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GEOLOGICAL SURVEY

Reconnaissance geologic map of the Bradfield Canal quadrangle, southeastern Alaska

(Pamphlet to accompany map sheet 81-728A)

by

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with an Introduction by H. C. Berg[2]

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION
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This pamphlet and accompanying map sheet describe the geology of the Bradfield Canal 1:250,000-scale quadrangle in southeastern Alaska (fig. 1). The report is chiefly the result of a reconnaissance investigation of the geology and mineral resources of the quadrangle by the U.S. Geological Survey during 1978 and 1979. It also incorporates the results of earlier geological mapping by Buddington (1929), Buddington and Chapin (1929), Berg and others (1977), and Smith (1977). Published reconnaissance geologic maps of the 1:250,000-scale quadrangles that adjoin the Bradfield Canal quadrangle cover the Ketchikan quadrangle to the south (Berg and others, 1988) and Petersburg quadrangle to the west (Brew and others, 1984).

The Bradfield Canal quadrangle straddles the Coast Range of southern southeastern Alaska. The United States-Canada boundary bisects the quadrangle from southeast to northwest. The study area described in this report covers only the part of the quadrangle that is in the United States. It includes more than 12,200 km^2 of steep mountainous terrain that ranges in elevation from sea level to 2,285 m at the summit of Mount Jay on the U.S.-Canadian border. About 4,200 km^2 in the eastern and south-central parts of the study area are included in the Misty Fiords National Monument.

Classification and nomenclature in this report mainly follow those of Turner (1981) for metamorphic rocks, Turner and Verhoogen (1960) for metamorphic and plutonic rocks, and Williams and others (1982) for extrusive igneous rocks.

<u>Summary of geology</u>: Most of the rocks in the study area comprise a plutonic-metamorphic complex that is part of the Coast Range batholith (Buddington and Chapin, 1929). The plutonic components of the complex are mainly adamellite, granodiorite, and quartz diorite that range in emplacement age from Late Mesozoic to mid-Cenozoic. The ages of the protoliths of the metamorphosed bedded rocks range from Early Mesozoic to possibly as old as Precambrian (see “Age assignment of certain map units”). The pre-Eocene rocks underwent intense deformation and regional metamorphism as high as amphibolite grade in Middle or Late Cretaceous time. The plutonic-metamorphic complex is overlain in places by Cenozoic basaltic and rhyolitic lava flows and

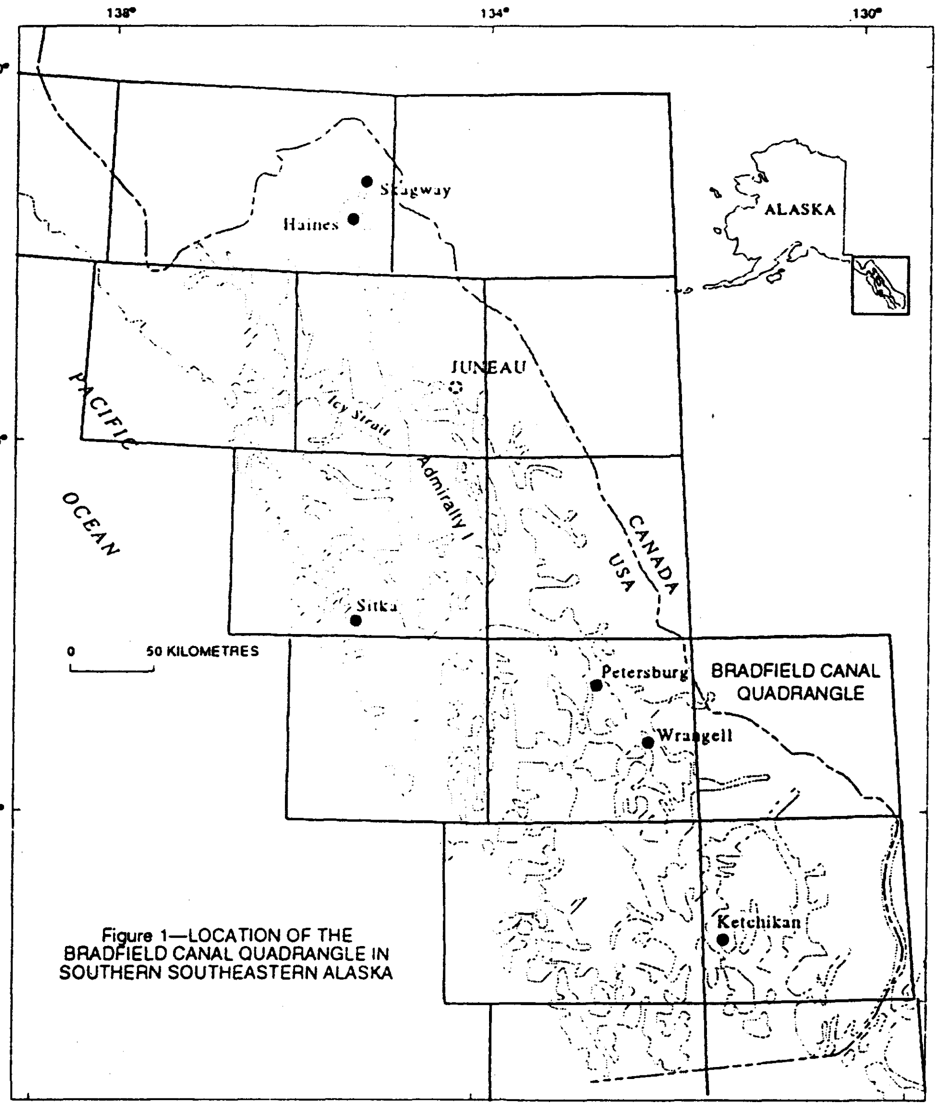


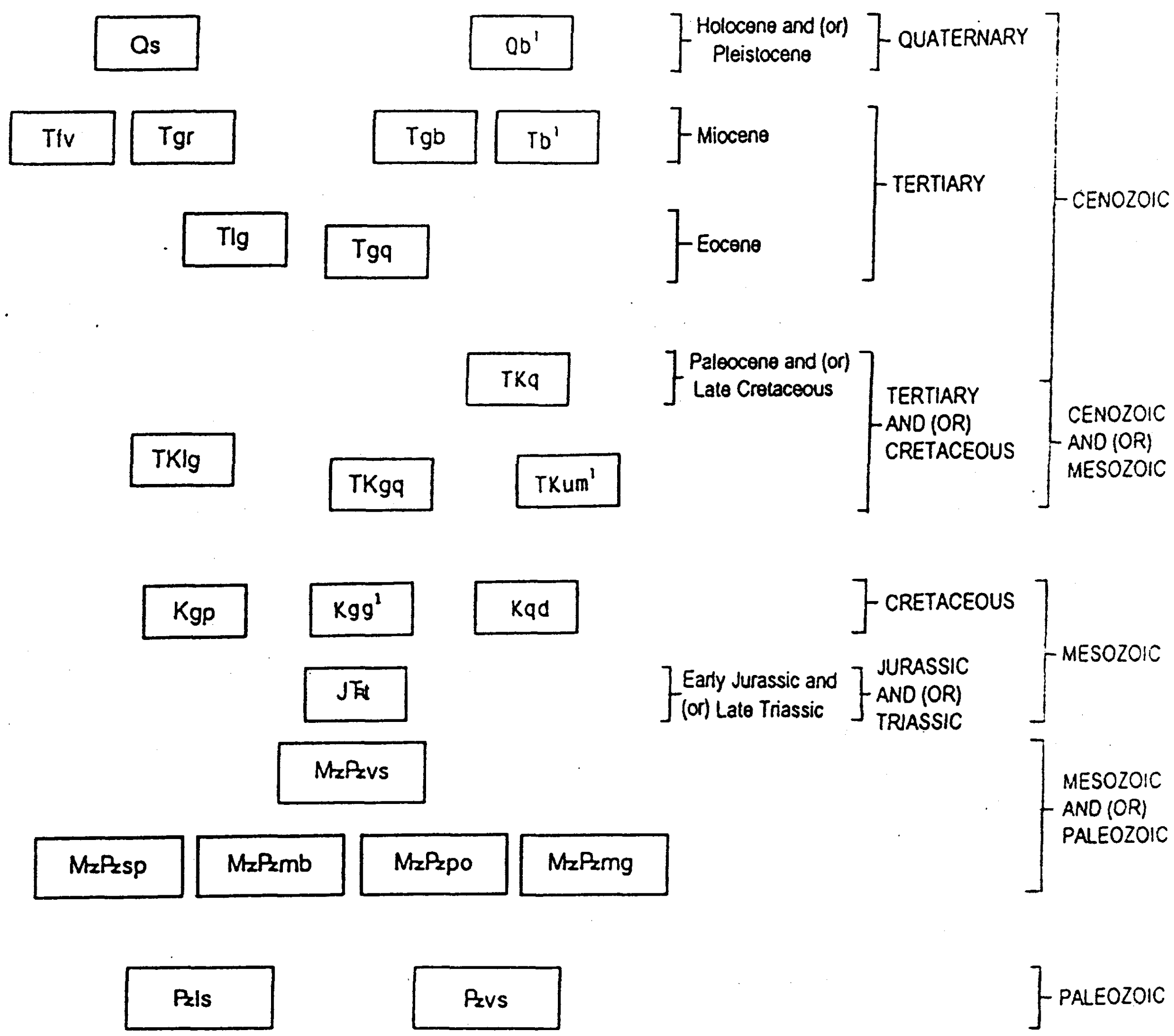
Figure 1—LOCATION OF THE BRADFIELD CANAL QUADRANGLE IN SOUTHERN SOUTHEASTERN ALASKA

pyroclastic materials, and by basalt flows that may have erupted as recently as 100-200 years ago. All of the pre-Quaternary rock units described in this report are cut by numerous lamprophyre dikes (Smith, 1973). These thin, dark-hued, and remarkably linear dikes are not shown on the geologic map and are not described further in this report. Unconsolidated Quaternary deposits include alluvium, talus, and partly reworked glacial and glacial-marine deposits. Except for the highest peaks, the study area was covered by glacial ice in Pleistocene time, and many remnants of those glaciers remain, mainly at higher elevations. Several faults are mapped in the study area, but the most prominent structural feature that was mapped is a complex shear zone, called the Coast Range megalineament (Brew and Ford, 1978) or the Coast shear zone (M.L. Crawford, oral commun., 1996). The zone is marked by a northwest-southeast linear topographic depression, mainly along stream valleys, from near Berg Mountain to beyond Eagle Lake, and which extends beyond the boundaries of the study area (Brew and others, 1984; Berg and others, 1988). The nearly vertical shear zone, which originated about 55 Ma, records intense ductile deformation, and forms the western boundary of the plutonic-metamorphic complex (Brew and Ford, 1978).

Age assignment of certain map units: Age assignments of units shown on the accompanying geologic map reflect interpretations made at the time of this investigation. Emplacement ages of most pre-Eocene foliated, gneissic, or migmatitic plutons, and protolith ages of the metamorphosed bedded rocks, are largely inferred from complex and commonly ambiguous field relations. Numerous samples of rocks in and near the study area were processed for age determination by the potassium-argon (K/Ar) method, but interpretation of emplacement or protolith ages of most pre-Eocene units by that method was largely stymied because their K/Ar isotopic clocks were reset during a 50 Ma regional thermal event (Smith and Diggles, 1981). Since 1979, however, relatively definitive ages have been determined by U-Pb isotopic dating of zircons in rock units in nearby areas that probably correlate with some units in the Bradfield Canal quadrangle (G. E. Gehrels and M. L. Crawford, oral communs., 1996). Such zircon-based studies suggest, for example, that the protoliths of originally bedded rocks in metamorphic map units MzPzsp, MzPzmb, MzPzpo, and MzPzmg are middle Paleozoic, early Paleozoic, or Precambrian in age.

Organization: The rest of this pamphlet contains a chart (table 1) showing the correlation of geologic units depicted on the accompanying map; an abbreviated description of the map units (table 2); an explanation of the geologic symbols used on the map (table 3); detailed descriptions of the map units; and a list of references.

Table 1. Correlation of map units.



[1] See DESCRIPTION OF MAP UNITS for specific unit age assignment.

Table 2. Abbreviated description of map units.

Qs	Surficial glacial, glacial-marine, alluvial, and talus deposits (Holocene and (or) Pleistocene)
Qb	Basalt (Holocene and Pleistocene?)
Tfv	Felsic volcanic rocks (Miocene)
Tgr	Alkali-feldspar granite (Miocene)
Tgb	Gabbro (Miocene)
Tb	Basalt and gabbro (Tertiary)
Tlg	Leucocratic granodiorite and adamellite (Eocene)
Tgq	Granodiorite and quartz diorite (Eocene)
TKq	Quartz diorite (Paleocene and (or) Late Cretaceous)
TKlg	Leucocratic granodiorite (Tertiary and (or) Cretaceous)
TKgq	Foliated granodiorite and quartz diorite (Tertiary and (or) Cretaceous)
TKum	Mafic and ultramafic rocks (Tertiary or Cretaceous)
Kgp	Porphyritic granodiorite (Cretaceous)
Kgg	Garnet-biotite granodiorite (Cretaceous?)
Kqd	Biotite-hornblende quartz diorite (Cretaceous)
JTrt	Texas Creek Granodiorite (Early Jurassic and Late Triassic)
MzPzvs	Metamorphosed and recrystallized volcanic and sedimentary rocks (Mesozoic and (or) Paleozoic)
MzPzsp	Schist and paragneiss (Mezozoic and (or) Paleozoic)
MzPzmb	Marble (Mesozoic and (or) Paleozoic)
MzPzpo	Paragneiss and orthogneiss (Mesozoic and (or) Paleozoic)
MzPzmg	Migmatite (Mesozoic and (or) Paleozoic)
Pzls	Limestone (Paleozoic)
Pzvs	Metavolcanic and metasedimentary rocks (Paleozoic)

Table 3. Explanation of symbols used on accompanying map sheet.

Contact—Dotted where concealed

Fault—Dashed where approximately located; dotted where concealed

Possible thrust fault—Teeth on upper plate.

Porphyritic Texture—Area of pronounced porphyritic texture in igneous body which is elsewhere not characteristically porphyritic

Strike and dip of foliation or schistosity

24 **Inclined**

Vertical

Strike and dip of bedding

24 **Inclined**

Vertical

* Cinder cone

Coast Range megalineament (CRML)

CRML

Boundary of Misty Fiords National Monument (MFNM)

MFNM

DESCRIPTION OF MAP UNITS

Qs **Surficial glacial, glacial-marine, alluvial, and talus deposits (Holocene and (or) Pleistocene)**--Unconsolidated deposits of poorly-sorted clay, silt sand, gravel, and boulders locally cover bedrock, sometimes to depths of many meters, throughout the study area. These deposits include alluvium and talus; partly reworked glacial drift, till, moraine, and glacial-marine deposits. Unconsolidated sedimentary deposits floor all major valleys, at least parts of most cirques, and mantle parts of many slopes. Only the largest exposures of these deposits are represented on the geologic map.

Qb **Basalt (Holocene and Pleistocene?)**--Deposits of alkali-olivine basalt referred to informally as the Blue River flows occur on both sides of the Canadian border in the valleys of Lava Fork, Blue River, and Unuk River (Wright, 1906). They consist primarily of lava flows, one cinder cone, and lesser cinder and ash deposits. Additional basalt flows travelled east down Canyon Creek, just north of Mount Stoeckl and the Alaska-British Columbia border, and spread out in the Unuk River valley at and above Border Lake. Small, loose deposits of basaltic ash were observed high on slopes southwest of Blue Lake, 13 km south of the main vent and more than 6 km northwest of the cinder cone in Blue River valley.

The main vent for most of the eruptive products presently exposed lies in British Columbia at about 1,400 m elevation on the top of the east valley wall of the Lava Fork of the Blue River, about halfway between Mount Stoeckl (a boundary peak) and Olatine Mountain. No well-formed cone is present in this vent area, and none is likely to have formed on the precipitous slopes. Lava flows cascaded in two broad channels down the valley wall and lava and debris fans dammed the glacial river. Lava flows disrupted the drainage in Lava Fork, proceeded 12 km down to the main fork of Blue River, which they dammed to form Blue Lake, and then followed Blue River south. At the mouth of Blue River, the flows fanned out across the valley floor, moving about 1 km upstream and 4 km down the Unuk River valley, pinning the Unuk to a narrow channel along the southern valley wall. A second vent is marked by a small cinder cone, now surrounded by lava flows, in Blue River valley between Blue Lake and the Unuk river. Ash mantles some steep slopes, snow fields, and stagnant glacial ice near the vent along Lava Fork, and a small hot spring has produced an iron-stained zone at the base of the valley wall below that vent.

The basalt flows consist of blocky lava and rubble, especially in Lava Fork, and pahoehoe lava that commonly is broken into large and small slabs. The flows cover alluvial and glacial(?) deposits in the glacially eroded valleys of Lava Fork, Blue River, and Unuk River, and completely fill the valley bottoms of Lava Fork and Blue River. A single drainage channel has been reestablished only in the lower part of the Blue River, and no single channel has formed in Lava Fork, where brilliant aqua-blue water flows through mazelike passages within the flows.

The eruptive history of these deposits has been one of several periods of activity separated by intervals of inactivity. Near the lower end of Blue River and in the Unuk River valley, the superposition of different flow tongues can be seen. The amount of lichen and plant growth decreases on higher (younger) flows, indicating at least some age difference.

Recent deposition of these volcanic materials is indicated by a number of factors. The cinder cone and intact pahoehoe surfaces have never been glaciated. Most of the upper flow surfaces are fresh and free of any significant plant growth other than lichen and are largely devoid of any soil cover. Significant regrowth of trees has occurred only in some areas of older flows, on the cinder cone, and adjacent to river channels where waterborne sediment is present. Ash and other easily eroded pyroclastic deposits still mantle steep rock slopes and stagnant ice along the margins of the glacier at the head of Canyon Creek near the main vent area, while the active stream in the center of this glacier has had no difficulty carrying the ash away and depositing it at the toe of the glacier. The remains of fallen trees, some with trunks partly charred on their undersides, are abundant and evenly distributed on some flow surfaces.

At least the most recent basalt flows and pyroclastic deposits near Blue River are Holocene in age and may be the youngest eruptive rocks in southern southeastern Alaska, although some flows at Mount Edgecumbe have been interpreted to be at least as young as postglacial (Brew, 1988). A radiocarbon age of 360±60 yr B.P. was determined on wood from a tree trunk on the surface of one of the flows (Elliott and others, 1981). This age was near the younger age limit determinable by this technique for that particular sample. Other flows are stratigraphically higher than the one from which the wood was collected.

Quaternary basalt and basaltic ash and scoria also occur in a number of places in the Ketchikan quadrangle to the south (Berg and others, 1988). Those occurrences include both preglacial deposits (flows showing glacial striae) and postglacial deposits (constructional features and ash deposits that could not have withstood glacial processes). K-Ar age determinations on samples from the Ketchikan quadrangle (Smith and Diggles, 1981) have yielded ages ranging between 0.5 Ma and 1 Ma, with one determination of 5 Ma.

Quaternary basalt and basaltic ash and scoria also occur in British Columbia to the southeast ot Blue River (e.g., the Holocene Aiyansh lava flow, which also is alkali-olivine basalt: Sutherland Brown, 1969). Two cinder cones at the Aiyansh lava flow show conspicuous differences in erosion and vegetation cover corresponding to a 375-year radiocarbon age difference (Wuorinen, 1978). The older cone has been dated by the carbon-14 method on wood as 625 yr B.P. and shows significant erosion and plant cover. The younger cone, dated by carbon-14 as 250 yr B.P., has lichens and small bushes, but no significant erosion.

The physical appearance of the flows, vegetation cover, and tree trunk dates at Blue River, suggest that eruptions occurred in this area within the last 100 to 200 years. The cinder cone in Blue River and the ash patches near the main vent and west of Blue Lake have little or no vegetation or erosional features. As rainfall probably is heavier in the Blue Lake area, plant growth and erosion might be expected to proceed more swiftly there than at Aiyansh. This suggests that volcanic activity at Blue River may have occurred at or since 250 yr B.P.

Tfv **Felsic volcanic rocks (Miocene)**--A variety of volcanic rocks overlies parts of the alkali-feldspar granite (Tgr) at Cone Mountain. These volcanic rocks include flowbanded rhyolite, rhyodacite, volcanic breccia, and welded ash-flow tuff. In addition to subaerial exposures, debris from these rocks occurs as float emerging from the toe of a glacier just west of Cone Mountain. This glacier clings to a steep slope, with its head about 2 km above its toe. There seems little likelihood that this float came from a source other than under the relatively restricted area of this glacier. The nearest outcrops of lithologically similar rocks lie in the Kuiu-Etolin belt (Brew and others, 1985), more than 74 km to the west.

Flowbanded rhyolite is light gray and purplish gray, with fine, contorted laminae of whitish devitrified volcanic glass alternating with laminae of very fine-grained massive microgranite consisting of quartz, feldspar, and minute mafic minerals (and possibly also glass). Crystals are anhedral and no greater than 0.5 mm in diameter.

Quartz-porphyritic rhyolite breccia contains equant anhedral glassy quartz phenocrysts 0.5 to 3 mm across. Clasts are generally less than 3 cm in diameter and consist of rhyolite and devitrified glass fragments.

Microgranite porphyry is a massive, medium-gray rock having a very fine-grained groundmass of quartz and feldspar and evenly distributed minute biotite flakes. All mineral grains are less than 0.1 mm in diameter. Equant, anhedral, glassy quartz forms abundant phenocrysts up to 5 mm in diameter. Potassium-feldspar phenocrysts about the same size are also abundant; they are light tan, anhedral to subhedral, and equant to 1:3 elongate. Phenocrysts are randomly oriented.

Volcanic breccia is massive, with angular lithic fragments up to 2 cm in diameter; they include phyllite, thinly laminated rhyolite, and light-gray rhyodacite. Quartz is anhedral to commonly euhedral, glassy, and up to 7 mm in diameter. Many quartz phenocrysts are embayed. Feldspar crystals are white to light tan and commonly broken.

Age and association--These felsic volcanic rocks are not deformed or metamorphosed, and depositionally overlie older metavolcanic rocks (Pzvs). They are similar in composition to the nearby alkali-feldspar granite (Tgr), which was intruded at a shallow level in the crust. The felsic volcanic rocks herein are considered to be genetically related to the granite and to have formed at about the same time, about 12 Ma.

Tgr **Alkali-feldspar granite (Miocene)**--A stock and an adjacent sliver (apophysis) of leucocratic alkali-feldspar granite crop out at Cone Mountain. The main body is exposed in an area 5.6 km by 12 km, and about 1,600 m vertically. A cap of strongly hornfelsed, thinly layered siliceous siltstone is perched atop the granite at Black Crag, indicating that this is the top of the pluton.

Most of the stock is medium-grained leucocratic biotite alkali-feldspar granite that weathers white, light buff, tan, light gray, or light purplish pink due to iron-oxide staining of the feldspar. Outcrops and hand samples are uniform and homogeneous. The texture is massive, commonly miarolitic, relatively equigranular, and hypidiomorphic. The main granite body is compositionally zoned, with leucocratic granite at the periphery giving way in the lowest exposures to somewhat more alkaline composition in which the mafic mineral is stocky, strongly blue-green amphibole. Quartz is anhedral and glassy, ranging up to 5 mm in diameter. The feldspar is light-tan to pinkish potassium feldspar. Mafic minerals are discrete, evenly distributed grains, mostly of black (fresh) and rusty (altered) anhedral biotite that makes up 3% or less of the rock. At the deepest exposed level, the mafic mineral is mainly stocky black amphibole that appears distinctly blue in transmitted light.

The miarolitic texture indicates emplacement at shallow depth, and the intensely hornfelsed overlying country rock indicates that this magma was emplaced into relatively cool country rocks. The contacts of the granite are sharp and discordant to foliation in adjacent rocks. The granite thus was emplaced late in the tectonic evolution of the region, after significant uplift and cooling of this part of the crust. Potassium-argon (K/Ar) age determinations yield an age of 12.1±0.4 Ma on biotite, and an age of 11.9±0.4 Ma on blue amphibole (Donald Turner, written commun., 1982). The granite thus is assigned a middle Miocene emplacement age.

Tgb **Gabbro (Miocene)**--A complex intrusive body crops out on Deer Island in the Petersburg quadrangle, and part of it extends into the study area along the eastern shore of the island, where the unit consists of biotite-pyroxene gabbro and biotite-olivine gabbro. The unit is compositionally and texturally heterogeneous and locally forms dikes in adjacent units. The gabbro intrudes biotite-hornblende quartz diorite (Kqd) and schist and paragneiss (MzPzsp).

The gabbro generally is massive, medium-grained, and hypidiomorphic granular, and locally diabasic (mainly in dikes and inclusions). Plagioclase mainly is anhedral to subhedral, but locally is euhedral; some of it is strongly concentrically zoned. Mafic minerals consist of pale-yellow to medium-orange-brown anhedral biotite, anhedral clinopyroxene (augite), and olivine locally in addition to, or in place of, pyroxene. Pale-brown hornblende has replaced some of the pyroxene. Interstitial and equant anhedral opaque grains constitute up to 1% of the rock. Much of the unit exposed within the study area is moderately deuterically(?) altered.

A potassium-argon age determination on biotite from the gabbro on the west side of Deer Island has yielded an age of 20.0±0.5 Ma (J.G. Smith, unpublished data, 1982). The gabbro thus is assigned an early Miocene emplacement age.

Tb **Basalt and gabbro (Tertiary)**--Basalt and andesite(?) flows and breccia crop out on a hill about 300 m high in the southwest corner of the study area, north of Standing Rock Lake and east of Deer Island. The outcrop area extends about 5.6 km and is surrounded by quartz diorite (Kqd). Contacts between unit Kqd and unit Tb are covered by dense vegetation, but the extrusive rocks are presumed to depositionally overlie the quartz diorite. From the field relations, it is possible, but unlikely, that the basalt represents a subvolcanic intrusion rather than extrusive flows.

Gabbro--Locally, the basalt is cut by sharp-edged dikes composed of medium-grained, massive-appearing gabbro that is presumed to be cogenetic with the basalt.

Age--Neither the basalt nor the gabbro was isotopically dated. The rocks are deuterically(?) altered, but have not been penetratively deformed or regionally metamorphosed. They therefore probably are younger than the underlying(?) foliated quartz diorite (Kqd) of Cretaceous age. Assuming that the basalt is extrusive, the flows also largely postdate the regional uplift that has mainly affected nearby rocks of Oligocene or older age (Brew and others, 1984). Unit Tb herein is assigned a Tertiary, probably post-Oligocene, age, correlative with similar volcanic rocks on Kuiu and Etolin islands in the Petersburg quadrangle (Brew and others, 1979, 1984, 1985). It is possible that unit Tb is genetically related to the gabbro complex (Tgb) that crops out on Deer Island 9 km to the west.

Tlg **Leucocratic granodiorite and adamellite (Eocene)**--Massive to weakly foliated, potassium-feldspar-porphyritic, leucocratic biotite granodiorite and adamellite forms a number of plutons near the Alaska-Canada border from Mount Stoeckl to Mount Pounder. These intrusive bodies are roughly circular in outcrop area, ranging up to 12 km x 22 km in size. Small bodies assigned to this unit also intrude unit TKq southeast of Berg Mountain and southwest of Mount Cote. This unit is characterized by generally massive texture, low color index, and ubiquitous prominent feldspar phenocrysts that average about 7 mm in length but range up to 3 to 4 cm long. Modes of most samples fall in the left (plagioclase) side of the adamellite field, but a few samples are granodiorite. Average composition is 30% quartz, 40% plagioclase, and 30% potassium feldspar.

Structure--The bodies are relatively uniform in appearance throughout, and generally massive, except near contacts where weak foliation is defined by indistinct streaks of higher color index. This foliation is parallel to the contacts and to the foliation in the surrounding country rocks.

Texture--Potassium-feldspar megacrysts float in a generally massive, medium-grained matrix of anhedral quartz and potassium feldspar, and subhedral plagioclase.

Quartz--Always anhedral, the quartz occurs as crystals a mm or so in diameter, and locally as up-to-cm-size crystal aggregates.

Potassium feldspar--Potassium feldspar in the groundmass consists mainly of anhedral microcline. Phenocrysts are mostly perthite, and commonly are poikilitic. Myrmekite occurs locally.

Plagioclase--Plagioclase comprises subhedral and anhedral crystals up to a few mm in maximum dimension that show weak or no compositional zoning and weak albite twinning.

Mafic mineral--The mafic mineral generally consists only of brown biotite that makes up 0 to 5% of the rock. The biotite commonly is interstitial to and bent around felsic grains, and forms minute subhedral flakes, either separately or in small clusters. Both the Mount Stoeckl body and the intrusion west of Blue Lake have concentric, somewhat asymmetric, color index distributions, their cores being slightly more mafic than their margins.

Accessory minerals--Minute crystals of euhedral and anhedral sphene and euhedral apatite are ubiquitous. Microscopic euhedral garnet occurs in a few samples. In places, euhedral garnets appear to have been pseudomorphed by an opaque mineral.

Contacts--Contacts are intrusive, and generally concordant to layering and foliation in adjacent country rocks, implying that they yielded to create space for the magma. In the Mount Stoeckl body, a fine-grained border phase up to 100 m wide has relatively low color index (about 1), and no quartz or potassium feldspar megacrysts. Small crystals of garnet and sphene are visible in hand specimens there, and foliation is defined by the alignment of elongate quartz grains. Sills, up to 1 m thick, and discordant dikes, only a few cm thick and of inconsistent orientation, cut the country rocks. Locally, amphibolite country rocks adjacent to the Mount Stoeckl body contain small-scale recumbent folds near the contacts.

Age--These rocks are assigned an Eocene intrusive age based on concordant potassium-argon (K/Ar) ages of 51±1.5 Ma for biotite and 53.5±0.5 Ma for hornblende (J.G. Smith, unpub. data, 1982) from a sample collected near the Canadian border. The textures of these plutons indicates that they were emplaced in a low-strain environment either during the waning stages of, or following, regional tectonic deformation. They thus presumably were emplaced as the crust was cooling, and have not undergone major thermal or dynamic events. Their K/Ar systems therefore probably reliably record their emplacement age.

Tgq **Granodiorite and quartz diorite (Eocene)**--Hornblende-biotite granodiorite and quartz diorite form two large subequant plutons near boundary peak Mount Fawcett and near the east fork of the Bradfield River. Smaller bodies occur north of the Stikine River near boundary peak Mount Talbot. These rocks are dominantly massive, medium-grained, and hypidiomorphic granular, but their texture and mineral composition vary from place to place, and they can be subdivided into three main suites: (1) Medium-grained, equigranular, hornblende-biotite quartz diorite containing little potassium feldspar, which occurs only interstitially. Biotite forms flakes 2-4 mm in diameter, and most commonly are anhedral. Foliation is faint to absent; (2) Potassium-feldspar-porphyritic granodiorite, a volumetrically minor constituent. Phenocrysts are up to 1.5 cm in maximum dimension; (3) Massive hornblende-biotite granodiorite characterized by conspicuous books 3 to more than 6 mm in diameter of fresh, blackish-brown biotite that is uniformly distributed in parts of several different bodies. The books commonly are as thick as they are wide. These conspicuous mafic crystals contrast with the fresh white feldspar and quartz and give the rock a distinctive "polka-dot" appearance. The quartz forms anhedral, 1 mm to 2 mm grains. Potassium feldspar is mainly anhedral and poikilitic; hornblende is subhedral, and some crystals contain plagioclase inclusions. Mild foliation locally is developed by mineral (especially quartz) elongation and alignment.

Texture--Massive to weakly foliated.

Mafic minerals--Hornblende and biotite collectively compose 10% to 15%, and rarely 20%, of the rock. Hornblende mostly forms stubby crystals 3 mm to 5 mm long that are slightly smaller than the biotite "polka-dots." The biotite also ranges downward in size to a mm or so in diameter.

Inclusions--Inclusions most commonly are sparse, small, and consist of fine-grained equigranular micro-quartz diorite having a color index of 30 to 40.

Accessory minerals--Sphene occurs locally in trace amounts.

Outcrops--Most rock exposures are homogeneous in composition and texture.

Dikes--This unit is cut by a relatively small number of sharp- and irregularly-edged quartzofeldspathic dikes of pegmatite and aplite. In places it is also cut by dikes of leucocratic hornblende-biotite granodiorite and adamellite. The body near Mount Fawcett also is intruded by the alkali-feldspar granite (Tgr) of the Cone Mountain body.

Age--This map unit is assigned an Eocene emplacement age on the same basis as unit Tlg.

TKq **Quartz diorite (Paleocene and (or) Late Cretaceous)**--Biotite-hornblende quartz diorite, commonly lineated and (or) foliated, locally schlieric, especially near contacts, and locally conspicuously gneissic. This unit forms a number of separate bodies that are part of a nearly continuous belt of elongate quartz diorite and lesser granodiorite plutons referred to collectively as the tonalite sill belt (Brew and Ford, 1981; Brew and others, 1976, 1984), or the Great Tonalite Sill (Brew, 1988). The belt extends along the east side of the Coast Range megalineament (Brew and Ford, 1978), and is traceable for more than 1,500 km, throughout the length of southeastern Alaska and into British Columbia (see, for example, Quottoon pluton, in Woodsworth and others, 1983).

Both throughout the length of the belt and within the study area, the rocks display considerable variation in texture and structure, and somewhat less variation in composition. Most rocks are are quartz diorite (tonalite); granodiorite and diorite are less abundant. Mafic minerals consist of biotite and hornblende. Parts of the unit characteristically contain up to several percent of hornblende crystals as much as 5 mm x 20 mm in size. Accessory minerals are subhedral to euhedral sphene, euhedral apatite, zircon, and opaque grains that at least partly are magnetite.

Whereas some of the rocks in this unit are massive, most have moderately to well-developed lineation and (or) foliation resulting mainly from alignment of mafic grains. Additional features defining foliation are individual elongate mafic inclusions, and local swarms of inclusions, schlieric layering, and well-developed gneissic texture. Shear zones exhibiting intense strain (foliation) relative to surrounding rocks of similar composition occur within the unit; they are less than 1 m to 10 m wide and have relatively sharp boundaries with the relatively less-foliated rock. Aside from these zones, the general level of strain and the degree of development of alignment fabrics generally increase to the west.

Inclusions are ubiquitous in unit TKq, ranging in volume from less than a percent of outcrops to more than half the rock in some local "inclusion swarms." They are fine grained, equigranular, and massive to foliated (aligned mafic grains), but never layered. The inclusions are mineralogically the same as the host rock, but have higher mafic content and color index, which ranges from 35 to 40. Some inclusions have several percent of up to cm-size or larger hornblende and (or) plagioclase phenocrysts floating in the equigranular matrix. Inclusion margins are generally smooth and sharp, and rarely "sculptured" or convoluted. Inclusion shapes range from equant to extremely elongate (more than 1:10 aspect ratio) bodies parallel to foliation in the host rock; they probably are a good indication of strain.

Contact relations and age--Contacts of this unit with schist and paragneiss country rocks are concordant. The westernmost contact commonly forms a strikingly continuous planar boundary dipping 65 to 85 degrees to the northeast. The unit is intruded by rhyolite quartz-porphyry dikes, and by dikes and small apophyses of leucocratic granodiorite and adamellite of unit TKlg. Unit TKq is continuous with foliated tonalite of Late Cretaceous and (or) Paleocene age in the adjacent Petersburg quadrangle to the northwest (map unit Ttos *in* Brew and others, 1984).

TKlg **Leucocratic granodiorite (Tertiary and (or) Cretaceous)**--Leucocratic granodiorite and adamellite crop out along the east side of unit TKq from Mount Cote south to the headwaters of North Bradfield River. Unit TKlg also crops out throughout large areas southeast of Unuk River.

Unit TKlg is extremely heterogeneous in composition, texture, and structure. It is locally massive, foliated, schlieric, and gneissic. Despite their leucocratic (light tan to light gray) appearance, these rocks are predominantly granodiorite, along with much less adamellite. Mafic minerals and potassium feldspar generally are irregularly distributed. Quartz forms gray, glassy, aggregates of anhedral crystals. In many places, the rocks are at least sparsely potassium-feldspar porphyritic, with seriate K-feldspar ranging from less than 1 mm to 10 mm in size; the smaller grains are anhedral and the larger ones are subhedral to euhedral. Plagioclase is anhedral and averages a few mm in diameter. Mafic minerals are biotite and hornblende that form discrete, disseminated, anhedral grains ranging from less than 1 mm to 2 mm across. The mafic minerals locally are aligned into streaks parallel to, and which also help to define, the foliation.

Contacts with adjacent foliated units (e.g., metamorphic rocks and unit TKq) are concordant. Contacts with units Tlg and MzPzpo are gradational. The contact with unit Tlg is arbitrarily drawn to separate foliated and relatively non-porphyritic rocks (TKlg) from massive and conspicuously porphyritic rocks (Tlg) of similar composition. Unit MzPzpo contains considerable amounts of rocks indistinguishable from unit TKlg as leucosome within migmatite.

Age and association--Potassium-argon dating of all Eocene or older rocks in this part of the Coast Range batholith yields ages of approximately 50 Ma (J.G. Smith, unpub. data, 1982), regardless of the material being processed, because their K/Ar isotopic clocks were thermally reset at that time. Its gradatonal relations with unit Tlg suggest that at least some of unit TKlg is Tertiary in age, whereas its strongly gneissic and schistose phases suggest that they originated before or during the Cretaceous regional metamorphism. The unit consequently is assigned a Cretaceous or Tertiary age.

TKgq **Foliated granodiorite and quartz diorite (Tertiary and (or)**

Cretaceous)--Foliated granodiorite and quartz diorite underlie large areas on either side of Unuk River from Burroughs Bay to the Canadian border, and along the border from Blue River to Mount Bayard.

Light to medium gray, medium grained, and relatively equigranular, these rocks generally have moderately developed foliation formed by the alignment of discrete anhedral biotite and hornblende crystals (and also of elongate quartz and feldspar) and, more commonly, by the alignment of small elongate aggregates of the mafic minerals. Outcrops of unit TKgq commonly have a slightly dull appearance relative to other units, such as Tgq and TKq. The mafic minerals also look comparatively dull, possibly due to their anhedral and aggregated habits.

Unit TKgq locally is intruded by unit Tlg and by leucocratic granodiorite of unit TKlg. Its Cretaceous and (or) Tertiary age assignment, however, is based on the presumption that at least part of unit TKgq is gradational with unit TKlg, some of whose phases are compositionally and texturally nearly identical.

TKum **Mafic and ultramafic rocks (Tertiary or Cretaceous)**--Several bodies of mafic and ultramafic rocks occur within the study area, but only one is large enough to show on the accompanying map sheet. They comprise two types:

1. <u>Hornblendite</u>--The largest occurrence of hornblendite is a concordant intrusive body about 15 m in outcrop width on the northern shore of Bradfield Canal. Its contacts are parallel to the foliation and layering in the enclosing schist. The hornblendite is massive and consists of about 90% black hornblende in crystals up to more than 2 cm long. About 5 to 10 percent of the rock volume is brown biotite, and 0 to 2 percent is plagioclase. Small unmapped bodies of similar composition occur in a number of places in the central part of the study area and are included within areas underlain by unit MzPzmg. Schlieric layers and mafic-rich zones up to several meters across within unit TKq also are rich in coarse hornblende, but they also contain appreciable quartz and have much lower color indexes (40 to 60). It is not known whether those mafic concentrations are related to, or have an origin similar to, the hornblendite of unit TKum.

<u>Age</u>--The age of the hornblendite is uncertain. It is assigned a Cretaceous or Tertiary age on the presumption that most intrusive igneous activity in the study area

occurred during that interval. The hornblendite bodies appear to be undeformed, which suggests that they may have been emplaced after the Late Cretaceous regional metamorphism.

2. Actinolitite--A small, unmapped body of pale- to medium-green actinolitite is exposed near the southern edge of the study area south of the Klahini River. This occurrence underlies an area about 7 m across. There are no occurrences of lithologically similar rocks known elsewhere in the study area or to the south in the Ketchikan quadrangle. The rock is massive and does not appear to be concordant with adjacent gneiss; its age and origin are unknown.

Kgp **Porphyritic granodiorite (Cretaceous)**--Plagioclase-porphyritic granodiorite and equigranular biotite-hornblende quartz diorite form a body 10 km x 20 km at Martin Lake, elongated roughly parallel to the trend of the regional structure and foliation. Moderately to intensely sheared plagioclase-porphyritic granodiorite forms several small concordant bodies too small to show on the accompanying map along the southern shore of Bradfield Canal.

The main body, at Martin Lake, consists of granodiorite and quartz diorite having two textural and compositional phases. The eastern half of the pluton is characterized mainly by distinctive coarsely plagioclase-porphyritic biotite granodiorite. This texture and composition are similar to those of plutons (unit Kpg, in Berg and others, 1988) in the Ketchikan quadrangle west of the megalineament, and to the northwest in the Petersburg quadrangle (Brew and others, 1984). The plagioclase forms subhedral to euhedral crowded phenocrysts 4 mm to 9 mm in maximum dimension. Interstitial to the plagioclase is a fine- to medium-grained aggregate of anhedral quartz and potassium feldspar (microcline), flakes of fresh brown biotite, and sparse but ubiquitous garnet that forms unevenly distributed skeletal clumps and irregular grains. The unit characteristically contains mm-size crystals of apple-green magmatic epidote, the petrogenetic significance of which has been described by Zen and Hammarstrom (1984a, b). Other accessory minerals include sphene, apatite, zircon, and opaques.

The western half of this pluton is hypidiomorphic rather than porphyritic, contains less garnet, and contains green hornblende in amounts equal to or greater than biotite.

Otherwise, the mineralogy and quartz-potassium feldspar-plagioclase ratio is in the same range in both parts of the pluton. Based on limited sampling, the change in texture and composition apears to be gradational from east to west, with the size and euhedral shape of plagioclase decreasing to the west and the amount of hornblende falling off to zero to the east.

The western part of the pluton is foliated, especially near and parallel to its margins, but this mineral alignment is generally weak. The porphyritic eastern part is not foliated, but has a cataclastic fluxion structure superimposed on it that gradually increases in intensity to a nearly schistose texture locally near the eastern margin. The cataclastic foliation is parallel to, and grades into, the regional foliation in the surrounding country rocks and is presumed to have formed at the same time.

Potassium-argon age determinations on a biotite-hornblende pair from the western part of the pluton have yielded discordant ages of 58.6±1.4 Ma and 83.2±2.3 Ma, respectively (J.G. Smith, unpub. data, 1982). This is consistent with the patterns of age discordance observed in compositionally and texturally similar rocks in the Ketchikan quadrangle (Smith and others, 1979; Smith and Diggles, 1981). Based on these dates, and on those of the similar rocks in the Ketchikan quadrangle, the pluton at Martin Lake is assigned a Late Cretaceous age and is presumed to have been emplaced at about 90 Ma.

Several concordant bodies of plagioclase-porphyritic biotite granodiorite having textures similar to those observed in the eastern part of the Martin Lake body crop out along the southern shore of Bradfield Canal. Most are too small to show on the accompanying map sheet. All of these rocks contain small orange garnets and have strong superimposed cataclastic fabric. The intensity of cataclasis increases eastward toward Eagle Bay, to the degree that these rocks are barely distinguishable from adjacent quartzofeldspathic schist and gneiss. Clues to their identity include their relatively uniform texture and unlayered nature, mineralogical composition, and relict, broken plagioclase phenocrysts. Because of textural and compositional similarities, these bodies are presumed to be related to, and to have the same emplacement age as, the Martin Lake body.

Kgg **Garnet-biotite granodiorite (Cretaceous?)**--A single small, elongate body of garnet-rich biotite granodiorite is exposed on the north and south shores of Bradfield Canal, just west of Eagle Bay (Buddington and Chapin, 1929). The rock is unusually mafic, having a color index approaching 50, and contains up to 20 volume percent of orange garnets as much as a centimeter or more in diameter, especially on the north shore of Bradfield Canal. Contacts are concordant to the foliation in the surrounding schist, and the body appears to have a roughly tabular form parallel to that trend.

This body has not been dated directly. Because of its composition, it is presumed to have formed from magma, perhaps highly contaminated by country rocks, related to unit Kgp, and thus may possibly be Cretaceous in age.

Kqd **Biotite-hornblende quartz diorite (Cretaceous)**--A mildly foliated sphene-epidote-biotite-hornblende quartz diorite batholith underlies more than 200 square miles of the southwestern part of the study area, and includes parts of Deer and Wrangell Islands. This intrusive body extends south throughout a large area of the Ketchikan quadrangle (unit Kq, in Berg and others, 1988). The rock is relatively uniform in texture and composition both in hand specimen and at outcrop scale, as well as throughout most of the batholith. Modes from throughout the pluton cluster fairly well within the quartz diorite field, and six of twenty-five samples are granodiorite. The color index ranges from 15 to 35; biotite and hornblende occur in approximately equal amounts in most samples; and a few samples from the eastern part of the unit in the Ketchikan quadrangle contain pyroxene partly replaced by hornblende. Potassium feldspar is unequally distributed, ranging from 0 to 25 volume percent, and a small area, shown by a stipple pattern on the accompanying map sheet, contains conspicuous potassium-feldspar phenocrysts. Elsewhere, potassium feldspar occurs as irregularly distributed, poikilitic, anhedral grains a few mm in size. The dominant accessory mineral is epidote that occurs in microscopically conspicuous amounts throughout the Bradfield Canal part of the batholith, except in its southeast corner. The epidote forms anhedral to subhedral crystals 1 mm to 2.3 mm in diameter. Sphene is common as minute interstitial grains, a few of which are euhedral. Garnets are present within 11 km of the northeastern contact with unit MzPzsp. Near the southern half of the northeastern contact, the rock is distinguished by fine-grained aggregates of interstitial quartz that weather in conspicuous relief.

Structure--In most areas, mafic mineral alignment produces mild foliation, but the rock is gneissic (mafic:felsic ratio layering) within a mile or two of the northeastern contact. Foliation is parallel to the contacts near the eastern and western margins of the batholith, but does not show a consistent pattern in the central part of the body.

Contacts--On Deer Island, unit Kqd is intruded by middle Tertiary gabbro (Tgb). Contacts with schist of unit MzPzsp are concordant; the contact, local plutonic foliation, and gneissic layering are parallel to the foliation and layering in the metamorphic country rocks. A topographic depression, including Eagle Lake and Blake Channel, marks the estern contact of this body, suggesting less-resistant rocks along this zone. Such less-resistant rocks, combined with the gneissic structure of the pluton along this contact, may indicate a locus of shearing during or soon after emplacement of unit Kqd. If so, this crustal weakness may have provided a channel for magma emplacement, which may explain why this particular pluton is much larger than the other bodies of similar composition that were emplaced at about the same time. Kyanite and sillimanite, not noted in country rocks adjacent to this body in the Bradfield Canal quadrangle, occur near it in the Ketchikan quadrangle, where these minerals are conspicuously discordant to the gradual northeastward increase in metamorphic grade in this region (Berg and others, 1988). This anomaly is probably due to heating of the country rocks by the intruding pluton.

Age--Potassium-argon age determinations on two samples from the west-central part of the body have yielded ages of 67.8±1.7 Ma and 69.6±1.7 Ma on biotite and 71.8±2.2 Ma and 80.0± 0.6 Ma on hornblende (J.G. Smith, unpub. data, 1982). An age of nearly 90 Ma, also partly reset, was obtained from this same body in the Ketchikan quadrangle (Berg and others, 1988). Unit Kqd is assigned an emplacement age of Late Cretaceous (probably 90-95 Ma) based on those dates, and on patterns of ages determined in the Ketchikan quadrangle (Smith and others, 1979; Smith and Diggles, 1981).

J₸t **Texas Creek Granodiorite (Early Jurassic and Late Triassic)**--The Texas Creek Granodiorite (Buddington, 1929.) comprises a metamorphosed and sheared batholith exposed in the southeastern corner of the study area, extending south into the Ketchikan quadrangle (Berg and others, 1988) and east into British Columbia (Grove, 1971; Smith, 1977). This body consists mainly of recrystallized, locally cataclastically deformed granodiorite and minor quartz diorite. The rock commonly has a greasy green appearance with cloudy feldspars and indistinct grain boundaries. The rock is medium-grained and hypidiomorphic granular, and is composed of andesine or oligoclase, quartz, and potassium feldspar, and accessory sphene and opaque minerals. The mafic minerals are green hornblende and green biotite. Secondary minerals include albite, muscovite, clinozoisite-epidote, actinolite, chlorite, and calcite. In many specimens, euhedral crystals of potassium feldspar and hornblende, up to 2 cm long, impart a distinct and characteristic porphyritic texture.

In general, the Texas Creek Granodiorite is relatively massive and lacks pronounced primary or metamorphic foliation. Parts of it are characterized by cataclastic textures. The intensity of the cataclasis is generally low, but locally the rocks have been converted to mylonite. In addition to widespread incipient cataclasis, the pluton was affected by low-grade regional metamorphism and up to hornblende-hornfels facies thermal metamorphism. The regional metamorphism partly obliterated original textures and produced mineral assemblages typical of the greenschist facies. The regional metamorphism and the cataclasis predate the intrusion of Eocene plutons, which produced thermal aureoles up to 1.5 km wide along their contacts with the batholith (Smith, 1977).

Age--The Texas Creek Granodiorite is considered to have a Late Triassic and Early Jurassic emplacement age on the basis of radiometric data. The granodiorite intrudes Paleozoic and (or) Mesozoic bedded rocks (MzPzvs) and is cut by Eocene granodiorite and adamellite (Tgq). Conventional K/Ar dates on two biotite-hornblende pairs collected from the core of the body yielded strongly discordant ages, with hornblende ages of 200.2±6 Ma and 210.7±6 Ma, which are interpreted as minimum emplacement ages. The discordance between biotite and hornblende is attributed to partial resetting during post-emplacement greenschist-facies regional metamorphism (Smith, 1977; Smith and Diggles, 1981). A uranium-lead (U-Pb) age determination on zircon from the border phase of the pluton has yielded an age of 195.0±2.0 Ma, and a similar analysis of each of two samples from porphyry dikes believed to be apophyses of the pluton has yielded an age of 194.8±2.0 Ma (Alldrick and others, 1985). The difference between the hornblende and zircon ages is slightly greater than the combined range of analytical uncertainty. It is not known if this is the result of sampling rocks formed by different pulses of magma, or if it reflects a problem with one of the dating experiments, such as excess argon or lead loss. Greenschist-facies metamorphism should not be enough to partially reset U-Pb systems in zircon and should have affected the hornblende more strongly, making that age younger if both radiometric clocks were started at essentially the same time. The close agreement of the U-Pb ages suggests that they may be more reliable than the K/Ar ages.

MzPzvs **Metamorphosed and recrystallized volcanic and sedimentary rocks (Mesozoic and (or) Paleozoic)**--Metamorphosed to lower greenschist facies, these lightly recrystallized volcanic and volcaniclastic rocks, flysch, and minor limestone crop out in the southeastern corner of the study area, near Banded Mountain and Salmon River (Smith, 1977; Berg and others, 1977). The sequence extends north and east into British Columbia (Grove, 1971). The dominant rocks in this sequence are interbedded andesitic tuff breccia, volcanic graywacke, siltstone, and argillite. Coarse volcanic conglomerate, possible broken-pillow breccia, and dark-blue-gray marble occur as lesser constituents.

The tuff breccia is massive and commonly occurs in beds 0.5 m -4 m thick. Representative samples contain 5 to 50 percent, poorly sorted, angular to subrounded, slightly vesicular lapilli set in an unsorted and unstratified volcanic graywacke matrix. Phenocrysts of euhedral, zoned plagioclase, 1-10 mm long, constitute 5-20 percent of the lapilli. The phenocrysts are largely recrystallized to albite or oligoclase and clinozoisite-epidote, but those that survived recrystallization retain their original andesine composition. Phenocrysts of mafic minerals are much less common than plagioclase; most lapilli contain none. The mafic minerals are strongly pleochroic, euhedral, green or brown hornblende and subordinate colorless subcalcic augite. Most mafic phenocrysts have recrystallized to aphanitic aggregates of albite, quartz, chlorite, epidote, and opaque minerals. Shapes suggestive of microlites are still visible in some samples. The graywacke matrix of the tuff breccia consists of sand-size, angular mineral fragments identical to the phenocrysts in the lapilli, as well as a pasty (palagonite?) filling.

This sequence is characterized by lower greenschist-facies mineral assemblages. Most of these rocks are not foliated or otherwise penetratively deformed, but parts characterized by schist and cataclastic deformation are common. Locally the sequence is also contact metamorphosed both by the intrusion of the Texas Creek Granodiorite and Eocene plutons. In some places, the strata are tightly to isoclinally folded with steep axial planes. In other places, they are deformed into nearly recumbent folds with gently to moderately northeastward-dipping axial planes. Berg and others (1977) postulated a zone of large-scale overthrusting, parallel to the semi-recumbent structures, and which subsequently was intruded by granitic magmas, to explain these observations. No direct evidence of such a thrust is preserved in the study area.

Neither the stratigraphic base nor top of this unit is exposed in the study area. Its minimum structural thickness, based on cliff exposures, is about 750 m. The sequence forms erosional remnants of an arched roof intruded by the Texas Creek Granodiorite (Smith, 1977).

Age--No fossils have been found in these rocks in the study area. Their intrusion by the Upper Triassic and Lower Jurassic Texas Creek Granodiorite provides an upper limit on their time of deposition. The volcanic sequence in the Banded Mountain-Salmon River area has previously been "questionably assigned to the [Lower Jurassic] Hazelton Group" (Smith, 1977; Buddington and Chapin, 1929; and Grove, 1971) on the basis of lithologic similarity, structural equivalency, and prior usage by Canadian geologists. "Individual beds and structures can be traced across the international boundary" (Smith, 1977). The type area for the Hazelton Group is near Hazelton, British Columbia. Near Stewart, British Columbia, just across the Canadian border, rocks laterally equivalent to unit MzPzvs are unconformably overlain by Middle Jurassic (Bajocian or Bathonian) sedimentary rocks of the Bowser assemblage (Grove, 1971), although no such capping formation has been recognized in the study area.

Fossils of late Paleozoic age were collected near Mount Whipple on the Alaska-Canada boundary from marble (Pzls) intercalated with rocks (Pzvs) similar in composition and metamorphic grade to unit MzPzvs. The metamorphic rocks assigned herein to unit MzPzvs could originally have been coextensive with the fossiliferous rocks, but they are mapped separately in this study to be consistent with past usage.

Berg and others (1988) proposed that some of the volcanic rocks of this sequence may be cogenetically related to the Texas Creek Granodiorite. The radiometric ages of that pluton are partly reset and thus are minimum ages. If the correlation of the volcaniclastic rocks of unit MzPzvs with the Hazelton Group is correct, the probable age of these rocks is very close to that of the pluton that intruded them. Because the volcanic rocks and the pluton both are of generally similar composition, it is at least possible that they are cogenetic.

Assuming that unit MzPzvs correlates at least partly with rocks of the Hazelton Group, and that it may also include the faunally-dated Permian rocks at Mount Whipple, it is provisionally assigned a depositional age of Paleozoic and (or) Mesozoic. Its intrusion by the Texas Creek Granodiorite demonstrates that at least part of it probably is older than Late Triassic.

MzPzsp **Schist and paragneiss (Mezozoic and (or) Paleozoic)**--A belt of heterogeneous schist and paragneiss stretches from Berg Mountain on the western edge of the study area to Burroughs Bay on the southern border. The eastern margin of this unit is an unusually long, uniform contact with quartz diorite of unit TKq. This contact is concordant, at least in gross aspect, to the foliation in both units. No discordancy was observed, suggesting that any discordancy is minor. General lithologies comprising this unit are:

Psammitic schist--The most common compositional type in this unit is generally fine-grained, equigranular, moderately to strongly foliated, quartzofeldspathic biotite schist containing subordinate to accessory muscovite, opaque minerals (mainly pyrite), and, locally, garnet. Some of these rocks have relatively low color index (5-10) and do not have enough micaceous minerals to form continuous partings. Such rocks, perhaps more properly described as semischist or foliated granofels, cleave poorly except along layers relatively rich in micas; this foliation results partly from aligned discrete biotite crystals and partly from compositional layering. Some of these low-color-index rocks have a distinctly bimodal alignment of biotite.

Pelitic and semi-pelitic schist--Generally fine-grained quartz-feldspar-biotite schist containing subordinate to accessory muscovite, opaque minerals, ±garnet, ±sphene, ±apatite,
±zircon, and ±cordierite (rare). In a few places near the northern border of unit Kqd, and at the northern end of Blake Channel, the rocks also contain kyanite and (or) sillimanite. As in the Ketchikan quadrangle to the south, the only kyanite known occurs in schist within a short distance of of the contact of unit Kqd (Berg and others,

1988). Presumably, this body provided a heat source to raise metamorphic temperatures into the kyanite stability field.

Paragneiss--The paragneiss is characterized by compositional layering a few cm to a m or so thick. The layers typically alternate between relatively quartzofeldspathic and relatively mafic rocks. In places, the paragneiss is compositionally and texturally gradational with the pelitic schist.

Amphibolite and mafic schist--Amphibole-rich schist and semischist are distributed throughout unit MzPzsp, and are especially abundant near its eastern border. This mode of occurrence is similar to that in the Ketchikan quadrangle, where Berg and others (1988, map unit MzPza) mapped a separate unit consisting of mafic-rich quartz-plagioclase-biotite-hornblende schist and leucocratic biotite-hornblende-quartz-plagioclase pegmatite.

Protoliths--The rocks of unit MzPzsp are too highly metamorphosed to preserve any relict sedimentary or volcanic features. Minor intercalated marble indicates at least partial marine deposition. Compositions of the schists indicate a preponderance of psammitic and less abundant pelitic rocks, and intermediate to mafic rocks, probably of volcanic and (or) intrusive origin.

Age--The age of the protoliths of this unit is not known[1]. No fossils have been discovered in the schists or intercalated marble (including unit MzPzmb). It can be demonstrated in lower-grade parts of equivalent rock units in the Ketchikan quadrangle that regional metamorphism had established a foliation in the country rocks prior to the thermal metamorphism that accompanied the emplacement of at least some of the Cretaceous plutons (best exemplified, perhaps, by the occurrence of kyanite overprinting an earlier foliation in the schist unit near the contact of unit Kqd). This Cretaceous metamorphism, in turn, was overprinted, at least in the eastern part of unit MzPzsp, by dynamothermal metamorphism during early Eocene time. Since the rocks in unit MzPzsp record only these three postdepositional events, we arbitrarily assign their protoliths a premetamorphic age of Paleozoic and (or) Mesozoic.

[1] See “Age assignments of certain map units” in Introduction

MzPzmb **Marble (Mesozoic and (or) Paleozoic)**--Medium- to light-gray and buff to white marble that is predomintly calcite, but locally is dolomitic. Most of this marble is massive, any pre-existing layering having been obliterated by strain and recrystallization. Marble forms thin interlayers with silicic (quartz-rich) calcareous granofels and fine-grained psammitic schist, and thick layers within schist and paragneiss. Within the study area, most marble occurrences consist of pods and lenses that are several meters to less than a third of a meter long, and which are too small to show on the accompanying map sheet. Larger bodies occur on Blake Island, farther south near the margin of the quartz diorite batholith (Kqd), and between the headwaters of Harding and Aaron Creeks. The marble varies from pure calcite to rock containing significant amounts of quartz, feldspar, pyrite, and, in some places, muscovite and (or) biotite. These silicate impurities occur either as disseminated grains or as silicate-rich layers, pods, and lenses. Locally, as near the northern border of unit Kqd west of Hoya Creek, the marble contains blebs of wollastonite and (or) pods of other calcsilicate minerals. All occurrences of marble are too strained and recrystallized to be likely fossil sources, and no fossils were found[1]. Several samples were tested for conodonts without success.

MzPzpo **Paragneiss and orthogneiss (Mesozoic and (or) Paleozoic)**--A belt of paragneiss and orthogneiss trends diagonally across the central part of the study area from Aaron Creek in the northwest to Grant Creek, just north of Burroughs Bay. This belt is parallel to the main strands of unit TKq and to the Coast Range megalineament. This heterogeneous collection of paragneiss, schist, and orthogneiss apparently originated as silicic to intermediate plutonic rocks, and is intruded by dikes of various granitic types, chiefly lithologies like those in units TKq, TKlg, and TKg.

The paragneiss and schist of unit MzPzpo are similar to those in unit MzPzsp, and include psammitic, pelitic, silicic, and mafic variants, and minor metacarbonate. The difference between the units may be due entirely to their different metamorphic histories. The apparent peak metamorphic conditions resulted in crystallization of kyanite and kyanite plus sillimanite in unit MzPzsp, whereas in unit MzPzpo they produced sillimanite and

[1] See "Age assignments of certain map units" in Introduction

cordierite, but not kyanite. The kyanite in unit MzPzsp appears to be related to its proximity to unit Kqd. A further distinction is that rocks of unit MzPzsp generally have the aspect of schists, whereas rocks in unit MzPzpo tend to be of higher textural grade and are more commonly termed "gneiss" because of their more highly developed mineral segregation.

Psammitic schist and gneiss--These rocks typically contain quartz, plagioclase, biotite, and, locally, muscovite and garnet.

Pelitic schist and gneiss--In addition to quartz, plagioclase, and biotite, these rocks may contain almandine garnet, cordierite, sillimanite, hercynite, and opaque minerals (mainly pyrite).

Amphibolite and mafic schist--Biotite- and amphibole-rich schist and gneiss and amphibolite are irregularly distributed throughout unit MzPzpo. These rocks generally contain quartz, plagioclase, biotite, and hornblende, and may also contain garnet.

Protoliths--Field relations show that unit MzPzpo is derived from originally stratified and plutonic rocks, but metamorphism has destroyed all original textures and structures. Their lithologic similarities, however, suggest that the protoliths of the metasedimentary rocks in both units probably were the same.

Age--Assuming premetamorphic consanguineity with at least some of the compositionally similar metamorphosed bedded rocks in unit MzPzsp, the paragneiss and schist components of unit MzPzpo also are arbitrarily assigned a protolith age of Mesozoic and (or) Paleozoic[1]. The orthogneiss (metaplutonic) component is presumed to have originated after deposition and consolidation of the premetamorphic bedded rocks and before intrusion of crosscutting dikes that are compositionally equivalent to units TKq, TKlg, and Tlg.

MzPzmg **Migmatite (Mesozoic and (or) Paleozoic)**--An area near the center of the study area is underlain by a complex assemblage of intrusive rocks and less abundant

[1] See "Age assignments of certain map units" in Introduction

heterogeneous paragneiss and orthogneiss. The intrusive rocks consist of generally leucocratic granodiorite and adamellite lithologically similar to rocks of unit TKlg, and probably are apophyses of neighboring plutons.

Textures and structures--Textures of the intrusive components of this unit range from massive to foliated and finely gneissic, and from fine-grained aplitic to coarse-grained pegmatitic. Structural habits include massive-appearing, homogeneous rock, schlieric layering, banded gneiss, swirled, streaked, irregularly-veined and nebulitic gneiss, and rounded and angular agmatite.

Composition of intrusive components--The intrusive phases in this unit vary from quartz diorite having color indexes ranging from 20 to 30 (locally more mafic in schlieren) to leucocratic granodiorite and adamellite having color indexes ranging from 0 to 5.

Composition of paragneiss components--Paragneiss constitutes only a small part of the rocks in this unit. It forms inclusions, thin layers, and small pendants enclosed by intrusive rocks. Lithologies include psammitic and pelitic geneisses containing quartz, plagioclase, biotite, hornblene, and, locally, pyroxene.

Age and associations--Similarities in composition and field relations suggest that the protolith of the paragneiss component of unit MzPzmg is probably the same as that of units MzPzps and MzPzpo. In this report, the protoliths of originally bedded rocks in all three units are arbitrarily assigned a premetamorphic age of Paleozoic and (or) Mesozoic[1]. Most of the rocks in this unit, however, are either intrusive rocks or orthogneiss. The orthogneiss may have formed from plutonic rocks essentially contemporaneously with their emplacement, whereas the crosscutting intrusive rocks postdate development of the metamorphic fabrics. The emplacement age of the orthogneiss is unknown, except that it is older than crosscutting intrusive rocks that may be apophyses of units TKlg and Tlg.

[1] See "Age assignments of certain map units" in Introduction

Pzls Limestone (Paleozoic)--Light- to dark-gray and medium-brown layers enclosed within metasedimentary and metavolcaniclastic rocks. Locally, the carbonate layers excede 10 m thick.

Fossils--Fossils have been found in the unit in one locality, near the summit of boundary peak Mount Whipple. Recrystallization and mild deformation make absolute identification of most of the fauna tentative, but their aspect and variety point to a late Paleozoic, most probably Early Permian (Wolfcampian), age for the limestone layers containing the fossils. The fossils tentatively identified are described in table 4.

Table 4.—Fossils collected from unit Pzls at Mount Whipple.

Fossil Type	Fossil Name	Age	Reference
conodont	ADETOGNATHUS LAUTUS (Gunnell)	latest Mississippian to Early Permian (Wolfcampian)	Bruce R. Wardlaw, USGS (written commun., 1980)
conodont	ADETOGNATHUS (?)	late Mississippian to Early Permian	Bruce R. Wardlaw, USGS (written commun., 1980)
linoproductid brachiopod	possibly YAKOVLEVIA (?)	Permian is permissible and reasonable age	J.T. Dutro, Jr., USGS (written commun., 1980)
fusulinid	PSEUDOFUSULINELLA sp. (?)	possibly Early Permian	R.Douglas and A.K.Armstrong, USGS (written commun., 1980)
fusulinid	PSEUDOSCHWAGERINA sp.	Permian (probably Wolfcampian)	Raymond C. Douglas, USGS (written commun., 1980)
fusulinid	SCHWAGERINA sp.	Permian (probably Wolfcampian)	Raymond C. Douglass, USGS (written commun., 1980)
gastropod	OMPHALOTROCHUS (?)	Early Permian	Ellis L. Yochelson, USGS, (written commun., 1979)

Additional organic debris includes solitary corals, spiriferoid fragments, echinodermal debris, and bryozoan(?) fragments.

Metamorphic temperature--Conodont CAI values of 6.0 and 7.0 indicate hostrock temperatures during metamorphism of 400-500°C and 450-500°C, respectively (Bruce R. Wardlaw, written commun., 1980).

Contact relations--The abrupt difference in metamorphic grade between the fossiliferous limestone at Mount Whipple and the more highly deformed and recrystallized marble in nearby areas suggests that these carbonate units, and their interbedded strata, are separated by a structural discordance, possibly a thrust fault. A high-angle fault or an unconformity is also possible, but field relations, chiefly absence of topographic expression of a steep fault and the possibility that both carbonate units were originally coextensive, indicate that either is less likely.

Pzvs **Metavolcanic and metasedimentary rocks (Paleozoic)**--Isolated small roof pendants of metamorphic rocks scattered across the central Coast Range and larger bodies of metamorphic rocks exposed discontinuously along the US-Canada border from Mount Gallatin to Mount Willibert are assigned to unit Pzvs. Depending on their position relative to the core of the Coast Range batholith, these rocks range in metamorphic grade from amphibolite facies to greenschist facies. The lowest grade rocks are along the border near Mount Whipple, where some contain relict volcanic textures.

Lithologies--Rocks of unit Pzvs near Mount Whipple consist of argillite and gray phyllite, greenschist, and metamorphosed intermediate volcanic and volcaniclastic rocks; and lesser amounts of interlayered limestone and marble. Elsewhere along the international boundary, the rocks consist of very fine-grained gray schist containing quartz, plagioclase, biotite, and minor amounts of opaque minerals and apatite; and thinly-layered siliceous siltstone, impure quartzite, and mafic schist containing quartz, plagioclase, green hornblende, biotite, clinopyroxene, opaque minerals, and sphene. All of the rocks are very fine grained. Probably the most common rock types are extremely fine-grained, medium-gray schists composed mostly of quartz, plagioclase, and biotite, and lesser amounts of other, undetermined, minerals. The mafic content of these rocks ranges from almost 0 to about 60 volume percent; most of the biotite semischist averages 25% to 30% mafic minerals. Small pods and layers of limestone, foliated and massive marble, and skarn occur locally; some of these are large enough to map as a separate unit (Pzls).

Age--This unit is assigned a Paleozoic age on the assumption that it is in stratigraphic continuity with the fossil-bearing limestone (Pzls) at Mount Whipple. The likely Permian age of the fossil suite, however, probably does not reflect the range in depositional age of the entire map unit, some of which may correlate with possibly Mesozoic strata in unit MzPzvs.

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