	Production record	Type of deposit	Major metals	Minor metals
16	Lake Marge mineralized zone	None recorded, no prospects.	Disseminated molybdenite, chalcopyrite in epidote-garnet skarn.	Cu-Zn-Mo	Pb-W
17a,c	Hetta Mountain	None recorded	Chalcopyrite-sphalerite limonite-diopside garnet quartz skarn.	Cu-Zn	Mo-Ag-Au-Co-Cd
18	Deer Bay occurrence	. . .	Pyrite-sericite quartz lenses in Wales Group green schist.	. . .	Pb-Nb-Au
19	Simmons Pt. Wright Creek zone	. . .	Pyrite-sericite quartz sulfide lense in Wales Group.	Not assayed	Not assayed
20	Copper City	1600 tons of ore shipped to smelter by 1903-05 believed to be typical of production during 8 years of operation (Bufvers, 1967)	Chalcopyrite-pyrite-sphalerite, massive sulfide lense in Wales Group.	Cu-Zn-Ag-Au	Mo-Ba-Pb-Sb
21	Lime Point barite	Test shipment made, no major production (Wright, 1915; Buddington and Chapin, 1929).	Barite lenses in Wales Group marble; some dolomitization along faults.	Not assayed	Not assayed
22	Keete Inlet prospect	None recorded	Chalcopyrite-pyrite massive sulfide lense in siliceous schist (Chapin, 1916).	Cu-Zn	. . .
23	Nutkwa Inlet	50 oz gold, 36 lb lead	Discontinuous quartz vein system in greenstone schist (Rohm, 1939).	Au-Ag-Pb	. . .
24	Polymetal	Not known; considerable development work to 1908.	Sphalerite-galena massive sulfide deposit.	Pb-Zn	Ag-Au
25	Friendship	None	Disseminated chalcopyrite in quartz-carbonate vein intruding Wales Group.	Cu	Y-Bi
26	Moonshine	Limited tonnage of 'high-grade' sacked and shipped (Bufvers, 1967).	Sphalerite-galena siderite-quartz carbonate vein system intrudes Ws.	Pb-Zn-Ag	Cu-Cd-Sb
27	Klakas Lake[1]	None	Chalcopyrite-quartz carbonate vein.	Cu	. . .

[1]Not described in this report

Group along Hetta Inlet. They form yellowish-brown outcrops along the beach, and consist of Wales Group tuffaceous schist (Wg) interbedded with metakeratophyre tuff (Wk). These lensoid pyritic zones contain 2- to 10-percent irregular, parallel, and crosscutting quartz veinlets with erratic orientation and some quartz 'knots' more than 20 cm in diameter. Emission spectrographic analyses of a chip sample of a pyritic-quartz-sericite zone south of Deer Bay (locality 18, pl. 1) show 20 ppm gold and 90 ppm lead. This is probably not an accurate analysis of the zone, but it indicates that more work is warranted on this zone and others like it. Zones such as these have been earlier noted at Niblack Anchorage, particularly the Dama prospect, and shown to be associated with the pyrite-chalcopyrite mineralization there (Herreid, 1964). Peek (1975) suggested that the zones at Niblack Anchorage are metarhyolitic tuff.

JUMBO MINE

The Jumbo mine (locality 10, pl. 1) is located on the steep headwall of a glacial cirque called the Jumbo Basin, on the western slopes of the ridge between Copper Mountain and Mount Jumbo. Development on the deposit, discovered by Aaron Shellhouse in 1897, was begun in 1902 by the Alaska Industrial Company. The tram from the beach to the adit at 1,700 ft (fig. 33) was completed in 1906 and ore was first shipped in 1907 to the Tyee Smelter in British Columbia (Wright, 1915, p. 56-61). According to Bufvers (1967, p. 19) "the largest ore body and also the best grade of ore was on the No. 4 claim where an irregular body of chalcopyrite ore, 30 to 40 feet wide, 120 feet long and about 140 feet deep, supplied ore during the first years." The last year of regular production was in 1918, but several thousand tons were mined in 1923 (Bufvers, 1967). At present no buildings are standing (fig. 34), but the tramline cut is still visible and the rusting cables can be followed from the beach to the adit at the 1,570-ft elevation. The upper workings, located in resistant skarn bedrock, are still open.

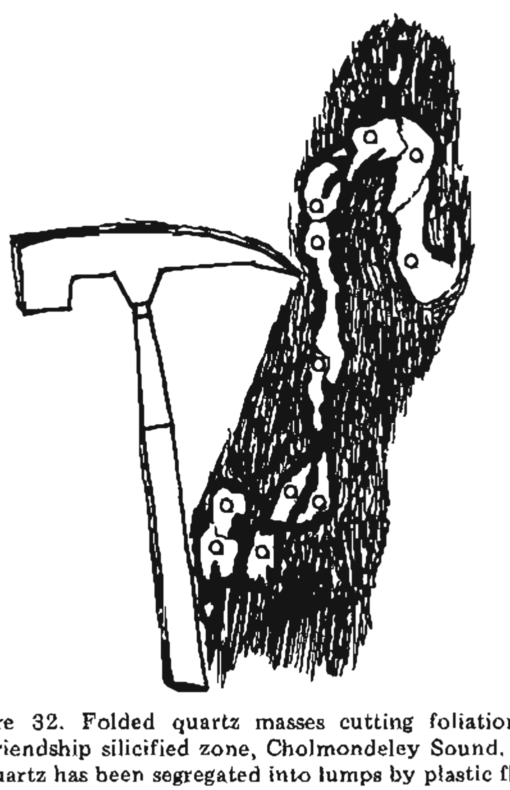

Figure 32. Folded quartz masses cutting foliation in Friendship silicified zone, Cholmondeley Sound. The quartz has been segregated into lumps by plastic flow.

Total production according to Kennedy (1953, p. 4) was 10,194,264 lb of copper, 7,076 oz of gold, and 87,778 oz of silver won from 122,937 tons of ore.

The ore deposits of the Jumbo Mine are in skarns derived from igneous rock and marble roof pendants along the west side of the Copper Mountain pluton (pl. 1). The ore contains irregular pyrrhotite-chalcopyrite-pyrite-sphalerite-molybdenite-epidote-garnet-diopside-quartz-calcite ore bodies that are small by modern standards. Ore occurs in both intrusive- and carbonate-derived skarns (although the latter predominates). Fracturing has played an important role in the localization of the ore. Kennedy (1953, p. 31) points out:

> "--fractures in the host rocks have been the loci of wall rock alteration and are filled with skarn minerals. The copper deposits fill fractures which extend into the marble adjacent to the skarn zone, and many late fractures cutting the skarn zone contain chalcopyrite."

In one area a contact-metamorphosed mafic dike was mined for copper. The richest ore on the No. 4 claim was mined from a small glory hole or open pit whose rim is at an elevation of about 1,800 ft. Both Kennedy (1953) and Bufvers (1967) stated that the ore zone probably extends below the present workings. High-grade copper mineralization has been reported at the bottom of a shaft at the 1,570-ft workings, but the shaft is now flooded (Kennedy, 1953). At this level there are four ore shoots that make a total of 300 tons per vertical meter (Hogg, 1965).

The Jumbo deposits are famous for their epidote crystals. According to Kennedy (1953, p. 24):

> "Locally epidote is an abundant mineral in the skarn zone at the Jumbo Mine. It occurs as medium-sized irregular grains replacing garnet, in groups of radiating crystals surrounded by later quartz and calcite, and as coarse crystals of exceptional beauty and complexity of crystal form lining the walls of vugs. The epidote specimens from the Jumbo area are rivaled only by those on the Tyrol."

The vugs, in many cases, are hydrothermal pockets in skarn, like those at Green Monster Mountain, with

Figure 33. Upper camp, Jumbo mine, 1913. (Photo courtesy University of Alaska archives.)

epidote crystals in a dark matrix of 'decomposed' minerals. According to Leavens (1967), the epidote mineralization is never more than "a few feet" from small basaltic dikes; he feels they are the source of the alteration solutions.

MAGNETITE CLIFF DEPOSIT

Several impressive shows of mineralization are present in Jumbo Basin north of the Jumbo deposit. The largest is the Magnetite Cliff deposit (locality 7, pl. 1), a thin 25-m-thick shell of magnetite that mantles the granodiorite that is in contact with skarn and nearly parallel to the hill slope. It forms a remarkable cliff exposure visible from Hetta Inlet. There are four short adits into this zone.

According to Kennedy (1953, p. 38-39), the magnetite mineralization has replaced garnet-diopside skarn, which was derived from marble; the skarn uniformly contains 2 to 3 percent chalcopyrite, and above the 1,400-ft elevation, 370,000 tons of mineralization grading 46 percent iron and 0.77 percent copper has been proven by exploration.

The Magnetite Cliff deposit may extend to significant depths along the igneous contact, as abandoned diamond-drilling stations on the slope south of the deposit attest.

UPPER MAGNETITE BODIES

On the ridge about 1 km northeast of Magnetite Cliff are five small magnetite deposits: four occur in roof pendants of skarn and marble and one is found in granodiorite-derived skarn (locality 8, pl. 1). Kennedy (1953, p. 40) estimated reserves of these deposits as about 50,000 tons of mineralization, with about the same iron and copper content as the Magnetite Cliff deposit.

GONNASON DEPOSIT

About 600 m northwest of the Jumbo 'glory hole' is a large body of magnetite-chalcopyrite-skarn mineralization, first found by A.G. Jones and W. Gonnason of the Hanna Mining Company in the 1960s. The deposit (locality 9, pl. 1) sporadically crops out through thick timber and is estimated to be an equant lense, 50 by 75 m on the surface with an unknown thickness (but believed to be less than half of its length).

A channel sample taken down the dip slope of the deposit averaged 50.6 percent iron and 0.94 percent copper along a 25-m-long sample line (Hogg, 1965). According to Hanna Mining geologists, the deposit is comparable in size and grade to the Magnetite Cliff deposit.

COPPER MOUNTAIN DEPOSITS

The Alaska Copper Company mines are on the south slope of Copper Mountain (fig. 34, localities 11a-c, pl. 1). The workings are near the Copper Mountain ridgetop at 3,200- to 3,500-ft elevations, but showings extend down to at least 2,200 ft. The deposit was discovered in 1897 by Charles Reynolds and Thomas Wright. Five hundred tons of ore worth about $18,000 was shipped in 1902, and by 1905, a 250-ton/day Allis-Chalmers smelter had been constructed at the base of the aerial tram on Copper Harbor. Between 1903 and 1906, 224,285 lb of copper, 10,331 oz of silver and 145 oz of gold were won from 5,768 tons of ore (Wolff and Heiner, 1971). By 1907, 1,200 m of tunnels, 145 m of shafts and raises, and numerous pits had been completed (Wright, 1915, p. 57). This work showed that the conspicuous showings of rich copper carbonate ore along the ridge failed to extend down to the adit at the 2,350-ft elevation. Work was halted in 1907 and resumed in 1914, but failed to produce additional ore (Bufvers, 1967, p. 21).

The relation of skarn mineralization to geology in the Copper Mountain district is evident along the southwest ridge of Copper Mountain (pl. 1). The 200-m-thick tongue of granodiorite (plagioclase An-20) that crosses the ridge is partly transformed by skarn by alteration of hornblende to diopside and additions of veins and masses of epidote, garnet, magnetite, and scapolite. Along the southwest side of the granodiorite tongue this replacement is stronger and the rock is skarn with relict patches of granodiorite (plagioclase An-30). The skarn contains scattered showings of chalcopyrite and discontinuous pods of copper carbonate. These small high-grade deposits were the richest on the property and most of the mining and development consisted of 'pocket mining' along this contact.

The northeast side of the granodiorite tongue is bordered by coarsely crystallized skarn. Here highly fractured marble was replaced and veined by quartz, garnet, epidote, speculerite, geothite, chalcopyrite, and pyrite, commonly with euhedral crystals. Low-grade copper mineralization is present sporadically along the contact of this skarn with dark hornfels. Small open cuts and shorts adits are present, but little commercial-grade mineralization was found.

HOUGHTON PROSPECT

The Houghton prospect (locality 3, pl. 1), on the northwest side of the Copper Mountain pluton, was located in 1901, and by 1908 had a camp, an aerial tram to the beach, a 30-m-long adit at the 1,600-ft elevation, and a 25-m-long adit at the 1,700-ft elevation (Wright, 1915, p. 62-63). In 1972 the lower adit was still open but the upper adit was partially caved; a steam-driven winch and the aerial tram cable were still visible.

The deposit consists of small pods of chalcopyrite, magnetite crystals, and pyrrhotite in a garnet-epidote skarn zone about 8 m wide and several hundred meters long along the faulted(?) contact of granodiorite (Kgdi) and marble (Wm). A grab sample (No. 72, pl. 2) of high-grade mineralization from the dump yielded 23.3 percent copper, 0.7 percent zinc, 25 ppm lead, 10.28 oz/ton silver, and 0.5 oz/ton gold.

Evidence for mineralization localized along a fracture zone was observed both in the field and under a microscope. A polished section of the sulfide-bearing skarn contains major chalcopyrite and pyrite with minor sphalerite and siderite(?). It seems to be a breccia with cracks and crevices filled with siderite. Some of the chalcopyrite has been altered to covellite.

SMALL SKARN PROSPECTS NEAR THE HOUGHTON PROSPECT

The Campbell prospect (locality 5, pl. 1) consists of small pyrrhotite-rich pods of mineralization exposed in a short adit about 1,200 m west of the Houghton prospect. The 15-m-long adit, located at the 700-ft elevation, is partly caved at the portal. The deposit is a marble-derived skarn near the contact of a small granodiorite plug that is probably an apophysis of the Copper Mountain pluton. A polished section of mineralized rock shows pyrrhotite with a little chalcopyrite in a skarn matrix. One sample (No. 78, pl. 2) produced 1,380 ppm copper, 20 ppm lead, 175 ppm zinc, 1.5 ppm silver, and a trace of gold.

The Mount Jumbo prospect (locality 6, pl. 1) is at the 1,200-ft elevation, about 600 m southwest of the Houghton prospect. A short adit driven into the ore zone shows irregular pods of massive pyrrhotite-chalcopyrite mineralization in a skarn zone peripheral to another small granodiorite body. A polished section from the deposit reveals major pyrrhotite, pyrite, and chalcopyrite with minor marcasite and geothite. The pyrrhotite is partly replaced by marcasite, and the pyrite forms colloform veins. Chalcopyrite and pyrrhotite were probably the first sulfides deposited. A grab sample of the ore yielded 4.2 percent copper, 45 ppm lead, 850 ppm zinc, 3.2 oz/ton silver, but no gold.

A small mineralized zone is present at the 760-ft elevation on the north slope of Billie Mountain, opposite Portage Bay (locality 4, pl. 1). This zone is in a skarn along the contact of an epidotized diorite body adjacent to the Copper Mountain pluton. The skarn was derived from marble host rock. A grab sample of material from the zone shows 840 ppm copper, 480 ppm

Figure 34. Alaska Copper Company open cut, southwest spur of Copper Mountain. Hetta Inlet in background.

zinc, 56 ppm lead, and 1.2 oz/ton silver. Several tungsten, silver, and zinc geochemical anomalies have been obtained from rock and stream-sediment samples taken from this area (pl. 2).

GREEN MONSTER MOUNTAIN PROSPECTS

The Green Monster Mountain copper and magnetite showings (localities 13a, b, pl. 1), on the east side of Green Monster Mountain, were discovered in 1900. When C.W. Wright visited in 1908, development work consisted of two 20-m-long tunnels and one pit about 3 m deep. He described the deposits as massive sulfides in skarn, disseminated sulfides in skarn, and sulfide-bearing vein deposits in skarn and hornfels (Wright, 1915, p. 61-62). There has been some stripping of the area where epidote crystals have been mined but otherwise little appears to have been done since then. Lessees of Eskil Anderson were exploring for pockets of epidote crystals when the authors visited in 1972.

The known skarn and associated sulfide and magnetite deposits are in marble near the southern end of the Green Monster Mountain epidotized diorite body (Keg on pl. 1). The sulfide, magnetite, and crystal deposits were deposited along steep faults shortly after intrusion of the igneous rocks. The epidote crystal area in skarn and the old adit in dolomitized marble are along a steep northeast-trending fault that runs along the northwest side of the epidotized diorite pluton. Movement along this fault took place after igneous intrusion but before the rocks had cooled, as shown by the offset of the Copper Mountain pluton, granulation of skarn, and growth of skarn minerals in fractures.

The area where the well-known Green Monster epidote crystals have been mined (locality 13a, pl. 1) is 110 m southwest of the epidotized diorite body at about the 2,550-ft elevation, an area of much-fractured epidote-garnet-quartz-uralite-pyrite-chalcopyrite skarn. There is no clear-cut dominant direction of shearing. Pockets of unfractured euhedral epidote and quartz up to 100 m

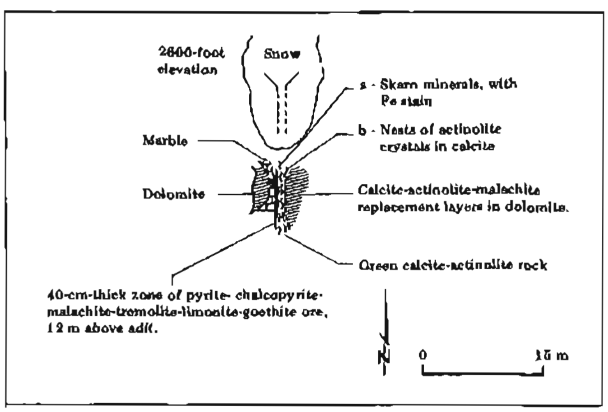

Figure 35. Sketch map of mineral zone, west side of Green Monster Mountain.

in diameter are found 'floating' in decomposed 'mud' within vugs in the skarn bedrock. Some epidote crystals were cracked and healed by the growths of tiny quartz crystals, and the crystals apparently grew during fracturing. One old adit at the 2,600-ft elevation, about 100 m north of the epidote-crystal locality, was driven along a skarn-sulfide zone, which is possibly fault controlled. The sketch map (fig. 35) shows the association of zones of sulfides, coarsely crystalline skarn minerals, and dolomite.

A skarn zone (locality 13b, pl. 1) about 30 m wide is located along the southeast side of the epidotized diorite pluton, on the northwest rim of Green Monster Mountain at about 2,900 ft. The skarn minerals are monticellite, calcite, and chlorite at the north end and diopside, actinolite, and calcite at the south end. The skarn is right-laterally offset 15 m by each of two steep northwest-trending faults. Along one of these faults at the pluton-skarn contact is a small pod of magnetite mineralization. This is the 2.5-m-deep (8-ft) prospect pit mentioned by Wright (1915). A 6-m-wide band of discontinuous dolomite of metasomatic origin lies on the marble side of the skarn. Dolomitization has also occurred along a N. 80° E.-trending, steeply dipping right-lateral fault at the north end of the mapped skarn zone. The skarn may extend farther north but the contact was snow covered when the mapping was done in late July 1972.

Two other copper-magnetite prospects were visited on the north side of Summit Lake, about 2.5 km southeast of the epidote-crystal locality at about the 1,900- and 1,850-ft elevations. Both are clearly fault controlled. At the Summit Lake 'A' prospect (locality 14, pl. 1; fig. 36), three small caved adits and an ore dump of sulfide-bearing skarn are now overgrown with vegetation. An irregular skarn zone separates hornblende diorite and coarsely crystalline marble bedrock, which is truncated by a fault that trends N. 70° E. The fault trace follows a linear saddle on the crest of the hill. A polished section of the sulfide-bearing skarn shows major chalcopyrite and minor sphalerite in a gangue of quartz. The latest mineral to form is euhderal chalcopyrite grains that contain blades of skarn. An assay was not obtained from this sample, but it undoubtedly has a high copper content.

The Summit Lake 'B' prospect (locality 15, pl. 1), located along a fault offset on the diorite-marble contact in a situation similar to the 'A' prospect, has a pit that contains several tons of magnetite-chalcopyrite mineralization. An assay of a high grade sample (No. 254, pl. 2) showed 16.0 percent copper, 2.0 percent zinc, 175 ppm lead, and 5.1 oz/ton silver.

GOULD ISLAND PROSPECT

Near the southwest tip of Gould Island (locality 1, pl. 1) is a 4-m-wide white quartz vein containing minor pyrite, chalcopyrite, and malachite in a prospect pit;

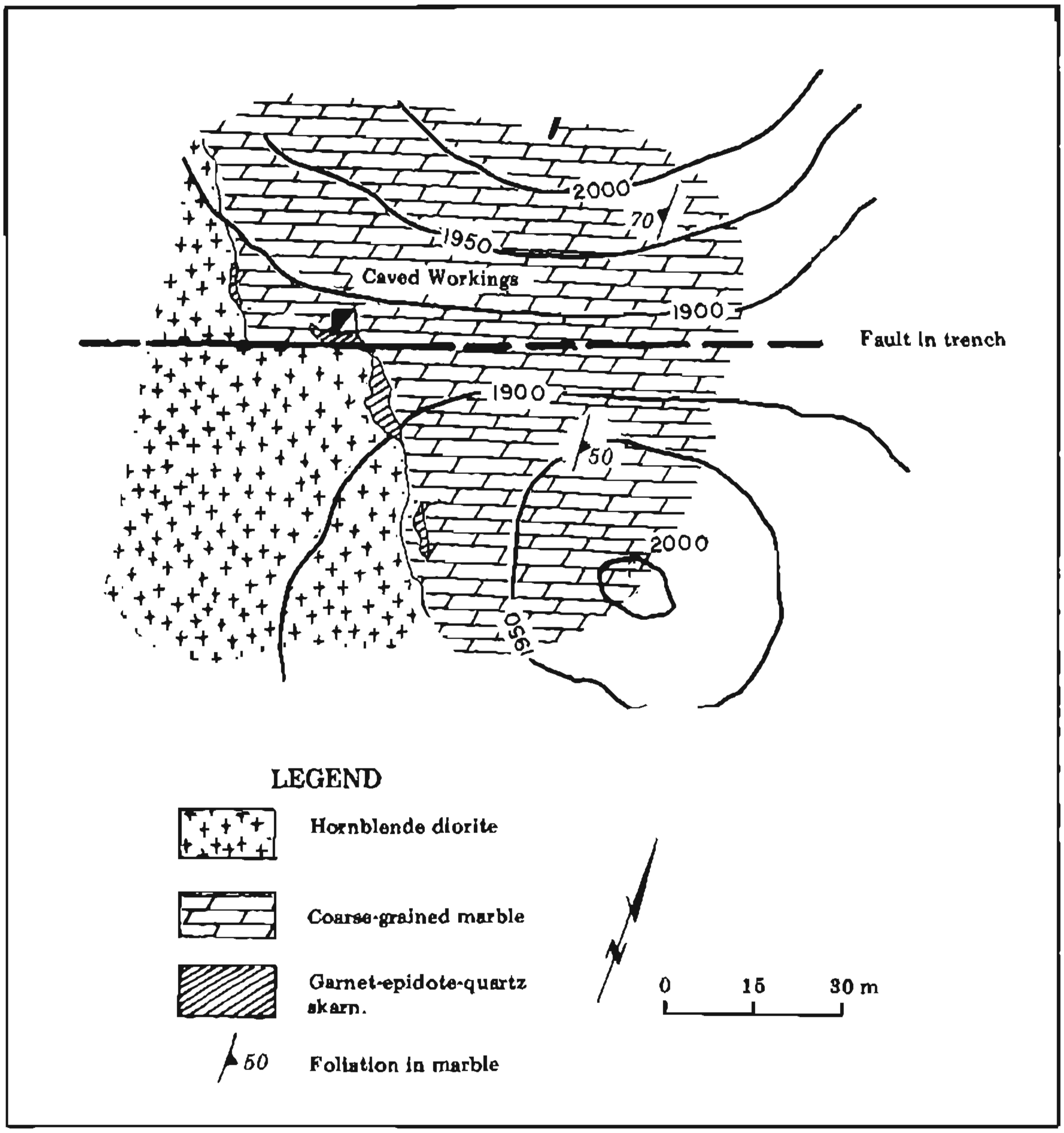

Figure 36. Geologic sketch map of Summit Lake prospect (locality 14, pl. 1).

the vein strikes east-west, dips steeply, and is located along a marble-hornfels contact. A selected sample (No. 67, pl. 2) of quartz-sulfide material yielded 3.0 oz/ton silver, 0.91 percent copper, 140 ppm lead, and 0.21 percent zinc. This showing is probably the one described by Wright (1915, p. 64-65) as a pit 3 m deep and 100 m east of the main exposure of Gould Island, which contains a low-grade zone of galena, sphalerite, and chalcopyrite veinlets. According to Wright, the zone at the main exposure is 9 m wide, contains low-grade ore, strikes east-west, and dips steeply north; it contains calcite, quartz, garnet, epidote, and wollastonite in marble and has been explored by a 21-m-long adit, a 3-m-deep shaft, and an open cut. This mineralized zone likely represents a metasomatic skarn deposit.

HETTA MOUNTAIN PROSPECTS

Two copper-bearing zones in marble cross the southwest end of the summit ridge of Hetta Mountain at the 2,800-ft elevation (localities 17a,b, pl. 1). These and other showings are mentioned briefly by Wright (1915, p. 65) and all adits and pits probably predate Wright's visit in 1908. There are two short adits near the top of the ridge. One is at about 2,700 ft (Wright's "2,480-ft adit") in a shear zone 25 m thick in which the marble matrix is cut by veinlets and blebs of chalcopyrite and limonitized skarn veins with a diopside-garnet-quartz mineralogy. The trenched shear zone strikes east-west, and dips 75° north, and is cut off 100 m to the east by a north-trending fault.

About 30 m north of the 2,700-ft adit, at the 2,675 ft elevation, is a 40-m-long adit used to explore three short en echalon pods, 6 to 20 m apart, of massive pyrite-pyrrhotite-chalcopyrite mineralization. These strongly limonitized pods, which are up to 3-1/2 m thick, are replacements in marble along a porphyritic diorite dike. A polished section of sulfides from the deposit shows major pyrrhotite and chalcopyrite with minor goethite, pyrite, and sphalerite. The chalcopyrite makes flamelike intrusions into the pyrrhotite along crystal boundaries and small cracks. The pyrrhotite is partly replaced by goethite, pyrite, and possibly marcasite. 'Breccia dikes' of fragmental chalcopyrite and pyrite-bearing material crosscut all sulfides and suggest movement during or after mineralization. A grab sample (No. 144, pl. 2) had 2.2 percent copper, 0.74 percent zinc, 22 ppm lead, 12.3 oz/ton silver, 0.10 oz/ton gold, 600 ppm molybdenum, and 750 ppm cobalt. These two copper-zinc-bearing zones on either side of the porphyry dike do not extend beyond the fault to the east and underlie a 15-m-thick rusty-weathering layer of quartz-diopside hornfels that extends to the west.

The pyrite-chalcopyrite-garnet-epidote showings between Hetta Mountain and Wright Creek mentioned by Wright (1915, p. 65) were not visited. Their estimated locations are shown on plate 1.

CORBIN MINE

Production began on the Corbin mine (locality 12, pl. 1), located on the east side of Hetta Inlet, 2 km north of Copper Harbor, in 1906 (Wright, 1915) and continued intermittently for 7 years (Bufvers, 1967, p. 21). Workings included a 30-m-long shaft, several 30 m drifts, and an adit about 70 m long on the level of the drifts (fig. 37).

Apparently, the only ore mined was in a 25-cm- to 1-m-thick steeply plunging lense of massive, banded, pyrite-chalcopyrite-sphalerite mineralization carrying about \$3.00/ton in 1908 gold and silver prices and several percent copper and zinc (the zinc was not recovered). The ore shoot parallels the foliation and compositional banding in the Wales Group schist bedrock and shows extensive shearing and faulting along the bedding planes. Exposures at the south end of the stope show a bedding-plane shear zone about 1.5 m wide with talcy fault planes and both parallel and crosscutting quartz veins. Along the fault east of the mined-out ore body, the bedrock is bleached green schist with sparcely disseminated pyrite, minor chalcopyrite, and encrustations of malachite and azurite. A chip sample (No. 98, pl. 2) across 3 m of limonite and disseminated pyrite contained only 500 ppm copper, 200 ppm zinc,

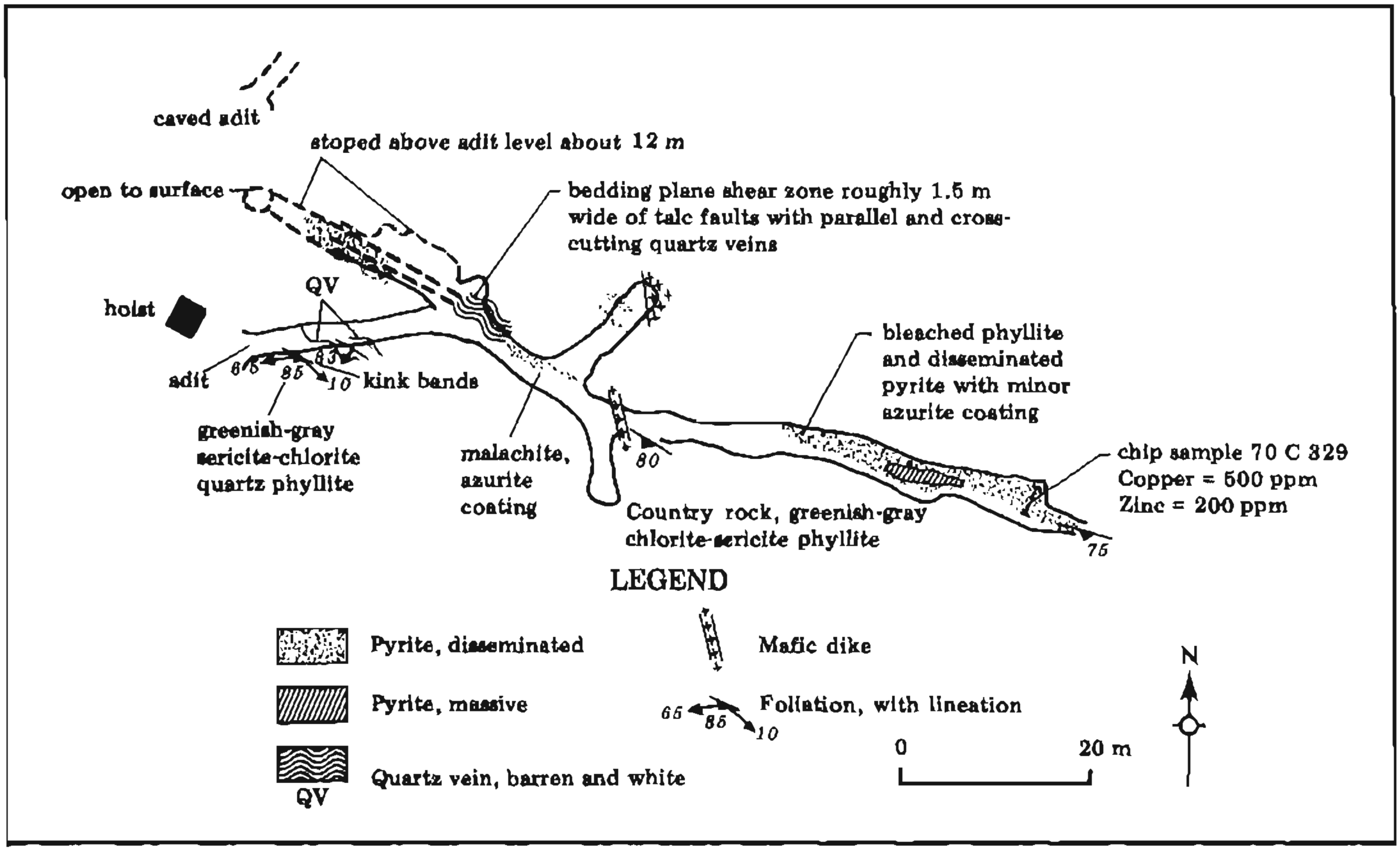

Figure 37. Geologic sketch map of the Corbin mine workings, east side of Hetta Inlet (locality 12, pl. 1).

and background amounts of other metals. A grab sample of siliceous rock from the dump (No. 96, pl. 2) contained 5.6 percent copper, 0.1 percent zinc, 80 ppm lead, 15 ppm silver, and 300 ppm molybdenum.

Prospect trenches north of the mine have a 25-m-wide exposure of kink-banded sericitized green schist with quartz veinlets and malachite stain. Several zones of pyritized rock and irregular quartz veins along the beach in the vicinity indicate a fairly extensive area of siliceous schists.

Although the geologic setting suggests a massive sulfide volcanogenic origin for the Corbin deposit, it could be a fault-controlled sulfide shoot associated with the end of the last regional deformation.

COPPER CITY MINE

The Copper City mine (locality 20, pl. 1; figs. 38, 39) is situated just above the high-tide line on the east shore of Hetta Inlet, approximately 10 km south of Copper Harbor. It was prospected by E.E. Wynan in 1898 (Bufvers, 1967, p. 21-22). Production began 5 years later (Wright, 1915, p. 64) and continued fairly continuously on a small scale until 1910, when the mine was flooded through a drill hole.

An inclined shaft was sunk to a depth of about 100 m, drifts were run at various levels along the deposit and the mineralization was stoped to the surface. According to Wright, the deposit exposed in the shaft was massive-sulfide ore ranging from 20 cm to 1.2 m thick. The ore is cut by diabase dikes in which "subsequent mineralization has deposited small amounts of minerals in veinlets" (Wright, 1915). He continues (p. 64):

> "Similar but smaller veins, trending parallel to the main vein, have been exposed by surface cuts and trenches.....The ore is composed essentially of chalcopyrite, pyrite, sphalerite, and rarely hematite (specularite), associated with quartz, calcite, and epidote gangue minerals.....In addition to copper each ton of ore contains gold amounting to $3 to $6 and silver amounting to $1 to $4, as well as six to nine percent zinc."

According to Wright and Wright (1906), a total of 1,600 tons of ore worth $60,000 had been mined through 1905.

The site is now overgrown with timber but the main stope is visible just above high tide for more than 100 m along the beach. This deposit is closely associated with metakeratophyre, metaspilite, and a conspicious grayish-red quartz sericite schist of the Wales Group (fig. 38). The mineralized zone is parallel to compositional banding and foliation in the bedrock. The deposit is faulted and some wall-rock alteration is evident. Talcose micaceous material is found in the hanging wall of the deposit and there are many irregular crosscutting quartz veins 2 to 25 cm thick in the grayish-red quartz sericite schist. These veins roughly parallel gently plunging later kink bands that deform earlier fine crenulations that plunge steeply to the northwest. The quartz veins were probably deposited during kink-band deformation in the Wales Group. The movement indicated by these kink bands is compatible with compression from the west. A distinct airphoto lineament crosses the creek near the Copper City mine, about 0.5 km from the workings.

A chip sample across 25 cm of banded mineralization yielded 8.50 percent copper, 7.30 percent zinc, 2.5 oz/ton silver, 0.05 oz/ton gold, 570 ppm lead, and 7,000 ppm barium (No. 183, pl. 2). A polished section of secondary(?) vein mineralization revealed major chalcopyrite and minor sphalerite in a gangue of quartz. The chalcopyrite is partly replaced by digenite.

The deposit appears to be, in part, a quartz vein system associated with a fracture zone; however, its bedrock associations, metallic content, banded sulfides that have been deformed, and parallelism to the wall rock suggest a massive-sulfide volcanogenic deposit that was modified during regional dynamothermal metamorphism of the Wales Group.

LIME POINT BARITE PROSPECT

The barite deposit at Lime Point (locality 21, pl. 1) was discovered in 1912 and in 1915 Charles Sulzer made a test shipment of the ore that returned "satisfactory" results. The 12-m-long adit that exists today probably dates from this period. Twenhofel and others (1949, p. 17-19) estimated the tonnage of ore above high tide to be 5,000 tons of material containing 91 percent barite.

The deposit occurs as interlayered lenses of barite and dolomite in Wales Group marble (fig. 40). Most lenses are less than 2 m thick and are terminated within

Figure 38. Metakeratophyre bed (Krat) and underlying quartz sericite schist in hanging wall of Copper City Mine.

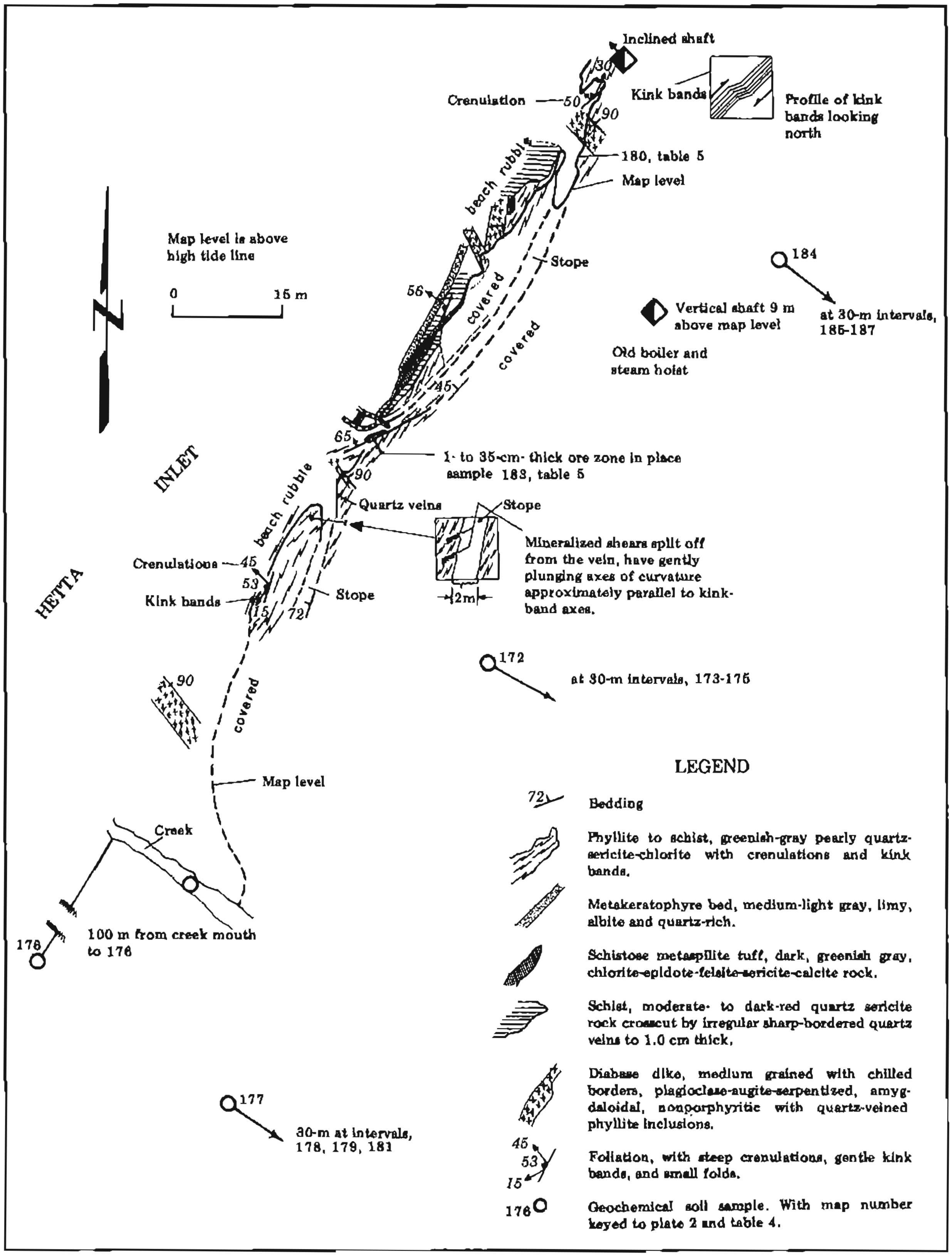

Figure 39. Geologic map of Copper City mine (locality 20, pl. 1).

12 m by faulting. Barite found in the axes of folds is deformed. As at Copper City and Corbin, the barite-deposit probably has a premetamorphic origin. Subsequent faulting displaced the Lime Point deposit in a complicated fashion, and altered andesite dikes were intruded along these faults.

NUTKWA LAGOON PROSPECT

This prospect is located at an elevation of 110 feet on the northwest side of Nutkwa Lagoon about 1,200 m from its head (locality 23, pl. 1). Nutkwa Lagoon has a narrow entrance that can only be entered by shallow draft boats at slack water near high tide.

The prospect has a 120-m-long adit with a 15-m-deep winze 60 m from the portal (Chapin, 1916, p. 90-91). According to Roehm (1939), the adit follows a discontinuous quartz vein(?) up to 2 m thick that is along a mineralized shear zone striking N. 20-30° W. and dipping 80° W. The wall rock is Wales Group (Wg) green schist. Sulfide minerals present are chalcopyrite, galena, and pyrite, but they generally make up only a small percentage of their mineralized zone (Twenhofel and others, 1949). The deposit reportedly produced 50 oz of gold, 3 oz of silver, and 36 lb of lead in 1938 (Wolff and Heiner, 1971). Twenty-two channel samples across the mineralized zone (Roehm, 1939, p. 3-5) average 0.06 oz/ton gold and 0.13 oz/ton silver. The highest value was 0.66 oz/ton gold, 70 m from the portal.

KEETE INLET PROSPECT

According to Chapin (1916, p. 90):

> "A prospect near the head of Keete Inlet has been developed recently on a copper-bearing lode strike N. 20° W. and dipping 60° NE. The lode is being opened by an incline, which below the 10-foot level was covered with water and inaccessible at the time of visit. The ore is a shear-

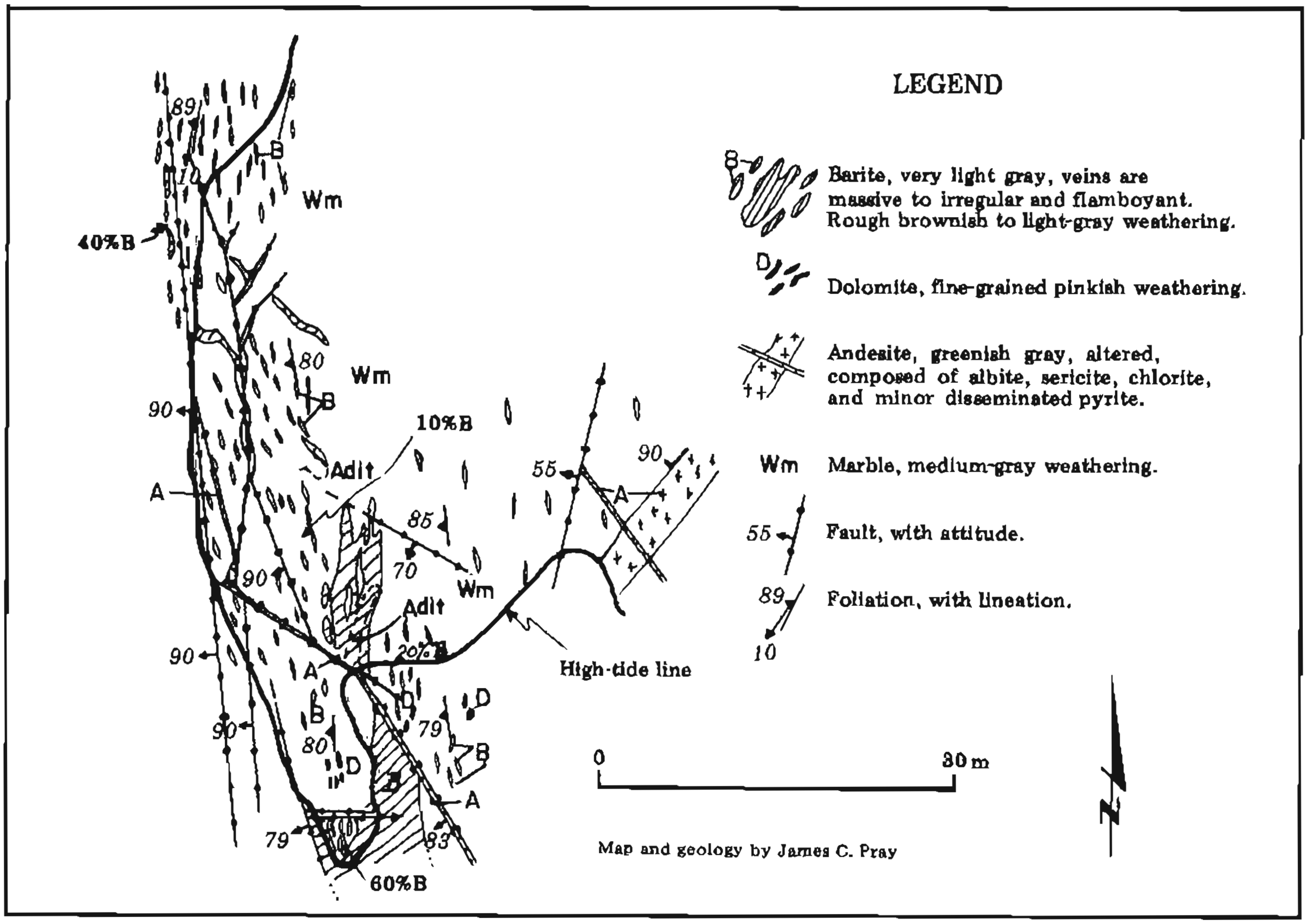

Figure 40. Geologic map of Lime Point barite deposit (locality 21, pl. 1).

> zone deposit containing disseminated particles and lenses of chalcopyrite and pyrite in siliceous beds occurring in greenstone schist. On the dump were samples of quartz veins carrying bornite and chalcopyrite, but similar rock was not seen in place. The property is a short distance from tidewater and is equipped with a blacksmith shop and cabins built on a small cove."

This prospect was sought but not found during mapping. Its location on plate 1 (location 22) is uncertain.

FRIENDSHIP SILICIFIED ZONE

On both sides of South Arm, near the north end (pl. 1), a large area of Wales Group silicified schist is believed to be formed either from metamorphic 'sweating' of quartz out of the country rock or from thermal heating by a buried intrusive. The silicified schist forms steep, grayish-orange weathered slopes and cliffs on the west shore of South Arm, where silicification and pyritization is strongest (pl. 1). Anomalous amounts of lead and zinc in creek sediments, soils, and bedrock are present. Two mineral deposits are known and both were under development in 1901 when Brooks visited the area: the Friendship and Polymetal lodes ("Ketchikan Copper Company," Brooks, 1902, p. 87-88). The silicfied zone extends up to and possibly beyond the ridge west of the inlet and east an unknown distance across the inlet.

The Friendship lode (locality 25, pl. 1) is a chalcopyrite-bornite-quartz vein deposit that extends 200 m along the Friendship fault, which is the contact between Wales Group marble and green schist (Brooks, 1902, p. 87). Several old pits and copper showings on this zone were visible in 1972. A polished section of the vein shows small masses of chalcopyrite, bornite, and pyrite in a gangue of quartz and calcite. Some of the pyrite has a botryoidal texture. Both chalcopyrite and pyrite are rimmed locally with goethite. Analysis of a vein sample shows 0.51 percent copper, 300 ppm yttrium, and 10 ppm bismuth.

The Polymetal lode has an adit reported by Brooks (1902, p. 88) to be 300 feet (95 m) long at an elevation of 900 feet. Fowler (1949) reports this adit to be about 280 feet (89 m) long at an elevation of 500 feet. According to Brooks (1902, p. 88):

> "The ore body, as far as determined, is a mineralized zone, which occurs in a quartz-sericite-schist. This schist is made up essentially of bluish quartz and sericite, and it is often banded. Chlorite is a very common accessory mineral. While it has many of the characteristics of an altered sediment, yet it strongly resembles the schists found in association with the ores at Niblack Anchorage, which are believed to be altered rhyolites."

During the mapping, several days were spent traversing the steep slopes, but the workings were not found. Fowler reported the mineralized zone to be 6.5 m wide and to contain 11.4 percent zinc, 2.8 percent lead, and a trace of silver. Low-grade disseminated sphalerite can be found in several schist outcrops in the hill slopes below the 500-ft elevation. The earlier descriptions suggest that this may be a stratiform mineral deposit as present at Niblack (Peek, 1975).

Geochemical stream-sediment and soil samples taken just above the beach below the Polymetal lode indicate that a zone highly mineralized in lead, zinc, and silver, with lesser amounts of copper, zirconium, and yttrium extends for about 600 m along the inlet and about 500 m up the mountain slope to the west.

The presence of rare-earth elements in stream sediments and the Friendship vein may indicate that a mineralized intrusion similar to Bokan Mountain (MacKevett, 1957) underlies the silicified schist (Ws).

MOONSHINE GROUP

A small group of lead-zinc-silver deposits is located on a prominent north-south ridge west of the South Arm of Cholmondeley Sound. The Moonshine mine (locality 26a,b; pl. 1) was staked around 1900. Development work was started in 1906, and a 3-m-thick vein that carried 1,500 oz/ton of silver was reportedly struck in 1909. Several tunnels, a shaft and a long raise to the top of the ore body were driven (Bufvers, 1967, p. 23) and an aerial tram was installed before the final mine closure (1922). An adit at the 2,230-ft elevation was driven to undercut the ore body at depth and an attempt was made to reach the shaft at the top of the ridge with a long raise. Unfortunately, a cavity in the marble was intersected and the ground caved, creating the glory hole at the 2,620-ft elevation. The partly caved adit at the 2,230-ft elevation shown on figures 41 and 42 is near the top of the ruined aerial tram and the remains of the old camp. No records of the production are available but it is not believed to have been great.

According to Wright (1909, p. 182-188):

> "The Moonshine vein, as it is called, occupies a well-defined fissure, cutting obliquely across limestone and schist country rock and traversing the top of the mountain ridge. Where it crosscuts the limestone it is apparently a replacement deposit, varying from a few inches to several feet in width and carrying considerable galena associated with quartz, siderite, and calcite, though where the schist forms the enclosing walls the vein is smaller and is in many places represented by a narrow gouge seam. The country rock strikes nearly east and west and dips north at steep angles, whereas the vein strikes N. 65° W. and has a vertical dip. In this vein deposit the mineral occurs irregularly, the ore being found in

small scattered masses or bunches. Besides the galena a small amount of sphalerite and chalcopyrite is present in the ore. Very little surface alteration or secondary enrichment was observed, and where present it extends but a few feet in depth. Diabase dikes from 1 foot to 6 feet in width crosscut both the country rock and the ore body."

The Moonshine deposits lie along a fault near a Wales Group marble—green schist contact adjacent to a large area of Wales Group silicified green schist. The mineralization was accompanied by dolomitization and quartz veining in the wall rock (fig. 42). Mineralization from the dump is composed of galena and sphalerite plus minor chalcopyrite and accessory pyrite and siderite. A polished section of the massive galena vein exposed in the glory hole shows galena, minor blebs of polybasite, and traces of covellite. Several grab samples (Nos. 419, 420, 421; pl. 2) varied in metal content from 20 to 83 percent lead and 12 to 30 oz/ton silver.

Several other lead-zinc prospects in Wales Group marble (Wm) are present on the ridge southeast of the Moonshine Mine (fig. 41). Two of them are along dolomitized fault zones in the marble near marble-present at prospect A (fig. 41, and locality 26b, pl. 1). Mineralization consists of small high-grade 'kidneys' less than a meter wide of galena, sphalerite, and siderite in a dolomitized vein breccia.

At prospect B (fig. 41 and locality 26c, pl. 1) a short adit into the marble wallrock near a marble-schist contact zone contains small isolated masses (<100 cm in diameter) of galena and sphalerite.

The two marble layers that contain the base-metal veins are on the limbs of a southeast-trending anticline. This anticline is apparently near the axis of a major fold structure mapped to the east as the Dolomi-Sulzer anticline (pl. 1, section D-D'). Longitudinal fracturing associated with the folding may have controlled the distribution of the vein channels; subsequently, the sulfides replaced $CaCO_3$ along the limestone schist contacts and within marble beds themselves.

DISCUSSION

The Precambrian and Paleozoic rock units described in this report are considered to be part of a larger group of problematically old border terranes that have been

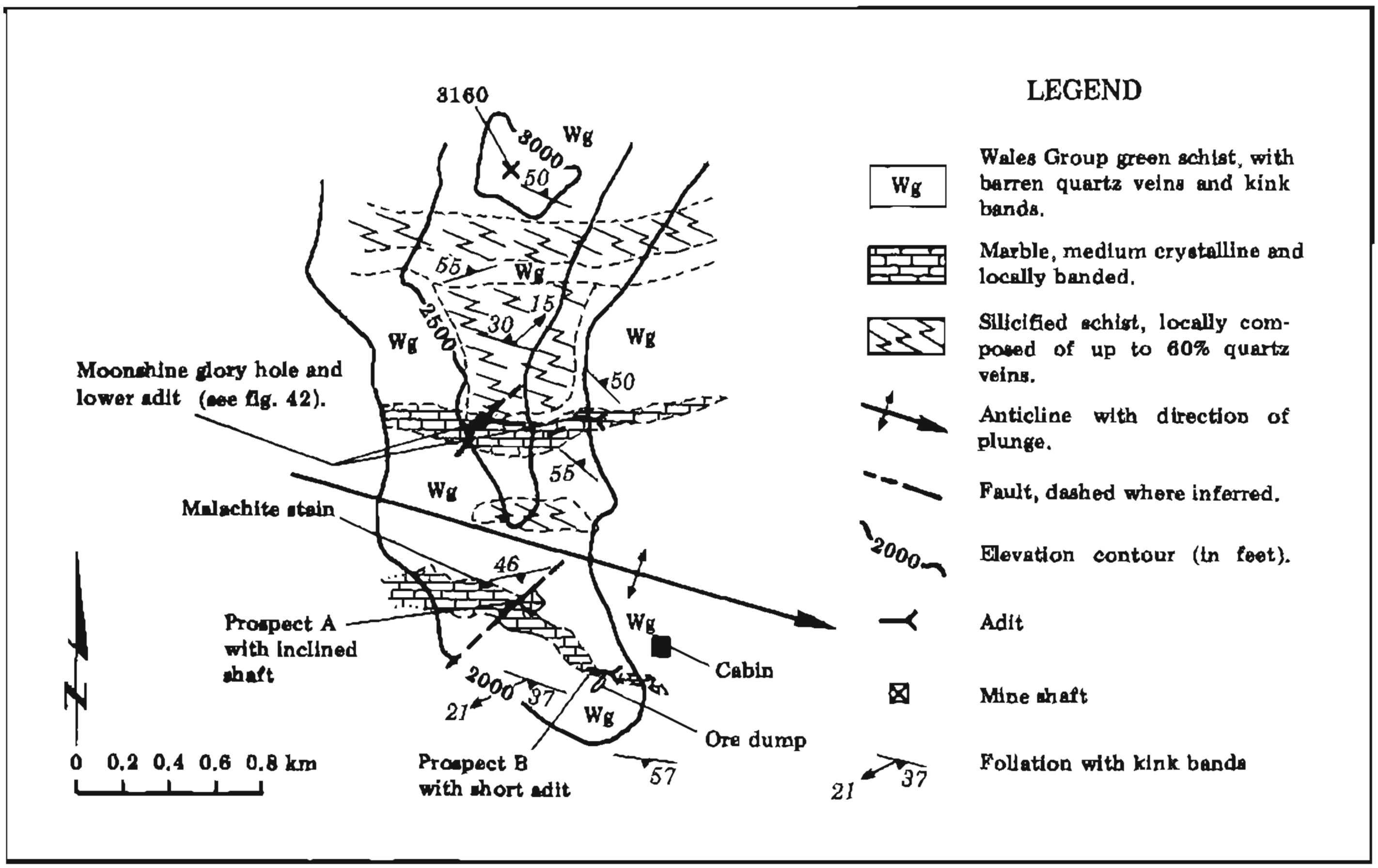

Figure 41. Geologic sketch of the Moonshine Group.

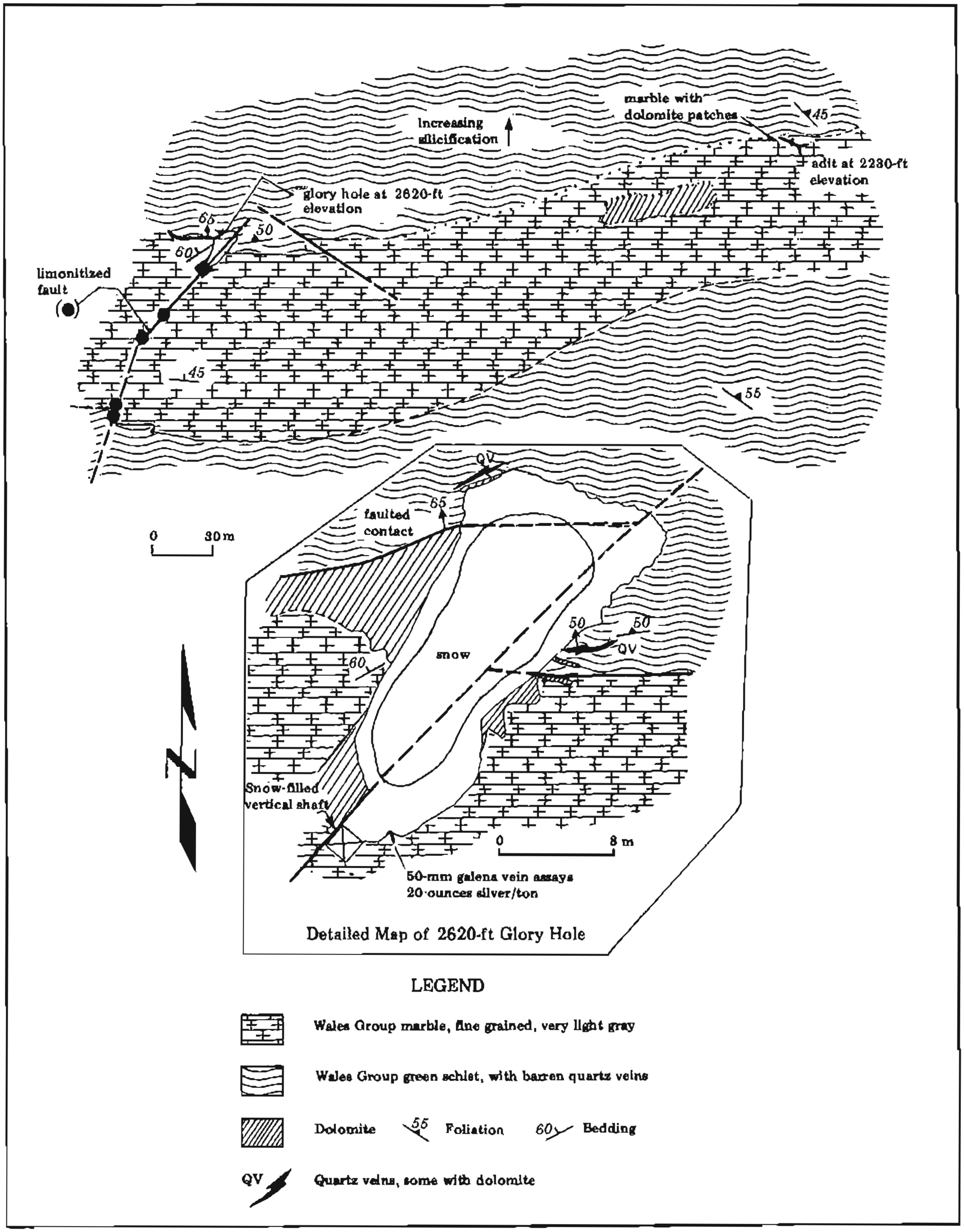

Figure 42. Geologic map of the Moonshine mine (locality 26, pl. 1).

sutured along the western edge of North America since Mesozoic time. Distinct Paleozoic and Precambrian sedimentary-plutonic-volcanic 'packages' extend discontinuously from southern Alaska to southern California (and possibly beyond) and are often seaward of younger orogenic sequences. This geological discrepancy, among others, has generated a number of theories on the tectonic history of these terranes that incorporate plate movement (Churkin and Eberlein, 1977).

Berg and others (1972) include the rocks on Prince of Wales Island as part of the 'Alexander terrane,' a group of fossiliferous volcanic-sedimentary sequences of early and mid-Paleozoic age that extends from south-central Alaska to the Queen Charlotte Islands in British Columbia. Attempting to match the rocks of the Alexander terrane with equivalents southward has proven extremely difficult and Churkin and Eberlein (1977), on the basis of studies of stratigraphic sections along the North American margin, propose that multiple plates or 'microplates' moved outboard and inboard from North America during Precambrian and Paleozoic orogenic cycles and were later rifted northward by large-scale strike-slip movement.

The detailed descriptions of the geology of southern Prince of Wales Island reported here and radiometric dating discussed by Turner and others (1977) may further define the problems of the rock-section correlations along the boundary of western North America. Such features as 1) the bimodal sodic-rich nature of Wales Group volcanism, 2) the base-metal content of massive-sulfide deposits hosted in the Wales Group, 3) the dynamothermal metamorphic signature of the Wales Group, 4) the detailed stratigraphic sections of Ordovician and Devonian sedimentary units, 5) the anomalous rare-earth elemental backgrounds of Devonian volcanics of the Craig A-2 quadrangle area, 6) the distinctive conjugate swarm of mafic dikes intruding the Paleozoic-Precambrian section, and 7) the chemistry and physical character of Paleozoic and Mesozoic granitic plutons of the area may be compared with equivalent terranes to the south.

In addition, the data derived from the Mineral Deposits section of this report may provide a framework to estimate the mineral resource potential of southern Prince of Wales Island.

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