Metamorphic Facies Map of Southeastern Alaska—Distribution, Facies, and Ages of Regionally Metamorphosed Rocks

By CYNTHIA DUSEL-BACON, DAVID A. BREW, *and* SUSAN L. DOUGLASS

REGIONALLY METAMORPHOSED ROCKS OF ALASKA

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

METAMORPHIC FACIES MAP OF SOUTHEASTERN ALASKA — DISTRIBUTION, FACIES, AND AGES OF REGIONALLY METAMORPHOSED ROCKS

By Cynthia Dusel-Bacon, David A. Brew, and Susan L. Douglass

ABSTRACT

Nearly all of the bedrock of southeastern Alaska has been metamorphosed to some degree. Much of it has been metamorphosed under medium- to high-grade conditions during episodes that were associated with widespread plutonism.

The two oldest known metamorphic episodes in southeastern Alaska occurred during an early Paleozoic and a middle Paleozoic orogeny and affected probable arc-type volcanic, sedimentary, and plutonic rocks in the area of southern Prince of Wales Island. During Late Cambrian to Early Ordovician time, rocks were penetratively deformed, flattened, and recrystallized under greenschist- to amphibolite-facies conditions. The subsequent metamorphic episode, which was Silurian to earliest Devonian in age, occurred under prehnite-pumpellyite-facies conditions and was not accompanied by penetrative deformation.

The predominant period of metamorphism and plutonism occurred during the interval of Early Cretaceous to early Tertiary time. The oldest documented metamorphic episode during this interval took place in northern southeastern Alaska and apparently was associated with the intrusion of elongate bodies of highly foliated, 120- to 110-Ma tonalite and diorite. Low-grade metamorphism of mid-Cretaceous age produced a weakly to moderately developed metamorphic fabric in rocks extending from Kupreanof Island in the north to the peninsula north and west of Revillagigedo Island (Cleveland Peninsula) and perhaps to Revillagigedo Island in the south. This episiode predated the intrusion of mafic-ultramafic bodies that have yielded K-Ar ages of 110–100 Ma. Low-grade metamorphism of mélange and flysch north of Cross Sound and on Chichagof and Baranof Islands, southwest of the Peril Strait fault, also took place sometime during the Early Cretaceous to early Tertiary interval. Metamorphism of the mélange occurred in a subduction environment and may have begun as early as latest Jurassic time.

Metamorphism during the next episode or phase was associated with the intrusion of garnet- and epidote-bearing plutons of early Late Cretaceous age (approximately 90 Ma). Experimental data on the composition of magmatic garnet and the pressure required to crystallize magmatic epidote have been used to infer a minimum 13–15 kb initial depth and a 6–10 kb final depth for crystallization of the magma body. Kyanite, indicative of intermediate-pressure conditions, occurs in extensively developed aureoles around some of the plutons within amphibolite-facies rocks in the central and southern part of the 90-Ma metamorphic belt. Other 90-Ma plutons that intrude low-grade rocks have narrow low-pressure aureoles. Relict andalusite that has been replaced by kyanite occurs in aureoles within amphibolite-facies rocks near the northern end of the 90-Ma belt, near northernmost Wrangell Island. The early formation of andalusite, indicative of low-pressure conditions, is hard to reconcile with the high to intermediate pressures inferred for the associated garnet- and epidote-bearing plutons.

The final metamorphic episode or phase was mostly synkinematic with, but may have slightly preceded, the lastest Cretaceous and early Tertiary mesozonal intrusion of a 600-km long, northwestward-trending composite body herein referred to as the "great tonalite sill." The northern two-thirds of the metamorphic belt produced in Alaska during this episode is composed of an intermediate-pressure (Barrovian) sequence in which metamorphic grade increases northeastward. Isograds marking the first appearance of biotite, garnet, staurolite, kyanite, and sillimanite are generally parallel to the sill and inverted. Kyanite has not been reported in the southern part of the belt, and metamorphic pressures may not have been as high as in the north. Intermediate and felsic epizonal plutons intruded the eastern part of the belt in Eocene time during the final phase of this metamorphic episode and produced low-pressure aureoles and zones of migmatite.

INTRODUCTION

This report identifies and describes the major, regionally developed metamorphic episodes that affected southeastern Alaska throughout its evolution. It is one of a series of four reports that presents the metamorphic history of Alaska (fig. 1). Metamorphic rocks are assigned to metamorphic-facies units, which are shown on a 1:1,000,000-scale colored map (pl. 1), on the basis of the occurrence of pressure- and temperature-sensitive minerals and the age of metamorphism. Plutonic rocks are also categorized on the basis of their age and the relation of their intrusion to metamorphism. By means of detailed unit descriptions, this report

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summarizes the present (about mid-1987) state of knowledge of the metamorphic grade, pressure conditions, age of protoliths and metamorphism, and, in some cases, the speculated or known tectonic origin of regional metamorphism. Metamorphic units are discussed in the same order as that used for the map explanation. Within each geographic area (fig. 2), units are discussed in chronologic order, from oldest to youngest; units of the same metamorphic age or age range are discussed in order of increasing metamorphic grade.

The metamorphic-facies determination scheme (fig. 3, table 1) on which the map (pl. 1) is based was developed by the Working Group for the Cartography of the Metamorphic Belts of the World (Zwart and others, 1967). This scheme is based on pressure- and temperature-sensitive metamorphic minerals that are petrographically identifiable by most geologists. Regionally metamorphosed rocks are divided into three facies groups based on increasing temperature: (1) laumontite and prehnite-pumpellyite facies (LPP), shown in shades of gray and tan; (2) greenschist facies (GNS), shown in shades of green; and (3) epidote-amphibolite and amphibolite facies (AMP), shown in shades of red and orange. Where possible, the greenschist-facies and the epidote-amphibolite- and amphibolite-facies groups are divided into three facies series based on pressure. A high-, intermediate-, or low-pressure-facies series is indicated by an H, I, or L in place of the final letter in the symbol used for the previously mentioned facies groups.

In this compilation, the scheme of Zwart and others (1967) is expanded. Specifically, combinations of letters and symbols are used to indicate metamorphic conditions transitional between different facies groups and series. Where two facies groups or facies series occur together but have not

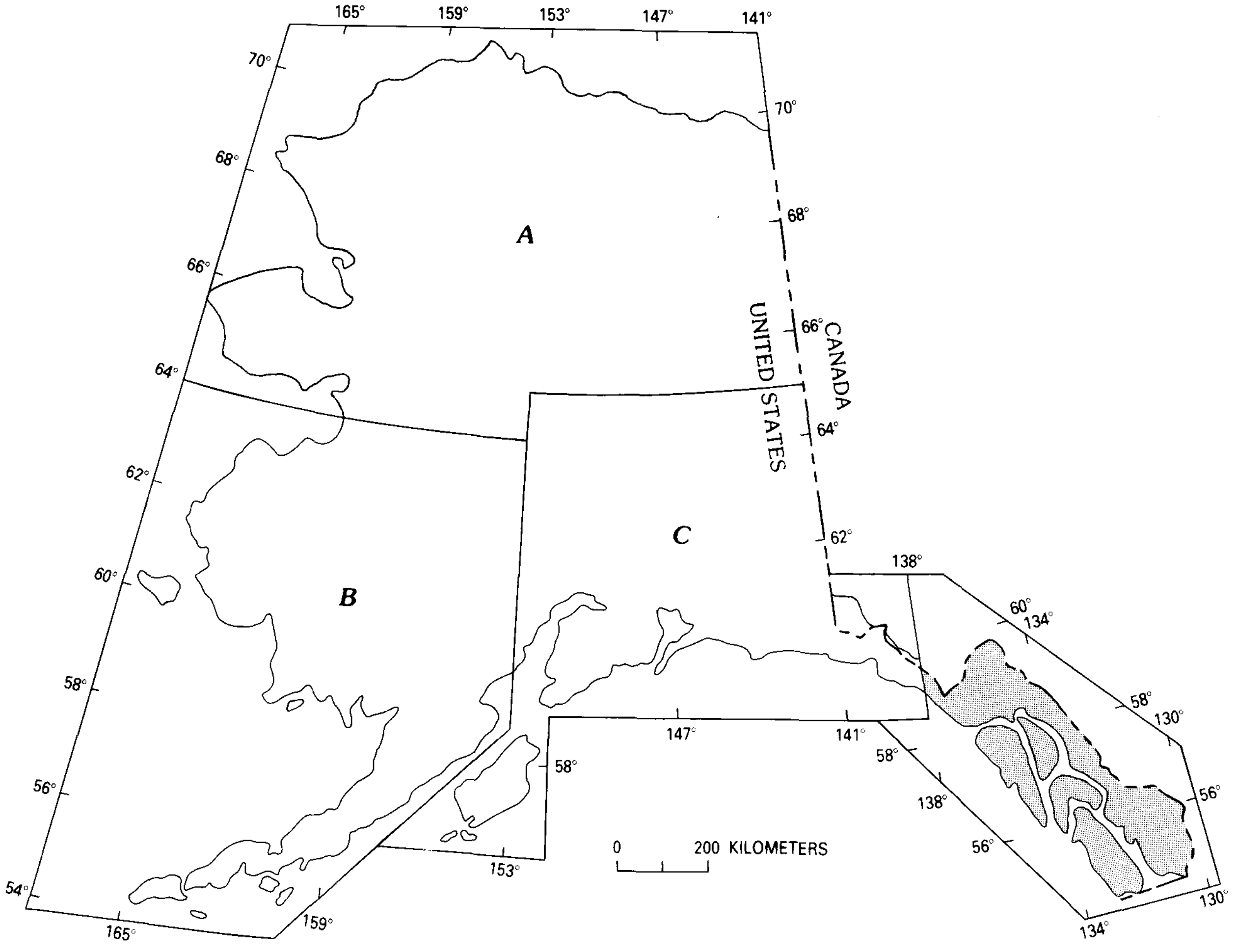

FIGURE 1.—Map showing area of this report (shaded) and other reports in the series of metamorphic studies of Alaska. A, Dusel-Bacon and others (1989); B, Dusel-Bacon and others (1996); C, Dusel-Bacon and others (1993).

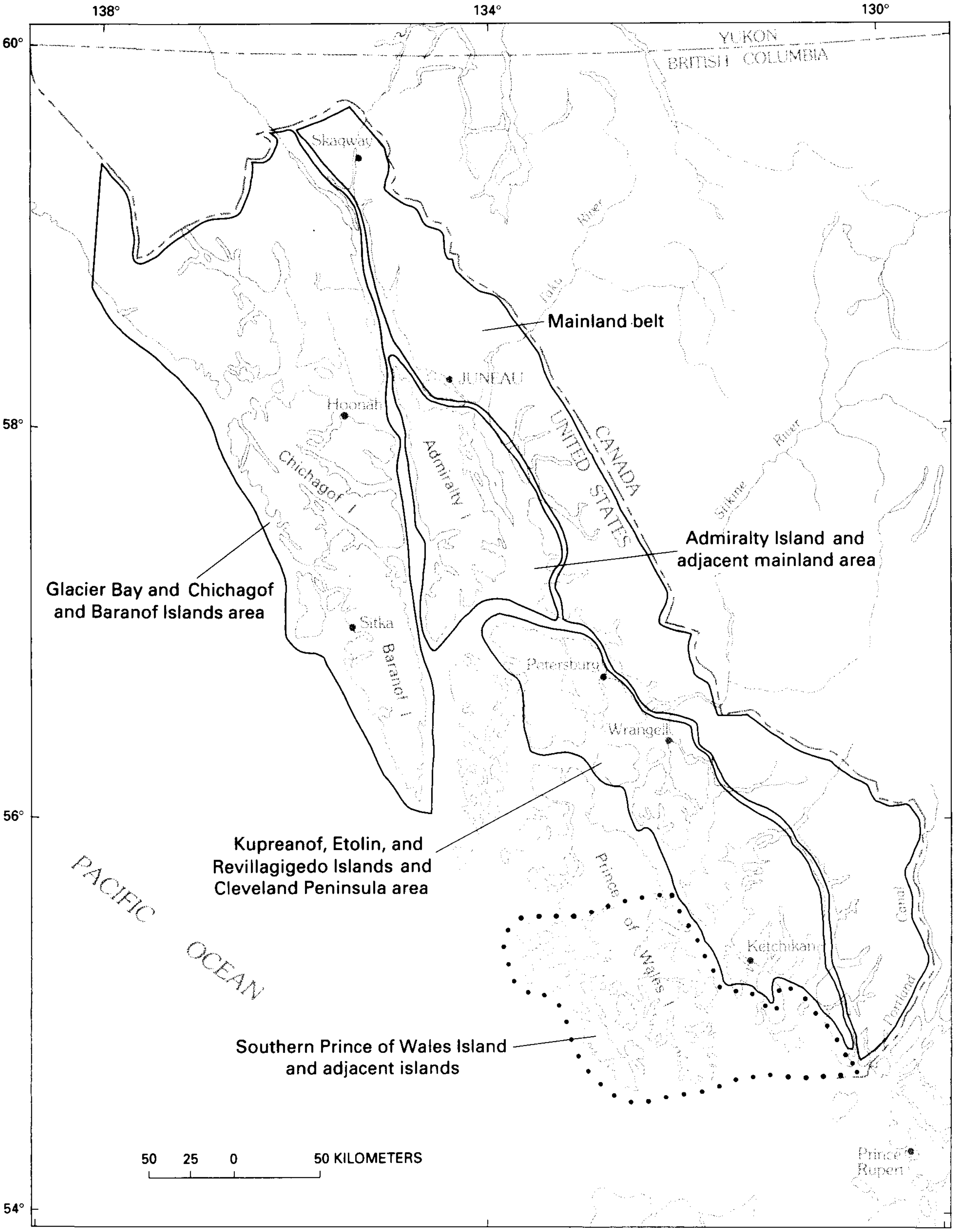

FIGURE 2.—Regional geographic areas in southeastern Alaska that are discussed in text.

been differentiated, the designation of the more abundant facies is given first, and the two designations are separated by a comma. Where the metamorphic grade of a unit was transitional between two facies groups, the lower grade designation is given first, and the two designations are separated by a slash. Where the pressure changes within a facies series, an arrow is used to show the direction of change. As a further expansion, a symbol for either the metamorphic age or minimum and maximum limits of the metamorphic age is given in parentheses following the facies symbol. In two instances, the numerical subscript "1" is used to differentiate between map units that have the same metamorphic grade and age but that have different protoliths and are believed to have different metamorphic histories. Where two metamorphic episodes have affected the rocks, the symbol gives the facies and age of each metamorphic episode, beginning with the oldest episode. Protolith and metamorphic age designations are based on the Decade of North American Geology Geologic Time Scale (Palmer, 1983). Radiometric ages cited herein have been calculated or recalculated using the decay constants of Steiger and Jäger (1977).

Metamorphic mineral assemblages for most metamorphic-facies units (table 2) follow the detailed descriptions of the metamorphic units and are keyed to the metamorphic-mineral locality map (pl. 2).

General sources of metamorphic data used to compile the metamorphic facies map (pl. 1) are shown on figure 4. Complete citations for published sources are given in the references. Additional sources are referred to in the detailed unit descriptions.

ACKNOWLEDGMENTS

We wish to thank the numerous geologists from the U.S. Geological Survey, the State of Alaska Department of Natural Resources, Division of Geological Surveys, and several universities who freely communicated their thoughts and unpublished data to this report. R.A. Loney, M.L. Crawford, G.E. Gehrels, R.D. Koch, and R.L. Elliott were par-

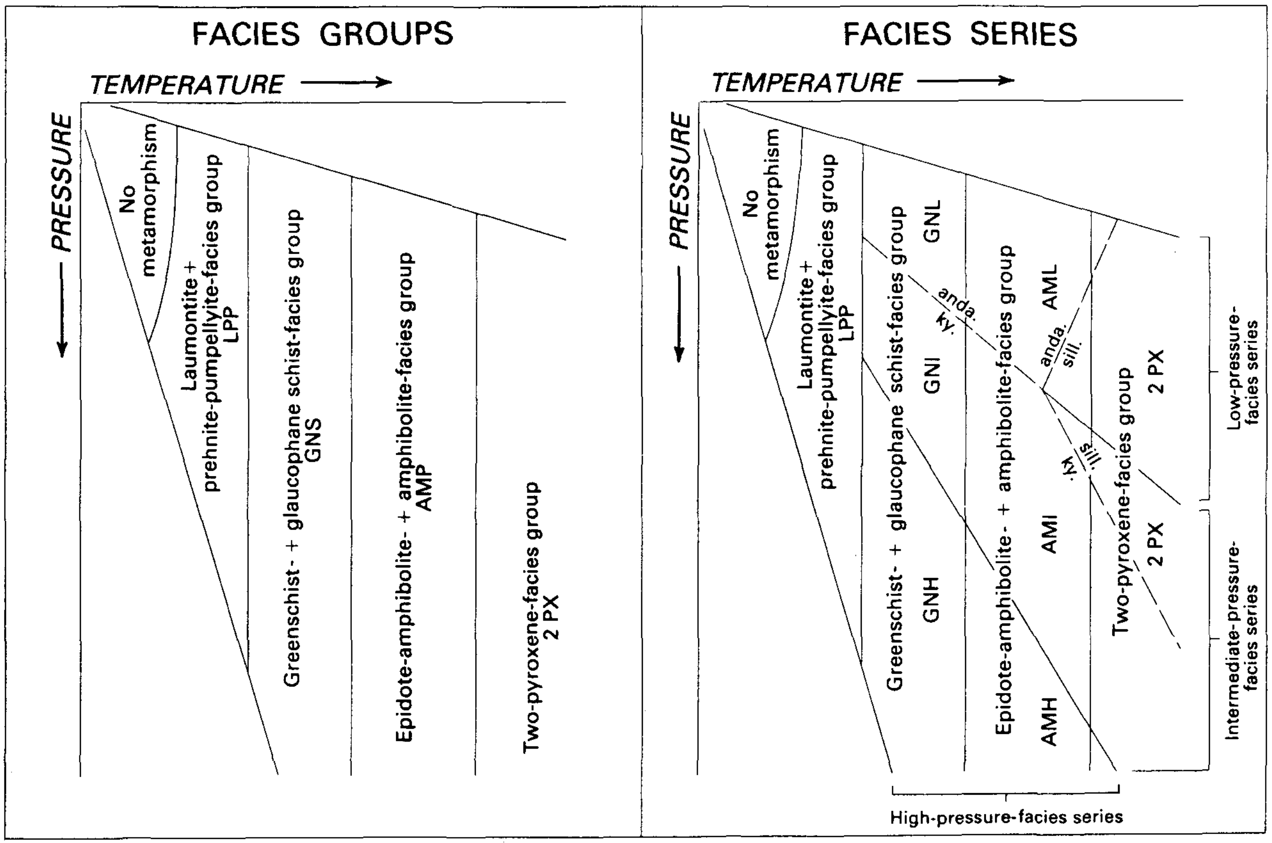

FIGURE 3.—Schematic representation of metamorphic-facies groups and series in pressure-temperature space and their letter symbols used in this report (modified from Zwart and others, 1967). Stability fields of Al_2SiO_5 polymorphs andalusite (anda.), kyanite (ky.), and sillimanite (sill.) shown by dashed lines.

Table 1.—*Scheme for determining metamorphic facies*

[Modified from Zwart and others, 1967]

Facies symbol	Diagnostic minerals and assemblages	Forbidden minerals and assemblages	Common minerals and assemblages	Remarks
LAUMONTITE AND PREHNITE-PUMPELLYITE FACIES				
LPP	Laumontite + quartz, prehnite + pumpellyite.	Pyrophyllite, analcime + quartz, heulandite.	"Chlorite", saponite, dolomite + quartz, ankerite + quartz, kaolinite, montmorillonite, albite, K-feldspar, "white mica".	Epidote, actinolite, and "sphene" possible in prehnite-pumpellyite facies.
GREENSCHIST FACIES				
GNS		Staurolite, andalusite, cordierite, plagioclase (An>10), laumontite + quartz, prehnite + pumpellyite.	Epidote, chlorite, chloritoid, albite, muscovite, calcite, dolomite, actinolite, talc.	
Low- and intermediate-pressure greenschist facies				
GNL and GNI		Hornblende, glaucophane, crossite, lawsonite, jadeite + quartz, aragonite.		Biotite and manganiferous garnet possible; stilpnomelane mainly restricted to intermediate-pressure greenschist facies.
High-pressure greenschist (blueschist) facies				
GNH	Glaucophane, crossite, aragonite, jadeite + quartz.		Almandine, paragonite, stilpnomelane.	Subcalcic hornblende (barroisite) may occur in highest temperature part of this facies.
Low-temperature subfacies of high-pressure greenschist facies				
GNH (with stipple)	Above minerals plus pumpellyite and (or) lawsonite.			
EPIDOTE-AMPHIBOLITE AND AMPHIBOLITE FACIES				
AMP	Staurolite.	Orthopyroxene + clinopyroxene, actinolite + calcic plagioclase + quartz, glaucophane.	Hornblende, plagioclase, garnet, biotite, muscovite, diopside, K-feldspar, rutile, calcite, dolomite, scapolite.	
Low-pressure amphibolite facies				
AML	Andalusite + staurolite, cordierite + orthoamphibole.	Kyanite.	Cordierite, sillimanite, cummingtonite.	Pyralspite garnet rare in lowest possible pressure part of this facies.
Intermediate- and high-pressure amphibolite facies				
AMI and AMH	Kyanite + staurolite.	Andalusite.		Sillimanite mainly restricted to intermediate-pressure amphibolite facies.
TWO-PYROXENE FACIES				
2PX	Orthopyroxene + clinopyroxene.	Staurolite, orthoamphibole, muscovite, epidote, zoisite.	Hypersthene, clinopyroxene, garnet, cordierite, anorthite, K-feldspar, sillimanite, biotite, scapolite, calcite, dolomite, rutile.	Hornblende possible. Kyanite may occur in higher pressure part of this facies and periclase and wollastonite in low-pressure part.

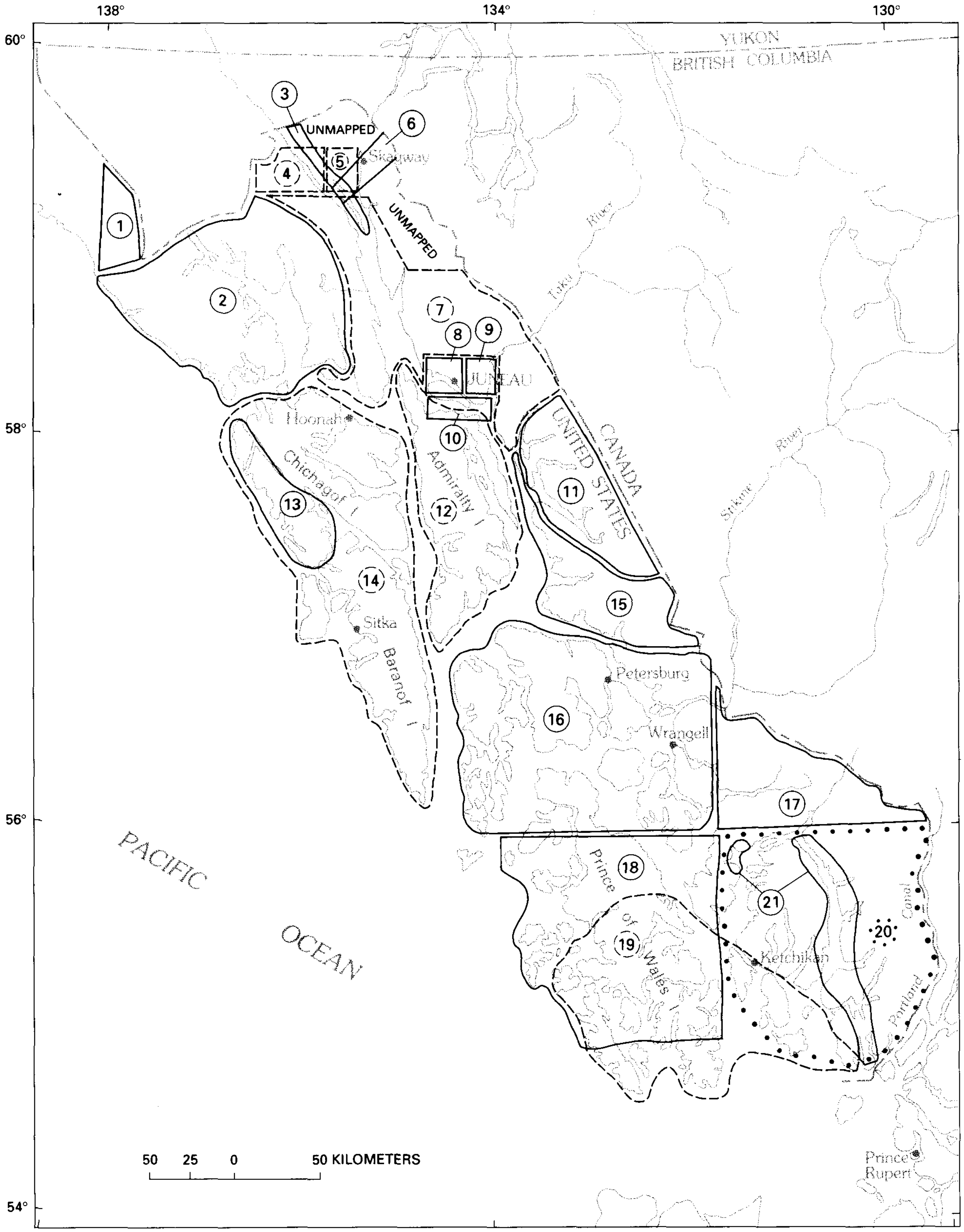

FIGURE 4.—General sources of metamorphic data for the metamorphic facies map of southeastern Alaska (pl. 1). Numbers refer to sources of data listed in explanation. Ring patterns around numbers correspond to boundary pattern used to delineate that area.

ticularly helpful in this regard. Drafting and technical assistance were provided by M.A. Klute, E.O. Doyle, and K.E. Reading. R.A. Loney and M.L. Crawford made valuable suggestions that helped improve the original version of this manuscript. The expert and patient map and text editing by J.S. Detterman is especially appreciated.

EXPLANATION

1. George Plafker and Travis Hudson (unpublished mapping, 1978)
2. Brew (1978)
3. Plafker and Hudson (1980)
4. MacKevett and others (1974)
5. Redman and others (1984)
6. Barker and others (1986)
7. Brew and Ford (1985)
8. Ford and Brew (1973)
9. Brew and Ford (1977)
10. Ford and Brew (1977a)
11. Brew and Grybeck (1984)
12. Lathram and others (1965)
13. Johnson and Karl (1985)
14. Loney and others (1975)
15. D.A. Brew and D.J. Grybeck (unpublished mapping, 1969)
16. Brew and others (1984); S.L. Douglass (unpublished metamorphic facies map, 1985)
17. R.L. Elliott and R.D. Koch (unpublished mapping, 1979)
18. Eberlein and others (1983)
19. Gehrels and Berg (1984); G.E. Gehrels (written commun., 1985)
20. Berg and others (1978; 1988)
21. M.L. Crawford (written commun., 1984)

FIGURE 4.—Continued.

SUMMARY OF THE MAJOR METAMORPHIC EPISODES THAT AFFECTED SOUTHEASTERN ALASKA

The oldest metamorphic episode in southeastern Alaska occurred during Late Cambrian and Early Ordovician time under greenschist- and amphibolite-facies conditions and produced greenstone, mafic schist, pelitic schist, phyllite, marble, and intermediate metaplutonic rocks, all of which are assigned to the Wales Group. These rocks crop out on southern Prince of Wales Island and adjacent islands and have been described most recently by Gehrels and Saleeby (1987b). In most areas, protolith features are obscured by penetrative metamorphic recrystallization and a high degree of flattening.

A weakly to moderately developed Silurian to earliest Devonian metamorphic episode was part of the subsequent orogenic event that affected the rocks in the vicinity of southern Prince of Wales Island (Klakas orogeny of Gehrels and others (1983) and Gehrels and Saleeby (1987b)). Rocks metamorphosed for the first time during this episode include basaltic to rhyolitic metavolcanic rocks, metasedimentary rocks, metachert, and metalimestone of late Early Ordovician to Early Silurian protolith age and quartz dioritic metaplutonic rocks of Middle Ordovician to Early Silurian age (Eberlein and others, 1983; Gehrels and Berg, 1984). Metamorphic grade is lowest (prehnite-pumpellyite facies) on southern Prince of Wales Island where the rocks are not penetratively deformed, and relict sedimentary and volcanic textures are widespread. Metamorphic grade increases southwestward to lower greenschist facies and eastward to greenschist facies and, locally, epidote-amphibolite facies. The Wales Group is presumed to have undergone weak retrograde metamorphism during this episode.

The dominant period of orogenic activity in southeastern Alaska took place from Early Cretaceous to early Tertiary time and consisted of multiple episodes of plutonism and dynamothermal metamorphism. In the northern half of southeastern Alaska, metamorphism of units that have metamorphic-age designation "eK" apparently was associated with the intrusion of elongate bodies of highly foliated tonalite and diorite of Early Cretaceous age (120–110 Ma; Loney and others, 1967; Decker and Plafker, 1982). Near Glacier Bay and on Chichagof Island, the Early Cretaceous metamorphic sequence consists of metasedimentary and metavolcanic rocks of Silurian to Devonian protolith age that were metamorphosed under amphibolite- or hornblende-hornfels-facies conditions. In these areas, structural trends in metamorphic rocks parallel those of the Early Cretaceous plutons. On Admiralty Island and the adjacent mainland, the Early Cretaceous metamorphic sequence comprises metasedimentary, metavolcanic, and metaplutonic rocks of Ordovician to Early Cretaceous protolith age. Metamorphic grade in the area of Admiralty Island increases progressively toward the Early Cretaceous plutons; in the highest grade part of the sequence, large areas of dynamothermally metamorphosed phyllite, schist, and gneiss merge with contact aureoles of the plutons (Loney and others, 1967).

Low-grade metamorphism of mélange and flysch north of Cross Sound and on Chichagof and Baranof Islands southwest of the Peril Strait fault took place prior to the intrusion of Eocene plutons and associated regional thermal metamorphism. Deposition of the mélange is interpreted to have occurred, in part, during Late Jurassic to Early Cretaceous time (Brew and others, 1988), and deposition of the flysch is inferred to have occurred sometime during the Cretaceous. Metamorphism of the mélange occurred in a subduction environment and may have begun as early as latest Jurassic time. East of the Chatham Strait fault, low-grade metamorphism of presumed mid-Cretaceous age produced a weakly to moderately developed metamorphic fabric. This episode predated the intrusion of mafic-ultramafic bodies that have yielded K-Ar ages of 110–100 Ma (Lanphere and Eberlein, 1966; Brew and others, 1984).

In many areas, the low-grade fabric developed during mid-Cretaceous time was subsequently overprinted by metamorphism associated with the early Late Cretaceous (about 90-Ma) intrusion of intermediate plutons that contain primary garnet and epidote. Zen and Hammarstrom (1984b), using experimental data on the composition of magmatic garnet and on the pressure required to crystallize magmatic epidote, propose that the magma for these plutons began to crystallize at a minimum pressure of 13–15 kb (about 40–50 km in depth) and finally crystallized at about 6–10 kb (about 20–30 km in depth).

The degree and regional extent of recrystallization associated with this plutonism decreases to the north and west as does the apparent pressure during metamorphism. In the central and southern part of the belt (on Wrangell Island, Cleveland Peninsula, and northern Revillagigedo Island), kyanite, which is indicative of intermediate-pressure metamorphic conditions, is common in staurolite+garnet±sillimanite-bearing pelitic schist adjacent to the larger 90-Ma plutons. In that area, metamorphic grade increases toward the plutons and sillimanite and kyanite isograds are concentric to large plutons. Geobarometric data from two samples of garnet-kyanite schist from northern Revillagigedo Island indicate a final equilibration pressure for mineral rims of about 7 to 9 kb, which falls in the range of pressures proposed for the garnet-epidote-bearing plutons.

Farther north near northernmost Wrangell Island, pelitic schist from the aureoles of small 90-Ma plutons contains relict andalusite that has been replaced by static (radial) kyanite or aggregates of intergrown kyanite and staurolite. The combination of the high- to intermediate-pressure magmatic and crystallization history inferred for the plutons and the occurrence of relict andalusite, which is indicative of low-pressure conditions (less than 3.8 kb; Holdaway, 1971), in their aureoles is indeed problematic. However, within lower grade rocks to the north and west of the amphibolite-facies rocks on Wrangell Island and to the south and west of the amphibolite-facies rocks on Revillagigedo Island, 90-Ma plutons that have narrow, low-pressure aureoles also occur (not shown or described in this report).

The final metamorphic episode or phase of a prolonged metamorphic cycle, may have slightly preceded but was mostly synkinematic with the lastest Cretaceous and early Tertiary mesozonal intrusion of a 600-km-long composite body here referred to as the "great tonalite sill." Intrusion of the sill has been dated by U-Pb zircon methods at about 69 Ma near Juneau in the north, at about 62 Ma near Petersburg in the central part of the sill's extent (Gehrels and others, 1984), and at about 58–55 Ma east of Revillagigedo Island in the south (Berg and others, 1988). The northern two-thirds of the metamorphic belt shown in Alaska is composed of an intermediate-pressure (Barrovian) sequence whose metamorphic grade increases northeastward. This sequence comprises metasedimentary and metavolcanic rocks, metalimestone, metachert, schist, amphibolite, gneiss, and migmatite that crop out along the mainland of southeastern Alaska from Skagway to the area east of Wrangell Island. Mineral isograds marking the first appearance of biotite, garnet, staurolite, kyanite, and sillimanite trend north-northwest, generally parallel with the elongate tonalite sill. Isogradic surfaces dip moderately to steeply northeast (Ford and Brew, 1973; 1977a; Brew and Ford, 1977) and, hence, are inverted. The southern one-third of the belt in Alaska is made up of high-grade migmatite, massive to foliated or gneissic batholiths, and smaller plutons that enclose metamorphic screens and roof pendants of paragneiss. Kyanite has not been reported in the southern part of the belt, and metamorphic pressures may not have been as high as in the north.

Evidence for the association of metamorphism and plutonism during this episode consists of the increase in metamorphic grade toward the sill, the general parallelism between the sill and isograds that define the Barrovian sequence, and the parallelism of foliation, contacts, and locally developed lineation of the sill with structural elements in the adjacent metamorphic rocks. During the final phase of this episode, intermediate and felsic epizonal plutons intruded the eastern part of the belt during Eocene time and produced low-pressure aureoles and zones of migmatite.

The tectonic environment of the widespread plutonometamorphic episode(s) that occurred along the western edge of the Coast Mountains in early Late Cretaceous and early Tertiary time was dominated by crustal thickening caused by the accretion of an outboard terrane(s) to the west. Petrologic and isotopic data from metamorphic and plutonic rocks near Prince Rupert, British Columbia, which are considered to be correlative with Alaskan rocks in the area of Revillagigedo Island and the mainland to the east, have been interpreted to indicate that crustal thickening resulted from west-directed tectonic stacking of crustal slabs along east-dipping thrusts, in places possibly lubricated by the intrusion of the epidote-bearing plutons discussed above (Crawford and others, 1987). Rapid (1 mm/yr) vertical uplift in the eastern half of the plutonometamorphic belt is proposed to have followed between about 60 and 48 Ma, when the tonalite sill was intruded at deep levels during the early stages of uplift, and the felsic and intermediate plutons were intruded at high levels during the late stages of uplift (Hollister, 1982; revised in Crawford and others, 1987). According to Crawford and others (1987), the intrusion of the tonalite sill facilitated uplift by weakening the crust and serving as a melt-lubricated shear zone.

DETAILED DESCRIPTION OF METAMORPHIC MAP UNITS

SOUTHERN PRINCE OF WALES ISLAND AND ADJACENT ISLANDS

GNS (O-Є) + LPP (DS)

Dynamothermally metamorphosed greenschist-facies greenschist, greenstone, pelitic schist and phyllite, quartz-sericite schist, and marble crop out on southern Prince of Wales Island (Gehrels and Saleeby, 1987b) and in an area (too small to show on pl. 1) on the southernmost tip of Gravina Island and the small islands adjacent to it (Gehrels and others, 1987). On Prince of Wales Island, this unit also includes small areas of amphibolite-facies schist and metaplutonic rocks in the northeastern (Herreid and others, 1978) and southwestern (Gehrels and Saleeby, 1987b) parts of the unit. Protoliths are mafic to intermediate volcanic rocks and volcaniclastic strata, locally interlayered limestone, and minor dioritic bodies, all of which are interpreted to have formed in a volcanic arc environment (Gehrels and Saleeby, 1987b, and references cited therein). The metavolcanic and metasedimentary rocks have been described as the Wales Series (Brooks, 1902), the Wales Group (Buddington and Chapin, 1929; Herreid and others, 1978; Eberlein and others, 1983), and most recently as the informally designated "Wales metamorphic suite" (Gehrels and Saleeby, 1987b). Preliminary U-Pb data on zircon indicate Middle and (or) Late Cambrian protolith ages for interlayered metaplutonic bodies and, therefore, Late Proterozoic and (or) Cambrian protolith ages for the metasedimentary and metavolcanic rocks (Gehrels and Saleeby, 1987b).

The most abundant and widely distributed rock type is greenschist (chlorite+albite+epidote ±quartz±actinolite); more siliceous and argillaceous variants contain sericite rather than chlorite. Metamorphosed silicic volcanic rocks (quartz keratophyre) are commonly associated with the greenschist and have a distinctive blastoporphyritic texture defined by quartz eyes and phenocrysts or glomeroporphyritic clots of albite in a fine-grained matrix of quartz and albite. On the basis of petrographic and chemical evidence, Herreid and others (1978) proposed that although much of the albite in the metamorphosed keratophyre and spilite is of igneous origin, some of the albite present in those rocks, like that present in metasedimentary phyllites and greenschists, is of metamorphic origin.

In most areas protolith features are obscured by penetrative metamorphic recrystallization and a high degree of flattening. Locally preserved protolith features include relict pillows and pyroclastic fragments in basaltic and andesitic metavolcanic rocks and rhythmic and graded bedding in metasedimentary rocks (Gehrels and Saleeby, 1987b). Schistosity in these and the other rocks of this unit generally is parallel to compositional layering (Herreid and others, 1978; Eberlein and others, 1983). Shallow-plunging upright folds, which have kilometer-scale wavelengths, and asymmetric outcrop-scale folds, which probably formed as parasitic structures on limbs of the regional folds, do not have an axial planar foliation and are interpreted to have formed during the waning stages or after the main phase of deformation and metamorphism (Gehrels and Saleeby, 1987b).

Metamorphism of the Wales Group took place during the Late Cambrian and Early Ordovician Wales orogeny of Gehrels and Saleeby (1987a, b) as indicated by the following data: (1) metaplutonic rocks of Middle and (or) Late Cambrian age are metamorphosed and deformed (Gehrels and Saleeby, 1987b); (2) uppermost Lower and Middle Ordovician marine clastic strata of the Descon Formation that occur near and probably overlie the

Wales Group are only weakly metamorphosed and lack the penetrative metamorphic fabric characteristic of the Wales Group (Eberlein and others, 1983; Gehrels and Saleeby, 1987b); and (3) K-Ar data indicate that the Wales Group was involved in a regional thermal event that cooled to argon-blocking temperatures about 483 Ma (Turner and others, 1977). This unit does not appear to have been retrograded by subsequent low-grade metamorphism, but geologic relations indicate that it was probably affected by the same low-grade metamorphic episode during Silurian and earliest Devonian time that is recorded in the adjacent Ordovician and Silurian rocks of unit LPP (DS).

AMP (O-Є) + LPP (DS)

Amphibolite-facies schist and gneiss that crop out on southern Dall Island are interpreted by G.E. Gehrels (oral commun., 1987) to compose higher grade equivalents of the greenschist-facies rocks of the Wales Group to the east (unit GNS (O-Є) + LPP (DS)) and to have been metamorphosed initially during the Late Cambrian and Early Ordovician Wales orogeny described above. Protoliths are marine clastic strata, basaltic and felsic volcanic rocks, and subordinate limestone (Gehrels and Berg, 1984) of probable Late Proterozoic and (or) Cambrian age (G.E. Gehrels, oral commun., 1987). Characteristic metamorphic mineral assemblages include sillimanite, garnet, muscovite, biotite, and hornblende (Eberlein and others, 1983; G.E. Gehrels, oral commun., 1985). This unit does not appear to have been retrograded by subsequent low-grade metamorphism, but geologic relations indicate that it was probably affected by the same low-grade metamorphic episode during Silurian and earliest Devonian time that is recorded in the adjacent Ordovician and Silurian rocks of unit LPP (DS).

LPP (DS)

This unit comprises (1) uppermost Lower Ordovician to Lower Silurian weakly metamorphosed subgreenschist- (probably prehnite-pumpellyite-) facies metagraywacke, metamudstone, argillite, metavolcanic rocks of basaltic, andesitic, and felsic composition, and minor metachert of the Descon Formation and age-equivalent rocks; (2) Silurian metalimestone on northern Dall Island (Eberlein and others, 1983; Gehrels and Berg, 1984); and (3) Middle Ordovician to Early Silurian plutonic rocks (shown as a weakly metamorphosed pluton, pl. 1), which include diorite, quartz diorite, granodiorite, quartz monzonite, granite, and subordinate gabbro, pyroxenite, trondhjemite, quartz syenite, and mafic dikes (Eberlein and others, 1983; Gehrels and Saleeby, 1987b). The plutonic rocks show no visible effects of the low-grade metamorphic episode, but they are presumed to have been metamorphosed because the proposed age of low-grade metamorphism postdates the protolith ages of these rocks. Low-grade metamorphism of metasedimentary and metavolcanic rocks is indicated in the southern area by fine-grained, felty aggregates of chlorite, albite, and epidote; this metamorphism decreases northward (G.E. Gehrels, oral commun., 1985). This unit is not penetratively deformed, and relict sedimentary and volcanic textures are widespread (Eberlein and others, 1983).

A Silurian and earliest Devonian metamorphic age is proposed on the basis of (1) strata of Early Silurian age are metamorphosed but overlying strata of middle Early Devonian age and younger are unmetamorphosed (Gehrels and others, 1983) and (2) geologic relations in greenschist-facies units GNS (DS) and GNS (DS) + GNS (K) (discussed below) that are presumed to have been metamorphosed during the same episode that affected unit LPP (DS). This metamorphic episode is considered to have been part of a metamorphic, deformational, and mountain-building event referred to as the Klakas orogeny by Gehrels and others (1983) and Gehrels and Saleeby (1987b).

GNS (DS)

This unit comprises lower greenschist-facies greenschist, semischist, phyllite, and slate, as well as metalimestone on Long and Dall Islands (Eberlein and others, 1983; Gehrels and Berg, 1984). Protoliths for these rocks include Silurian limestone, Lower Ordovician through Lower Silurian sedimentary and volcanic rocks of the Descon Formation, and Middle Ordovician to Silurian intrusive rocks (Eberlein and others, 1983; Gehrels and Berg, 1984). A Silurian and earliest Devonian metamorphic age is proposed for this unit because rocks of Silurian age are involved in the metamorphism and are cut by an undeformed latest Silurian to earliest Devonian (408±10-Ma) pyroxenite in the Dixon Entrance quadrangle (Eberlein and others, 1983; G.E. Gehrels, unpub. mapping, 1984). Metamorphism apparently decreases in grade to the north into unit LPP (DS) (Eberlein and others, 1983).

GNS (DS) + GNS (K)

Polymetamorphosed greenschist-facies and, locally, epidote-amphibolite-facies metavolcanic and metasedimentary rocks, metadiorite (shown as strongly metamorphosed plutons, pl. 1) and metatrondhjemite (shown as weakly metamorphosed plutons, pl. 1) (Berg, 1972, 1973; Berg and others, 1978; Gehrels and others, 1983, 1987) crop out on Gravina, Annette, and Duke Islands and near Cape Fox to the southeast. Volcanic and sedimentary protoliths are Ordovician to Early Silurian in age; crosscutting intrusive rocks yield Ordovician and Early Silurian (diorite) and Late Silurian (trondhjemite) U-Pb igneous crystallization ages on zircon (Gehrels and others, 1987). Greenschist-facies rocks include greenstone, fine-grained greenschists and quartz-rich schists (perhaps originally interbedded quartz keratophyres and spilites), impure quartzites, phyllite, marble, massive hornblende- and quartz-metadiorite, metadioritic migmatite and agmatite, and metabasites that probably represent dikes and sills associated with the dioritic intrusive rocks (Berg, 1972, 1973; Berg and others, 1978; Gehrels and others, 1987).

Cataclastic textures are common throughout this unit, and, although the rocks are locally schistose, they generally are only weakly foliated (Berg, 1972, 1973). Metadiorite and metavolcanic and metasedimentary rocks generally have a north-northwest-striking foliation (Gehrels and others, 1983). Metamorphic mineral assemblages contain, depending on their original rock types, combinations of chlorite, epidote-clinozoisite, albite, colorless to moderately pleochroic green amphibole, sericite, quartz, calcite, dolomite, and traces of brown biotite (Berg, 1972, 1973). Minor retrogressive metamorphism is apparent in the higher grade rocks of this unit (Berg, 1972, 1973).

The first and most intense metamorphism of these rocks predated the deposition of the overlying marine strata of middle Early Devonian age (Gehrels and others, 1983). On Annette Island, Late Silurian trondhjemite dikes crosscut the foliation of metadioritic rocks that were metamorphosed during the first episode, but the dikes have the same late-metamorphic deformational features as their wallrocks, indicating that the trondhjemite dikes and plutons were intruded before the final deformation that occurred during the latter stages of the episode (Gehrels and others, 1983, 1987). The early episode of greenschist-facies and, locally, epidote-amphibolite-facies metamorphism of the lower Paleozoic rocks of this unit is therefore considered to have occurred during the Silurian and earliest Devonian metamorphic, deformational, and mountain-building episode referred to as the Klakas orogeny by Gehrels and others (1983, 1987).

Near Cape Fox, the metamorphosed Late Silurian trondhjemite pluton has been more completely recrystallized than have been the other plutons of that age and composition within this unit: almost all primary biotite has been replaced by chlorite, metamorphic epidote is abundant, and parts of the pluton, particularly the northern part, have been reduced to quartzofeldspathic semischist and schist that are difficult to distinguish from the enclosing schistose country rocks (Berg and others, 1978, 1988). Much of the metamorphic recrystallization of this pluton may have occurred during the second metamorphic episode.

A Cretaceous age for the second metamorphic episode is indicated by the presence of lower greenschist-facies metamorphic mineral assemblages and fabrics in overlying Devonian, Triassic, Jurassic, and Cretaceous rocks (adjacent unit GNS (K)). This lower greenschist-facies metamorphism produced retrograde metamorphic effects in the higher grade parts of this unit (Berg, 1972, 1973). A K-Ar age determination of about 77 Ma on biotite from a metamorphosed diorite on the Metlakatla Peninsula of Annette Island (Berg, 1973) gives a local minimum metamorphic age for this episode.

GLACIER BAY AND CHICHAGOF AND BARANOF ISLANDS AREA

AMP (eKPz)

Amphibolite- or hornblende-hornfels-facies amphibolite, gneiss, hornblende schist, and biotite schist, locally intercalated with thin layers of marble and calc-silicate granofels (Loney and others, 1975; Johnson and Karl, 1985), crop out in the west-central part of the Sitka quadrangle. Protoliths are probably mafic volcanic rocks and marine sedimentary rocks (Johnson and Karl, 1985). These protoliths predate the Middle and Late Jurassic (168- to 155-Ma) K-Ar ages on biotite and hornblende from crosscutting diorite intrusions (Loney and others, 1967) and are thought to be Paleozoic or Mesozoic in age. The most abundant rock type is a quartz-andesine-biotite-hornblende schist that commonly contains almandine garnet; variations in the amount of quartz and feldspar versus mafic minerals are common and give the rocks a striking banded appearance. Calc-silicate granofels contains the assemblages bytownite-diopside-clinozoisite-calcite-pyrite-sphene and quartz-calcite-diopside-grossularite.

The age and origin of this metamorphic episode are unknown. Loney considers that the metamorphism of this unit is unrelated to the intrusion of the Jurassic plutons because the direction of an overall increase in metamorphic grade (generally northwest to southeast in the vicinity of Salisbury Sound) bears no relation to the distance from the plutons (R.A. Loney, oral commun., 1985). However, Johnson and Karl (1985) report that this unit grades into the dioritic rocks of Jurassic and Jurassic or Cretaceous age and that the metamorphic rocks become more migmatitic close to the plutons. The relations described by Johnson and Karl imply a genetic connection between plutonism and metamorphism. Following the interpretation of Johnson and Karl, these metamorphic rocks may be part of the basement of the Jurassic and Early Cretaceous arc that is now represented by the more voluminous late Early Cretaceous granitic rocks of Chichagof Island, as suggested by D.A. Brew and S.M. Karl (oral communs., 1985). Because of the uncertainty in the metamorphic history of this unit, we have shown the age of metamorphism to be sometime during Paleozoic to Early Cretaceous time to allow for the possibilities that metamorphism occurred long before plutonism (assumming the oldest possible protolith age for the rocks) or that metamorphism accompanied plutonism.

GNS (eKlTR)

Greenschist-facies chlorite schist, mica schist, phyllite, slate, metalimestone, and subordinate impure quartzite crop out in the central part of the Skagway quadrangle. Protoliths include mafic volcanic rocks, tuff, and quartzofeldspathic, pelitic, calcareous, and carbonaceous sedimentary rocks that have been correlated with rocks of Silurian to Permian age (MacKevett and others, 1974; Redman and others, 1985; Gilbert and others, 1987). Rocks of this unit are structurally complex; they have been multiply deformed and locally are complexly folded (MacKevett and others, 1974).

Schist and phyllite are fine grained and are composed primarily of chlorite, quartz, muscovite, calcite, and sodic plagioclase. Some chloritic schist and phyllite also contain biotite and epidote and trace amounts of sphene or garnet, particularly near plutons. Higher grade hornblende- or staurolite-bearing assemblages also occur near intrusive bodies (MacKevett and others, 1974). Large areas of thermally metamorphosed rocks are shown on the metamorphic facies map (contact aureole symbol, pl. 1). Temperature and pressure(?) conditions of regional dynamothermal metamorphism probably increased to the northeast because along the northeast margin of this unit schist and phyllite is in gradational contact with gneiss and amphibolite of the amphibolite-facies unit described immediately below.

The age of the metamorphism is not well known. It is bracketed between the inferred Permian age of the youngest protolith proposed by MacKevett and others (1974) to be present in the Skagway area and the Early Cretaceous (about 120- to 110-Ma) age of crosscutting intermediate plutons that postdate dynamothermal metamorphism (MacKevett and others, 1974). Geologic evidence from the apparent continuation of the metamorphic sequence about 105 km to the northwest in Canada suggests that the regional metamorphism and deformation occurred during latest Triassic to Early Cretaceous time and may have been associated with latest Jurassic to earliest Cretaceous (150- to 130-Ma) plutonism. According to R.B. Campbell and C.J. Dodds (written communs., 1986),

> The younger of the 130- to 150-Ma plutons seem clearly to postdate the metamorphism and deformation in the northeast, where they produce distinct contact metamorphic aureoles. The older plutons of this group to the southwest may have been intruded during the metamorphism and deformation; they are commonly elongate parallel with the regional structural grain, but they clearly have local crosscutting contacts and probably in part postdate those events. Upper Triassic strata probably rest unconformably on Paleozoic rocks but, nevertheless, appear to be equally deformed and metamorphosed; thus, the widespread deformation and metamorphism seem to be post-Late Triassic and pre-earliest Cretaceous.

Assuming continuation of the metamorphic unit and the continuity of the general geologic relations, we have assigned Late Triassic and Early Cretaceous metamorphic-age brackets to this unit.

AMP (eKlTR)

Quartz-biotite gneiss, amphibolite, hornblende schist, and minor phyllite and marble (MacKevett and others, 1974; Redman and others, 1985; Gilbert and others, 1987) crop out in the central part of the Skagway quadrangle. Protoliths are presumed to range in age from Silurian to Permian and include granitic rocks, from which the gneiss probably was derived, and mafic volcanic rocks and dikes, sedimentary rocks, and limestone, from which the other rocks were derived (MacKevett and others, 1974). Rocks of this unit are strongly foliated; gneissic rocks are locally folded or cataclastically deformed (MacKevett and others, 1974).

Probable orthogneiss contains abundant quartz +oligoclase+biotite±muscovite±potassium-feldspar. Less abundant minerals include epidote, calcite, and chlorite (largely as alteration products), opaque minerals, and rare garnet and staurolite (MacKevett and others, 1974). Amphibolite is composed primarily of hornblende, andesine, minor to abundant chlorite and biotite, and minor quartz, opaque minerals, calcite, epidote, and sphene. Hornblende-biotite-quartz schist locally contains small amounts of chlorite and garnet (MacKevett and others, 1974). Mineral assemblages indicate conditions of the lower amphibolite facies.

The age and origin of metamorphism are the same as those for unit GNS (eKlT̄R) discussed above.

GNS (eKlT̄R)$_1$

This unit comprises weakly metamorphosed metabasalt and, on the west side of the Chilkat Peninsula directly south of Haines, associated carbonaceous argillite, metasiltstone, volcaniclastic metasandstone, and metalimestone (MacKevett and others, 1974; Plafker and Hudson, 1980; Redman and others, 1984; Davis and Plafker, 1985).

Metabasalt between Klukwan and Haines is characterized by near-vertical foliation that strikes northwest, approximately parallel to the fault that occurs along the west margin of the unit (MacKevett and others, 1974; Redman and others, 1984). Metabasalt of the Chilkat Peninsula south of Haines is not penetratively deformed, and primary textures and structures are typically well preserved (Plafker and Hudson, 1980; Davis and Plafker, 1985). Metabasalt is recrystallized to lower greenschist-facies assemblages that include primarily chlorite, actinolite, epidote, clinozoisite, albite, white mica, and sphene. Geochemical data from metabasalt on the Chilkat Peninsula and the Carnian(?) age of associated weakly metamorphosed limestone have been interpreted to indicate that these rocks were originally part of, or were coextensive with, the Wrangellia terrane of Jones and others (1977) (Plafker and Hudson, 1980; Davis and Plafker, 1985).

Metamorphism is known to have occurred sometime between the Late Triassic (Carnian?) age of the protoliths and the late Early Cretaceous age of crosscutting plutons (MacKevett and others, 1974). Low-grade metamorphism may have been caused by heating as a result of the intrusion of Cretaceous dioritic or granodioritic rocks that crop out adjacent to the metabasalt along its east margin. The origin of the near-vertical foliation in the northern part of this unit is unknown.

LPP (eKeJ)

This unit comprises weakly metamorphosed Silurian and (or) Devonian metagraywacke, argillite, phyllite, slate, semischist, metalimestone, metaconglomerate, and mafic to intermediate metavolcanic rocks; Mississippian metalimestone and shale; Permian phyllite, slate, semischist, metalimestone, metavolcanic rocks, and metachert; and Lower Jurassic(?) metachert and argillite (Lathram and others, 1959; Loney and others, 1975; Brew, 1978; C.D. Blome, written commun., 1987). The rocks appear to be very weakly recrystallized but are lacking minerals that are diagnostic of a particular low-grade metamorphic facies. Upper Devonian andesitic and basaltic rocks on northern Chichagof Island have experienced widespread chloritization and epidotization and locallized albitization (Lathram and others, 1959). Metamorphic minerals developed in the matrix of graywackes on Chichagof Island include chlorite, epidote, white mica, albite, and quartz (Devonian Cedar Cove Formation) and chlorite and calcite (Silurian Point Augusta Formation) (Loney and others, 1975). Permian rocks that crop out northeast of Muir Inlet in Glacier Bay and Lower Jurassic(?) metachert and argillite in the north-central part of the Chilkat Range appear to have experienced the same general degree of recrystallization as the Silurian and Devonian rocks (D.A. Brew, unpub. data, 1985, 1986).

The age and origin of low-grade metamorphism are unknown. Metamorphism is known to be bracketed between the Early Jurassic(?) protolith age of the youngest rocks that are clearly metamorphosed and the late Early Cretaceous age of crosscutting plutons. A gradual increase in metamorphic grade between the low-grade rocks of this unit and the amphibolite-facies rocks (AMP (eK)) does not appear to be present on Chichagof Island; this suggests that, unlike the higher grade rocks whose metamorphism is considered to have been associated with late Early Cretaceous plutonism, low-grade metamorphism in that area may have occurred prior to plutonism. In the Glacier Bay area, evidence of overprinting by the locally adjacent AMP (eK) metamorphism is not present, however, and the low-grade metamorphism may be a more distant expression of the same event.

AMP (eK)

This unit constitutes a diverse assemblage of amphibolite-facies and hornblende-hornfels-facies pelitic and semipelitic schist and gneiss, marble, and amphibolite and minor amounts of lower grade greenstone and greenschist. Protoliths are known to be sedimentary and volcanic rocks of Silurian and Devonian age (Loney and others, 1975; Brew, 1978). These rocks are considered to be part of the Alexander terrane (Brew, 1978; Decker and Plafker, 1982). The unit is extensively intruded by elongate bodies of highly foliated tonalite and diorite of late Early Cretaceous age (M.A. Lanphere, unpub. data, 1980; Decker and Plafker, 1982) that generally trend north-northwest; in the northern part of the unit, west of Muir Inlet, these elongate bodies trend west-northwest and east-west (Brew, 1978). Structural trends in metamorphic rocks parallel those of the Cretaceous plutons. The unit is also intruded by a much lesser volume of unfoliated Tertiary granitoids.

North of Cross Sound, characteristic metamorphic mineral assemblages in metasedimentary rocks are calcic plagioclase+hornblende±quartz ±biotite±chlorite and calcic plagioclase+quartz +potassium-feldspar+hornblende+biotite+diopside (Seitz, 1959). Mafic rocks generally have been recrystallized into well-foliated and locally banded gneiss composed of hornblende+quartz+calcic plagioclase±garnet and poorly foliated to unfoliated hornblende-plagioclase rock of Rossman (1963) and (Brew, 1978).

On Chichagof Island, rocks are intensely folded, and a complete gradation in metamorphic textures between granofels or hornfels and foliated rocks is present (Loney and others, 1975). A characteristic metamorphic mineral assemblage in mafic rocks is andesine+hornblende±quartz±biotite±diopside. Quartzofeldspathic granofels and schist, derived from igneous rocks, contain quartz, microcline, oligoclase or andesine, biotite, and minor muscovite. These rocks also contain minor amounts of almandine garnet, but whether it is a metamorphic or relict igneous mineral is not known (Loney and others, 1975). Mineral assemblages found in calcareous granofels and marble are calcite+diopside± grossularite±wollastonite, calcite+serpentine+brucite +spinel+scapolite, and calcite+cummingtonite.

Metamorphism of this unit is considered to have taken place during intrusion of the late Early Cretaceous plutons. The general parallelism between the foliate fabric of the plutons, pluton-wallrock contacts, and structures in the wallrocks suggests that plutonism, folding, and thermal and dynamothermal metamorphism all took place as part of a continuum that occurred under roughly the same stress conditions. K-Ar ages of about 110–120 Ma for the plutonic rocks (Loney and others, 1967; Decker and Plafker, 1982) provide a minimum age for the late Early Cretaceous metamorphic episode.

LPP/GNS (eTlT̄R)

Transitional prehnite-pumpellyite- to greenschist-facies greenstone, greenschist, and metalimestone of presumed Late Triassic age (Goon Dip Greenstone and Whitestripe Marble) and unconformably(?) underlying metasedimentary and metavolcanic rocks of Paleozoic and (or) Mesozoic age (Loney and others, 1975; Johnson and Karl, 1985) compose this low-grade unit. The presumed Late Triassic age of the greenstone, greenschist, and metalimestone is based on their correlation with lithologically similar rocks of that age in the Wrangellia terrane (Jones and others, 1977). The rocks crop out adjacent to and east of the Border Ranges fault (Plafker and others, 1976; Decker and Johnson, 1981).

Mafic protoliths of the presumed Late Triassic rocks consist of commonly amygdaloidal basaltic flows, sills, and flow breccias. Most massive greenstone has been recrystallized to epidote, actinolite, chlorite, albite, prehnite, calcite, pyrite, and sphene; relict amygdules commonly are filled with quartz and epidote, accompanied by chlorite or prehnite. Greenschist is composed of albite, chlorite, and epidote. Pumpellyite has not been reported in any mafic assemblage, but this may reflect the lack of familiarity with this mineral by those doing the early, detailed petrography of these rocks (Rossman, 1959; Loney and others, 1963) rather than inappropriate chemical or physical conditions for the formation of this mineral (R.A.

Loney, oral comun., 1985). Marble is locally stylolitic and is composed of nearly pure calcite and, locally, accessory chlorite, sericite, graphite, quartz, albite, and pyrite (Johnson and Karl, 1985).

The low-grade rocks of Paleozoic or Mesozoic age that crop out discontinuously along the east edge of this unit (unit MzPzs of Loney and others (1975) and Johnson and Karl (1985)) include metachert, metasandstone, metatuff, metalimestone, and slaty argillite, all of which are intercalated with foliated greenstone and greenschist. In most places, the eastern part of this assemblage is extensively intruded by foliated granitic rocks of Jurassic and (or) Cretaceous age and by diabase and gabbro sills. Metamorphic mineral-assemblage data are not available for these rocks, but general lithologic descriptions of them suggest that they are either of prehnite-pumpellyite-facies or lower greenschist-facies grade. These rocks are described as being more deformed and as having a slightly higher metamorphic grade than the overlying Goon Dip Greenstone. Although available stratigraphic evidence suggests that these underlying rocks unconformably underlie the Goon Dip Greenstone (Rossman, 1959; Loney and others, 1975), they are lithologically distinct from the Permian basement rocks in stratigraphically comparable areas elsewhere within the Wrangellia terrane (Johnson and Karl, 1985).

Little is known about the age and tectonic origin of the low-grade metamorphism of this unit. Maximum and minimum metamorphic age constraints are indicated by the Triassic protolith age of the youngest rocks and the early Tertiary(?) age (Johnson and Karl, 1985) of the postmetamorphic granitoids that intrude them. Most of the Jurassic plutons (B.R. Johnson, oral commun., 1985) are foliated and locally highly altered and probably predate metamorphism. It is not known with certainty that metamorphism of the pre-Late Triassic rocks of this unit took place during the same episode that affected the overlying Late Triassic rocks, but for the time being this seems to be the most reasonable assumption.

LPP,GNS (eTIJ)

This unit consists of undifferentiated prehnite-pumpellyite- and lower greenschist-facies bedded turbiditic metasedimentary rocks and metavolcanic rocks (Sitka Graywacke) and a more inboard mélange unit (Kelp Bay Group). They are included in the flysch and mélange facies, respectively, of the Chugach terrane of Plafker and others (1977). Blocks within the mélange are Triassic or Jurassic, Late Jurassic (Tithonian), and Early Cretaceous (Valanginian) in age (Loney and others, 1975; Plafker and others, 1976; Decker and others, 1980; Johnson and Karl, 1985; Brew and others, 1988). Deposition of the mélange matrix is interpreted by Brew and others (1988) to have taken place, in part, during the Late Jurassic (Tithonian) and presumably to have continued during at least the Early Cretaceous (age of the youngest blocks) (Decker, 1980, Johnson and Karl, 1985; Brew and others, 1988). The depositional age of the bedded rocks is unknown but is considered to be Cretaceous on the basis of correlation with lithologically similar rocks in the Valdez Group and Yakutat Group to the northwest (Plafker and others, 1977; Brew and Morrell, 1979a). Eocene plutons intrude both the mélange and the bedded rocks and establish a minimum age for their protoliths. In the Fairweather Range north of Cross Sound, the unit includes graywacke, phyllite, and minor slate, phyllite, argillite, graywacke semischist, and metaconglomerate (Brew, 1978; Brew and Morrell, 1979a). On Yakobi, western Chichagof, and Baranof Islands, the unit includes these same lithologies as well as greenstone and greenschist and large areas of mélange. The mélange is composed of kilometer-scale blocks of greenstone, greenschist, metatuff, metagraywacke, meta-argillite, metachert, metalimestone, phyllite, quartzite, and graywacke semischist that are separated from one another by shear zones and faults; smaller blocks of these same lithologies are set in a matrix of moderately metamorphosed and penetratively sheared graywacke, argillite, and metatuff (undivided Kelp Bay Group, Khaz Formation, Freeburn assemblage, Waterfall Greenstone, Pinnacle Peak Phyllite, and related rocks) (Loney and others, 1975; Plafker and others, 1976; Johnson and Karl, 1985; Decker, 1980).

The part of this unit that is located between faults that occur in the area of Tarr Inlet and Brady Glacier (Tarr Inlet suture zone of Brew and Morrell (1979b)) comprises a similar sequence of structurally complicated, diverse, low-grade phyllite, slate, metaconglomerate, metachert, greenstone, greenschist, and marble that have been proposed to correlate with (1) the mélange unit described above (Kelp Bay Group and related rocks of the Chugach terrane) (Decker and Plafker, 1982), (2) Permian and (or) Triassic rocks of the Wrangellia terrane (Brew and Morrell, 1979b), or (3) the mélange unit in the southern part of the suture zone and the Wrangellia rocks in the northern part (D.A. Brew, unpub. data, 1985). Foliated, sheared, and highly altered diorite of late Early Cretaceous age (shown as a weakly metamorphosed pluton, pl. 1) invades the Tarr Inlet zone (Brew, 1978; Decker and Plafker, 1982), and the fabric and alteration in these rocks is probably related to the low-grade metamorphism that affected the rest of this unit.

Characteristic metamorphic mineral assemblages are those of the prehnite-pumpellyite facies and, locally, those of the lower greenschist facies. Metasedimentary rocks in the Fairweather Range contain chlorite, white mica, and quartz, minerals that are only diagnostic of low-grade metamorphism. Metamorphosed turbidites on Yakobi, Chichagof, and Baranof Islands commonly contain metamorphic chlorite and microcrystalline epidote aggregates; lesser amounts of quartz, white mica, albite, calcite, and prehnite (which typically occurs in veinlets or clots) (Loney and others, 1975; Johnson and Karl, 1985); and rare pumpellyite (Decker, 1980). Metamorphic assemblages and textures in the rocks of the more inboard mélange facies are more variable. Mineral assemblages within individual blocks are those of the prehnite-pumpellyite, lower greenschist, and blueschist(?) facies and indicate low-temperature and low- to intermediate- or perhaps high-pressure conditions (Decker, 1980).

Decker (1980) analyzed part of the mélange unit on western Chichagof Island and divided it into the following five-part textural-grade scheme that is based on both structural features and increasing degree of recrystallization in argillite and thinly layered volcanic rocks: (1) incipiently recrystallized, generally massive rocks that have slaty cleavage and metavolcanic rocks that contain chlorite, sericite, epidote minerals, actinolite needles, and rare prehnite and pumpellyite; (2) layered rocks that are weakly foliated, originally massive rocks that are still massive, and metavolcanic rocks that are characterized by finely disseminated chlorite, actinolite, and epidote minerals; (3) subphyllitic rocks that are distinctly foliated; metasedimentary rocks that contain detrital grains that have been moderately recrystallized and have new quartz, sericite, graphite, and carbonate; and metavolcanic rocks that contain chlorite, epidote-group minerals, actinolite, and, locally, blue amphibole and phlogopite; (4) phyllitic rocks that are completely recrystallized, metasedimentary rocks that contain new micaceous minerals, and metavolcanic rocks that contain actinolite and micaceous minerals; and (5) fine-grained schistose rocks in which metamorphic minerals are identifiable in hand specimen for the first time. Glaucophane and phlogopite occur in textural grades 3, 4, and 5; barroisite occurs only in textural grades 4 and 5; and fuchsite and talc occur only in textural grade 5. These textural grades were used by Decker, together with volcanic:sedimentary rock ratios, to subdivide the low-grade rocks into subduction units. Each unit is described as a piece of oceanic crust that records its own subduction history which differs from that of neighboring units. Metamorphic textures and mineral assemblages reflect factors such as subduction rate, depth of burial, uplift rates, and thermal history (Decker, 1980, p. 105).

The age of low-grade metamorphism is probably Early Cretaceous to early Tertiary, but a Late Jurassic age is possible. The maximum metamorphic age is unknown, but the oldest dated part of the mélange matrix (on northern Baranof Island) contains fossils of Tithonian age (Brew and others, 1988), and metamorphism may have closely followed deposition of that part of the mélange. An early Tertiary minimum metamorphic age is indicated by the overprinting of low-grade assemblages in the mélange and the bedded rocks by thermal metamorphism associated with Eocene plutons (Loney and others, 1975; Loney and Brew, 1987). A mid-Cretaceous metamorphic age for mélange on Chichagof Island is suggested by 106- to 91-Ma K-Ar ages on actinolite and sericite from interlayered metavolcanic and metasedimentary rocks (Decker and others, 1980). Metamorphism of this unit most likely occurred during subduction of the Chugach terrane beneath the adjacent continental margin that, in southeastern Alaska, was made up of the adjacent (composite) Wrangellia-Alexander terrane.

LPP,GNS (eTlJ) + GNL (eT)

This unit consists of polymetamorphosed metagraywacke, slate, amphibolite, greenschist, and minor phyllite and schist whose second metamorphism was low- to medium-temperature, low-pressure thermal metamorphism that was associated with Eocene plutonism. Albite-epidote hornfels assemblages are superimposed over the prehnite-pumpellyite- to lower greenschist-facies assemblages previously developed on a regional extent sometime during latest Jurassic to early Tertiary time (described above under unit LPP,GNS (eTlJ)). These rocks are described in detail by Loney and others (1975). Protoliths are sedimentary and volcanic rocks of the Sitka Graywacke west of the northwest-southeast-trending fault on Baranof Island and mélange of the Kelp Bay Group that contains blocks of Triassic or Jurassic, Late Jurassic, and Early Cretaceous age east of the fault, as described above for unit LPP,GNS (eTIJ). The first appearance of biotite, which was determined mainly in hand specimen, has been used to define the contact between the regionally metamorphosed prehnite-pumpellyite- to lower greenschist-facies rocks and the polymetamorphosed rocks of this unit.

On Kruzof Island and on southern Baranof Island, low-grade regional assemblages containing calcite, sphene, epidote, chlorite, albite, and muscovite have been replaced progressively toward the pluton by the low-pressure assemblage epidote-chlorite-albite-muscovite-biotite-plagioclase on into the plagioclase-quartz-biotite-andalusite and quartz-plagioclase-biotite-cordierite-tourmaline-garnet assemblages of the adjacent unit LPP,GNS (eTIJ) + AML (eT).

Metamorphism during Eocene time is considered to have taken place under low-pressure conditions that may have been transitional into medium-pressure conditions. On southern Baranof Island, metamorphism was accompanied by kinematic effects that intensified the preexisting foliation, produced new foliation, and developed new folds and lineations about axes subparallel to those of the earlier folds. Loney and others (1975) and Loney and Brew (1987) suggest that this area, referred to by them as "lineated and schistose Sitka Graywacke," may have been produced during emplacement of an inferred large igneous body that may be present at depth between the large pluton on Baranof Island and the smaller, elongate pluton near the southern tip of the island. This unit along the northern margin of the large pluton on Baranof Island contains the following metamorphic mineral assemblages that appear to indicate metamorphism was transitional between the albite-epidote-hornfels (or greenschist) facies and the hornblende hornfels facies: plagioclase+quartz+biotite±epidote±chlorite±sphene±calcite; plagioclase+actinolite+calcite+epidote; biotite+quartz+plagioclase+almandine+albite(?)+sphene+epidote; and plagioclase+quartz+biotite+cordierite(?)+muscovite. Andalusite, indicative of low-pressure conditions, along with cordierite and garnet, are present in the aureole adjacent to the pluton (area too small to show as a separate higher grade unit, pl. 1). Sedimentary textures in these rocks are well preserved and relatively unchanged to within about a hundred meters of the contact with the pluton (Loney and others, 1975).

Rocks east of the northwest-southeast-trending fault on Baranof Island consist of amphibolite and greenschist that are interlayered with subordinate amounts of phyllite and biotite schist. Metamorphism within this part of the unit increases both to the north and to the south as a result of proximity to two different plutons in those directions. Typical metamorphic assemblages are quartz-albite-epidote-actinolite (amphibolite) and quartz-albite-epidote-chlorite (greenschist). The rocks clearly show the remnants of an earlier cataclastic foliation.

Evidence that the second metamorphic episode is related to Eocene plutonism consists of the relation between metamorphic zonation and proximity to known or inferred plutons and the fact that two of three K-Ar ages from greenschist-facies rocks of this unit fall in the same age range (43 to 48 Ma) as was determined for the plutons (Loney and others, 1975).

LPP,GNS (eTIJ) + AML (eT)

This unit comprises polymetamorphosed metagraywacke and slate hornfels, biotite schist and gneiss, and greenschist whose second metamorphism was medium- to high-temperature, low-pressure thermal metamorphism associated with Eocene plutonism. Hornblende-hornfels-facies assemblages are superimposed over the prehnite-pumpellyite- to lower greenschist-facies assemblages previously developed on a regional extent sometime during latest Jurassic to early Tertiary time (described under unit LPP, GNS (eTIJ)). These rocks are described in detail by Loney and others (1975) and Loney and Brew (1987). Protoliths are sedimentary and volcanic rocks of the Sitka Graywacke (west of the northwest-southeast-trending fault on Baranof Island) and Kelp Bay Group (east of the fault), as described for unit LPP, GNS (eTIJ).

On Kruzof Island, the contact between this unit and the adjacent lower grade equivalents of these rocks is defined by the first appearance in the field of readily visible garnet or cordierite in biotite-orthoclase-plagioclase hornfels (Loney and others, 1975).

On Baranof Island, this unit south of the largest pluton is lineated and schistose, having experienced the kinematic effects presumed to have been produced during emplacement of an inferred large subsurface pluton connecting the largest pluton shown with the elongate one near the southern tip of the island (Loney and others, 1975; Loney and Brew, 1987). Diagnostic metamorphic minerals that mark the lower grade boundaries of this unit on southern Baranof Island are plagioclase, almandine garnet, and cordierite; andalusite occurs in a higher grade zone within this unit. Staurolite coexists with andalusite and garnet in small areas in the higher grade parts of this unit, and sillimanite occurs both east of the elongate pluton near the tip of the island and on the south side of the largest pluton (Loney and others, 1975). Narrow zones of pyroxene hornfels-facies rocks (too small to show on pl. 1) occur within this unit adjacent to the Eocene plutons. Metamorphic mineral assemblages in these rocks contain quartz+plagioclase+orthoclase+sillimanite±biotite±enstatite (Loney and others, 1975; Loney and Brew, 1987).

The area of this unit east of the northwest-southeast-trending fault consists of polymetamorphosed biotite schist and gneiss, minor amphibolite, and quartzite. The broadness of the aureole south of the large pluton suggests that the pluton underlies much of the southern part of this unit. Rocks are characterized by calcic plagioclase and almandine garnet, followed by fibrolitic sillimanite and staurolite in progressively higher metamorphic zones. With progressive metamorphism, grain size increases and a relict cataclastic foliation becomes indistinct and is replaced by a single schistosity (Loney and others, 1975). The presence of staurolite, sillimanite, and almandine garnet in these rocks and the absence of cordierite and andalusite suggest that pressures within this large aureole may have been intermediate between those of the hornblende-hornfels facies and the amphibolite facies.

Evidence for relating the second metamorphic episode to Eocene plutonism is discussed above.

GNS/AMP (eTK)

Transitional greenschist- to amphibolite-facies biotite schist and semischist derived from graywacke and argillite crop out in the Fairweather Range (Brew, 1978), and amphibolite and quartzofeldspathic biotite schist crop out farther to the northwest (George Plafker, unpub. mapping, 1980). Protoliths are interpreted to be sandstone and mudstone turbidites and volcanic rocks of Cretaceous age on the basis of lithologic similarity to the Valdez Group, Sitka Graywacke, and part of the Yakutat Group (Plafker and others, 1977; Brew and Morrell, 1979a; D.A. Brew and George Plafker, oral communs., 1985).

Biotite schist is fined grained, variably banded, granoblastic to strongly schistose, and composed of quartz+biotite±garnet±plagioclase±muscovite (Hudson and others, 1977; Brew, 1978). Mafic metavolcanic rocks in the Skagway quadrangle are fine to medium grained, variably segregated, and contain the following assemblages: chlorite+white mica+albite+epidote±quartz±sphene; plagioclase +biotite+chlorite+quartz+actinolite+calcite; and hornblende+epidote+plagioclase+sphene (George Plafker, written commun., 1984).

Exact timing of metamorphism is unknown. A Cretaceous maximum age of metamorphism is proposed on the basis of the age of the protoliths. Metamorphism is known to predate the intrusion of cross-cutting Oligocene (28±8 Ma) gabbroic plutons northwest of Cross Sound (Loney and Himmelberg, 1983), and probably also predates the intrusion of Eocene plutons of intermediate composition in the southwestern Skagway quadrangle (K-Ar age on hornblende from one pluton is about 51 Ma and that from another is about 45 Ma; G. Plafker, oral commun., 1989). A 67-Ma age on hornblende from amphibolite in the Nunatak Fiord area, 55 km northeast of Yakutat, may indicate a latest Cretaceous metamorphic age (Barker and others, 1985).

The origin of the metamorphic episode that resulted in the greenschist- to amphibolite-facies metamorphism of this unit and the adjacent amphibolite-facies unit described below is unknown. It is doubtful that metamorphism was associated with Tertiary plutonism because no clear cut spatial relation between higher grade metamorphic conditions and proximity to Tertiary plutons seems to be present. D.A. Brew infers that this medium-grade metamorphic episode was the higher temperature equivalent of the prehnite-pumpellyite- and lower greenschist-facies metamorphic episode (unit LPP,GNS (eTIJ)) that affected the rocks north of Cross Sound. However, a relatively high thermal gradient is required to explain the abrupt transition from prehnite-pumpellyite- and lower greenschist-facies rocks to amphibolite-facies rocks observed in the western part of the Fairweather Range. This high thermal gradient is incompatible with the low thermal gradient implied by the subduction-related metamorphic history proposed by Decker (1980) for the mélange part of unit LPP,GNS (eTIJ) south of Cross Sound on western Chichagof Island (discussed above). The two areas also are not analogous in that Decker's study concerned a simple, single gradient situation inboard of the flysch unit, whereas the Fairweather Range contains a complex situation in which the metamorphic grade increases abruptly within the flysch unit from both the east and west towards a maximum near the crest of the range.

AMP (eTK)

Amphibolite-facies biotite gneiss and hornblende schist and gneiss (amphibolite) (Brew, 1978; George Plafker, unpub. mapping, 1980) crop out in the Fairweather Range. Protoliths are interpreted to be sandstone and mudstone turbidites and volcanic rocks of Cretaceous age on the basis of lithologic similarity to the Valdez Group, Sitka Graywacke, and part of the Yakutat Group (Plafker and others, 1977; Brew and Morrell, 1979a; D.A. Brew and George Plafker, oral communs., 1985). The rocks are well foliated and amphibolite is also locally well lineated. Biotite gneiss is composed primarily of biotite, quartz, plagioclase, and locally garnet. Amphibolites contain hornblende+plagioclase±garnet±biotite ±chlorite (Brew, 1978; George Plafker, written commun., 1984).

Constraints on the age of metamorphism and questions about its origin are the same as those described for the unit immediately above.

LPP (eTlK)

This unit comprises laumontite+quartz- and (or) prehnite-pumpellyite-facies late Mesozoic flysch and mélange of the Yakutat block (Plafker, 1983), which consist of large blocks of greenstone, phyllite, metagraywacke, argillite, and metachert and thick sequences of slate, silty metalimestone, limy metasiltstone, and minor greenstone (Brew, 1978). Also included is a sheared and chloritized elongate diorite body of probable Cretaceous age (Brew, 1978; shown as a weakly metamorphosed pluton, pl. 1). The unit crops out in the vicinity of Cape Fairweather. Northwest of the map area, near Yakutat, correlative bedded sequences are Late Cretaceous in age, and disrupted blocks are Late Jurassic and (or) Early Cretaceous in age (George Plafker, written commun., 1985; Dusel-Bacon and others, 1993).

Petrographic study of correlative sandstones to the north in the Yakutat-St. Elias Mountains area has indicated that metamorphic minerals developed in these rocks include laumontite, prehnite, quartz, chlorite, sphene, pumpellyite, and white mica (Hudson and others, 1977). Similar assemblages are inferred to exist in this map area.

Metamorphism is known to postdate the Late Cretaceous protolith age of the bedded sequences in the Yakutat area (George Plafker, oral commun., 1984) and the probable Cretaceous age of diorite near Lituya Bay and to predate the deposition of overlying unmetamorphosed Oligocene volcanic rocks (Brew, 1978). A latest Cretaceous and (or) early Tertiary metamorphic age is provisionally assigned to these rocks on the basis of the youngest probable protolith age (Maastrichtian) and the fact that correlative low-grade rocks of the Yakutat Group that occur farther to the north in the Yakutat-St. Elias Mountains area appear to increase in grade into amphibolite-facies rocks (Dusel-Bacon and others, 1993) that yield a K-Ar age on hornblende of 65 Ma (Hudson and others, 1977).

WESTERN METAMORPHIC BELT

ADMIRALTY ISLAND AND ADJACENT MAINLAND AREA

LPP (eK)

Weakly metamorphosed argillite, slate, metagraywacke, metaconglomerate, intermediate to mafic metavolcanic rocks, metachert, and minor metalimestone and phyllite compose this low-grade unit (Buddington and Chapin, 1929; Loney, 1964; Lathram and others, 1965; Brew and Grybeck, 1984). Protoliths are sedimentary and volcanic rocks. On Admiralty Island, protoliths include rocks of Ordovician age (Carter, 1977) and Permian through Early Cretaceous age (Lathram and others, 1965). On the adjacent mainland to the east, protoliths are correlated with rocks that range in age from Permian through Cretaceous (Buddington and Chapin, 1929; Brew and Grybeck, 1984). Metamorphic minerals developed in this unit suggest conditions of the prehnite-pumpellyite facies and include chlorite, sericite, and calcite in Permian metasedimentary rocks; quartz, albite, calcite, chlorite, sericite, and pyrite in Triassic argillite; and chlorite, calcite, epidote, prehnite, and white mica in Jurassic and Lower Cretaceous metagraywacke (Loney, 1964).

Metamorphism is known to postdate the Early Cretaceous depositional age of the youngest low-grade rocks of this unit and to predate the early Tertiary (Paleocene to Miocene) age of overlying unmetamorphosed sedimentary rocks. A late Early Cretaceous age of metamorphism is proposed because the low-grade rocks of this unit grade into greenschist- and amphibolite-facies rocks (units GNS (eK) and GNS,AMP (eK)) whose major metamorphism was associated with the intrusion of intermediate plutons that yield K-Ar mineral ages of about 120 and 110 Ma (Loney and others, 1967). Whether the area of this unit on the mainland east of Admiralty Island was affected by this episode or whether some, if not all, of the low-grade metamorphism there was part of the eastward-increasing metamorphic episode that occurred during latest Cretaceous or early Tertiary time is not clear.

GNS (eK)

This unit comprises phyllite, greenschist, greenstone, slate, marble, and metaquartz diorite; it also includes poorly exposed migmatitic rocks and feldspathic schist south of the largest pluton on the island. The majority of sedimentary and volcanic protoliths ranges in age from Ordovician to Triassic (Loney, 1964; Lathram and others, 1965; Carter, 1977); Upper Jurassic and Lower Cretaceous sedimentary protoliths are present along the east side of the northern peninsula of the island (Lathram and others, 1965). This unit is generally schistose or phyllitic. Common metamorphic minerals are characteristic of greenschist-facies or perhaps albite-epidote hornfels-facies conditions and include chlorite, albite, white mica, and epidote. In the southeastern part of this unit, phyllite, greenschist, and calcareous rocks of the Gambier Bay Formation are massive appearing and are phyllonitic; these rocks contain the assemblages quartz-muscovite-chlorite-albite, quartz-talc-calcite, and chlorite-epidote-calcite. Augite porphyroclasts in metavolcanic rocks in that area have overgrowths of amphibole that consist of colorless tremolite except for the part in contact with the augite, which consist of a bluish (sodic) amphibole (Loney, 1964).

On the northern peninsula of the island, metaquartz diorite is lineated, well foliated, and sheared. The trend of the foliation is parallel to that of the country rock (Barker, 1957). Barker proposed that the pluton was intruded after the formation of the schistosity in the country rock and that after solidification the intrusive rock was deformed and metamorphosed in a later stage of the orogeny. However, neither the age of the igneous protolith nor of the country rocks has been determined, and possibly either (1) the pluton intruded unmetamorphosed country rocks and was subsequently metamorphosed along with the country rocks or (2) it was intruded synkinematically with regional metamorphism. Recent structural studies support the first interpretation and suggest that the pluton was intruded as a sill-like body, was subsequently deformed and metamorphosed with the country rocks, and was later sheared by movements on the Chatham Strait fault to the west (D.A. Brew, unpub. data, 1985). Intermediate intrusive rocks of the largest batholith on the island are poorly to well foliated, but the trend of the foliation relative to that of the country rocks has not been studied in detail (Lathram and others, 1965). However, because metamorphic grade apparently increases toward this pluton and because the contact aureoles merge with large areas of dynamothermally metamorphosed phyllite, schist, and gneiss (Loney and others, 1967), we consider that the intrusion of this pluton was associated with regional metamorphism on Admiralty Island. A late Early Cretaceous age for this episode is indicated by K-Ar ages of about 120 and 110 Ma on minerals from the batholith (Loney and others, 1967). Absolute age constraints on metamorphism are provided by the Early Cretaceous protolith age of the youngest affected rocks and the early Tertiary (Paleocene) age of overlying, unmetamorphosed sedimentary rocks.

GNS,AMP (eK)

This unit comprises undifferentiated greenschist-facies (or albite-epidote hornfels-facies) and amphibolite-facies (or hornblende hornfels-facies) rocks, including quartz-albite-chlorite epidote±biotite schist, hornblende-albite-epidote hornfels, micaceous schist, metachert, marble, slate, phyllite, quartz-andesine-hornblende-biotite amphibolite, quartz-andesine-diopside-microcline gneiss, and andesine-garnet-pyroxene gneiss; it also includes migmatitic rocks north of the largest pluton on the island (Lathram and others, 1965). Protoliths are the same as those described for the unit above. The northernmost area of this unit is poorly exposed, but a small granite body, whose boundary with the surrounding gneiss is gradational across several tens of meters, crops out near the center of the area (Lathram and others, 1965). The spatial association between this unit and late Early Cretaceous plu-tons and an apparent decrease in metamorphic grade away from the plutons suggest that meta-morphism was associated with plutonism, as is discussed above for lower grade equivalents of this late Early Cretaceous metamorphic episode.

KUPREANOF, ETOLIN, AND REVILLAGIGEDO ISLANDS AND CLEVELAND PENINSULA AREA

LPP/GNS (mK)

Prehnite-pumpellyite- to lower greenschist-facies greenschist, greenstone, phyllite, slate, meta-agglomerate, and minor argillite, semischist, metaconglomerate, metalimestone, and metachert (Eberlein and others, 1983; Brew and others, 1984) crop out from Kupreanof Island in the north to the peninsula north and west of Revillagigedo Island

(Cleveland Peninsula) in the south. Protoliths include clastic sedimentary rocks, intermediate to mafic volcanic rocks, limestone, and chert. Protoliths for much of this unit are considered to be temporally correlative with the unmetamorphosed strata of the Seymour Canal Formation (Brew and others, 1984) that has yielded Late Jurassic to Early Cretaceous (Berriasian) fossils on Admiralty Island (Loney, 1964) and similarly aged fossils on southwestern Etolin Island (Berg and others, 1972), including an Albian or Cenomanian ammonite (Brew and others, 1984). Conodonts from limestone layers in west-central Kupreanof Island indicate a Late Triassic protolith age for at least part of this unit (Brew and others, 1984). Protolith ages of this unit in the northeastern part of the Craig quadrangle were previously considered to be late Paleozoic or Mesozoic (Eberlein and others, 1983) and probably mainly Jurassic and Cretaceous (Berg and others, 1976; Eberlein and others, 1983). Recent studies (C.M. Rubin, oral commun., 1987) indicate that both rocks of both early Paleozoic and Jurassic and (or) Cretaceous protolith age are present.

Rocks have been dynamothermally metamorphosed and locally are very folded and faulted. Metasedimentary rocks are generally poorly foliated, but fine-grained variants have good cleavage; greenschist and greenstone appear less deformed and metamorphosed and locally contain abundant relict pyroxene phenocrysts (Brew and others, 1984). On northwestern Kupreanof Island, rocks have been metamorphosed to albite-muscovite-chlorite subfacies of the greenschist facies (Muffler, 1967); elsewhere typical metamorphic mineral assemblages include epidote-albite-actinolite-quartz-white mica-chlorite, as well as biotite in the northeastern part of the Craig quadrangle (Eberlein and others, 1983). The prehnite-pumpellyite-facies rocks are not yet well documented.

Regional low-grade metamorphism is known to predate the intrusion of Alaskan-type mafic-ultramafic bodies that have yielded K-Ar ages of 100–110 Ma (Lanphere and Eberlein, 1966; Clark and Greenwood, 1972; Brew and others, 1984; Douglass and Brew, 1985). The late Early Cretaceous minimum metamorphic age indicated by this dating is close to the Albian or Cenomanian protolith age of the youngest rocks included in this unit on Etolin Island. Allowing for minor age uncertainties in both the isotopic- and fossil-age determinations, a mid-Cretaceous metamorphic age is indicated for this unit. Hornblende-hornfels-facies thermal aureoles in which garnet and rarely sillimanite are developed occur adjacent to 90-Ma intermediate plutons (lKg) and 20-Ma intermediate plutons (lTg). The adjacent unit LPP/GNS (mK) + GNL→I (lK) differs from this unit in that the 90-Ma aureoles are regional in character and also contain porphyroblasts of either unreacted andalusite or andalusite that has been replaced by kyanite and staurolite. The geographic limits of the area affected by this episode are not known with certainty, and they may have extended toward the east into western Revillagigedo Island (unit GNS (K)).

LPP/GNS (mK) + GNL→I (lK)

Rocks included in this unit are polymetamorphosed greenschist, phyllite, semischist, greenstone, metavolcanic rocks, and minor metagraywacke and slate (Brew and others, 1984). Protoliths generally are similar to those described for the unit to the west (LPP/GNS (mK)); they are thought to be Late Jurassic to mid-Cretaceous in age and to be equivalent to the Seymour Canal Formation (Brew and others, 1984, p. 23). The rocks were regionally metamorphosed under prehnite-pumpellyite- to lower greenschist-facies conditions during mid-Cretaceous time (see description for unit LPP/GNS (mK) for discussion of metamorphic age constraints). Subsequently, these rocks were recrystallized under low-pressure evolving to intermediate-pressure greenschist-facies conditions during the metamorphic episode associated with the early Late Cretaceous (90 Ma) intrusion of the locally garnet- and (or) epidote-bearing intermediate plutons of the Admiralty-Revillagigedo belt of Brew and Morrell (1983) (Brew and others, 1984; Douglass and Brew, 1985). Original sedimentary textures and structures are generally obscured, but some relict igneous pyroxene is preserved in some greenstones (Brew and others, 1984).

The first metamorphic episode produced a weak to well-defined planar fabric, and the second episode produced porphyroblastic, decussate, and granoblastic textures (Brew and others, 1984). Typical mineral assemblages developed during the first episode include chlorite, quartz, white mica, plagioclase, clinozoisite, epidote, and less commonly biotite.

The second metamorphic episode occurred primarily under thermal conditions, but, locally, it occurred under dynamothermal conditions. It produced porphyroblasts of andalusite that in most areas are partly to totally replaced by static (radial) kyanite (locs. 27 and 28, Petersburg quadrangle, table 2, pl. 2), which indicates an increase in pressure during crystallization. At other localities, andalusite is not replaced by kyanite but, instead, is either partly replaced by staurolite (loc. 32, Petersburg quadrangle, table 2, pl. 2) or almost totally replaced by white mica (loc. 40, Petersburg quadrangle, table 2, pl. 2). Evidence of relict andalusite (pleochroic pink andalusite in cores of the replaced porphyroblast and chiastolite crosses within kyanite) is the same as that described for the aureoles near northern Wrangell Island in the adjacent, higher grade equivalent unit AMI (lK). Other mineral assemblages that formed in aureoles developed during the second episode include garnet, biotite, plagioclase, quartz, staurolite, and fibrolite (Douglass and Brew, 1985). The degree of metamorphism generally increases toward the plutons. Away from the aureoles, typical mineral assemblages developed during the second metamorphic episode include biotite, clinozoisite, quartz, plagioclase, actinolite, and white mica.

The regional extent of the two metamorphic episodes described for this unit is imprecisely known, owing to overprinting of these metamorphisms by subsequent metamorphic episodes that affected adjacent areas; for this reason, the boundaries of this unit are only approximate.

GNS (K)

In general, this unit consists of greenschist-facies flyschoid metasedimentary rocks, intermediate or mafic metavolcanic and metavolcaniclastic rocks, and relatively sparse intermediate or mafic metaplutonic rocks. On Revillagigedo Island, on Cleveland Peninsula, and on the mainland near the mouth of Boca de Quadra, common rock types are phyllite, semischist, pelitic schist, greenschist, minor marble, quartz-muscovite schist, slate, phyllitic grit or metaconglomerate, metadiorite, metagabbro, and greenstone (Berg and others, 1978, 1988). Few fossils have been found within this area, but most protoliths are considered to be Paleozoic or Mesozoic in age. Fossils of latest Middle Triassic and late Early Permian age have been found within this unit on southwestern Revillagigedo Island (Silberling and others, 1982). On Gravina and Annette Islands, the unit consists of Lower or Middle Devonian marble, phyllite, and metagraywacke; Upper Triassic metalimestone, metaconglomerate, semischist, meta-agglomerate, metatuff, metavolcanic breccia, and greenstone; and Jurassic and Cretaceous metagraywacke, metalimestone, argillite, metaconglomerate, and metatuff. Weakly metamorphosed diorite and quartz diorite of presumed Jurassic or Cretaceous age also occur within this unit on Annette Island (Berg and others, 1978, 1988). On Duke Island, the unit consists of weakly metamorphosed pyroxene gabbro that has yielded an apparent Late Triassic (226±3-Ma) U-Pb age on zircon (Gehrels and others, 1987). To the east on Cape Fox, the unit consists of metasedimentary and metaigneous rocks of unknown protolith age (Berg and others, 1978, 1988).

The intensity of regional metamorphism increases gradually northward and eastward from incipiently slaty rocks on western Gravina Island to upper greenschist-facies rocks near their apparent gradational contact with the amphibolite-facies rocks (unit AMI (lK) described below) according to Berg and others (1978, 1988) and R.L. Elliott and J.G. Smith (oral communs., 1985). On Annette Island, a typical metamorphic mineral assemblage in metasedimentary and mafic metavolcanic rocks consists of sericite, quartz, chlorite, calcite, and epidote and (or) clinozoisite; on Gravina Island, regional deformation and metamorphism generally are less intense (Berg, 1972, 1973; Berg and others, 1988). On Revillagigedo Island and the Cleveland Peninsula to the west, metamorphic foliation dips to the northeast, and the metamorphic sequence is cut by southwest-vergent thrust faults (Berg and others, 1988; Rubin and Saleeby, 1987). Metamorphic mineral assemblages on Revillagigedo Island contain quartz, feldspar, biotite, muscovite, pyrite, actinolite, and chlorite in metasedimentary rocks and actinolite, plagioclase, quartz, biotite, pyrite, and epidote and (or) clinozoisite in metavolcanic rocks; garnet occurs in both metasedimentary and metavolcanic rocks in the northern part of the island. Porphyroblastic minerals that replace older, fabric-forming metamorphic minerals or that randomly overprint the earlier fabric occur in narrow (less than 1-km-wide) contact aureoles around many of the Cretaceous plutons and in a wider aureole around the Tertiary pluton on Revillagigedo Island (J.G. Smith, oral commun., 1985; Berg and others, 1988). These narrow aureoles are similar to those described above within unit LPP/GNS (mK).

Widespread development of feather schist occurs locally on southern and southeastern Revillagigedo Island and across east Behm Canal on the mainland (Berg and others, 1978, 1988). This distinctive rock type contains bowtie-like porphyroblastic sheafs of actinolite as much as 2 m in length, almandine garnet idioblasts as much as 2 cm in diameter, and coarsely crystalline muscovite. The metamorphic origin of this distinctive texture is not known.

A Cretaceous age is indicated for the regional greenschist-facies metamorphic episode because metamorphism is known to postdate the Early Cretaceous age of the youngest protoliths on Gravina and Annette Islands and to predate the approximate 90-Ma age of crosscutting, unmetamorphosed plutons that intrude this metamorphic unit (Smith and Diggles, 1981). The 90-Ma plutons, which were mentioned above, are a critical element in understanding the history of metamorphism in this area; they define the Admiralty-Revillagigedo belt of Brew and Morrell (1983). Many of the plutons in this belt contain primary (magmatic) epidote and garnet (Zen and Hammarstrom, 1984a). The crosscutting age relations and the development of narrow contact aureoles around the postmetamorphic 90-Ma plutons are most clearly seen on the southwestern part of Revillagigedo Island (J.G. Smith, oral commun., 1986). Isotopic and metamorphic data are insufficient to determine the exact timing of regional metamorphism, and two different hypotheses about the metamorphic history of this unit have been inferred from the available data.

According to the first hypothesis, metamorphism preceded but was part of the same thermal episode that culminated in the intrusion of early Late Cretaceous (90-Ma) primary garnet- and epidote-bearing plutons of intermediate composition. The primary evidence for this origin is the apparent gradual northeastward increase in metamorphic grade (Berg and others, 1978, 1988; R.L. Elliott and J.G. Smith, oral communs., 1985) within this greenschist-facies unit. This increase is inferred to continue into the related kyanite-bearing amphibolite-facies rocks (AMI (IK)) that are spatially related to a large 90-Ma pluton on northern Revillagigedo Island that is interpreted to have been intruded synmetamorphically (Berg and others, 1988). According to this first hypothesis, the narrow contact aureoles around some of the 90-Ma plutons formed postkinematically and overprint the regional foliation developed earlier during this same early Late Cretaceous metamorphic episode. The location of the eastern and southern limits of the earlier (before 100- to 110-Ma) low-grade metamorphic episode (LPP/GNS (mK)) that occurs to the west and northwest is unknown. It presumably occurs somewhere within this unit and is overlapped by the effects of greenschist-facies metamorphism associated with the 90-Ma plutonism.

According to the second hypothesis, the regional greenschist-facies metamorphism and fabric is a higher grade equivalent of the low-grade metamorphism and fabric (diagnostic of unit LPP/GNS (mK)) that occurs to the northwest. There, it is crosscut by both 100- to 110-Ma mafic to ultramafic plutons and by 90-Ma primary epidote-bearing intermediate intrusions. This hypothesis questions the gradual northeastward increase in metamorphic grade reported by Berg and others (1978, 1988) and infers that the metamorphism on southwestern Revillagigedo Island is part of the episode that occurred before 100–110 Ma rather than the episode that slightly preceded or was synchronous with 90-Ma plutonism. According to this interpretation, the effects of the approximately 90-Ma metamorphic episode were (1) the development of narrow aureoles around some of the 90-Ma plutons that intrude this unit and (2) an extensive prograde aureole around the large pluton within unit AMI (IK) on northern Revillagigedo Island. This interpretation is based on: (1) extending the interpretation made from observations in the Petersburg quadrangle to the northwest (Brew and others, 1984; Douglass and Brew, 1985), (2) a reconnaissance of northwestern Revillagigedo Island by D.A. Brew (unpub. data, 1983), and (3) recent detailed mapping by M.L. Crawford (oral commun., 1988) that indicates an abrupt rather than a gradational increase in metamorphic grade at the boundary between units GNS (K) and AMI (IK). This second hypothesis makes this unit essentially the same as unit LPP/GNS (mK) + GNL→I (IK) to the northwest.

AMI (IK)

This unit comprises intermediate-pressure and, in a small area in the northern part, low-pressure evolving to intermediate-pressure amphibolite-facies, kyanite-staurolite±sillimanite-bearing pelitic schist, quartzofeldspathic schist and gneiss, amphibole schist and gneiss, and minor marble and calc-schist (Berg and others, 1978, 1988; Brew and others, 1984). The unit also includes migmatitic rocks on southwestern Wrangell and eastern Etolin Islands that consist primarily of agmatite and irregularly banded gneiss; metamorphic melasomes in these rocks are fine- to medium-grained biotite±garnet ±sillimanite-bearing hornfels, schist, and semischist (Brew and others, 1984). On Revillagigedo Island, the unit also includes a small body of metadiorite and a larger body of intermediate-composition metaplutonic rocks. East of Revillagigedo Channel, the unit consists of a heterogeneous assemblage of pelitic schist, hornblende schist, and minor semischist, phyllite, and marble (Berg and others, 1978, 1988). This unit is suffently recrystallized so that neither the original textures nor structures remain. No fossils have been found in these rocks. Protoliths include clastic sedimentary rocks, intermediate to mafic volcanic and volcaniclastic rocks, and limestone. On the basis of similarities with fossiliferous strata from nearby areas, protoliths of this unit are considered to include Jurassic and (or) Cretaceous flysch, Permian and Triassic limestone, and intrusive rocks of presumed Jurassic or Cretaceous age (Berg and others, 1978, 1988; Brew and others, 1984).

On and near Wrangell Island, intermediate-pressure metamorphic conditions are indicated for the latest and dominant phase of the metamorphic episode by the presence of kyanite and sillimanite in aureoles around 90-Ma garnet- and epidote-bearing plutons and in the adjacent more regionally extensive metamorphic rocks. The location of the sillimanite and kyanite isograds around the large 90-Ma plutons on central Wrangell Island and the increase in metamorphic grade toward the plutons is evidence that this metamorphism was associated with that particular plutonic episode. Typical mineral assemblages in pelitic aureole schists (shown by the contact aureole symbol, pl. 1) and in equivalent rocks farther from the large pluton (unit lKg with triangle pattern, pl. 1) are staurolite+garnet+biotite+quartz+plagioclase+muscovite±kyanite±sillimanite (Douglass and Brew, 1985); calcareous rocks contain hornblende+calcic plagioclase+quartz+garnet+diopside.

In addition to the widespread occurrence of kyanite in the area of Wrangell Island, relict andalusite has been observed in pelitic schist from aureoles of 90-Ma plutons that intrude this unit (loc. 35, Petersburg quadrangle, table 2, pl. 2) and from aureoles within unit LPP/GNS (mK) + GNL→I (lK) to the north. Samples from these aureoles contain relict porphyroblasts of andalusite that have been replaced by static (radial) kyanite or, in some locations, mineral aggregates of intergrown kyanite and staurolite. Although largely replaced, the relict andalusite is easily identified by the presence of relict chiastolite cross-shaped inclusions or by areas of pink andalusite in their cores. This crystallization sequence of the Al_2SiO_5 polymorphs appears to indicate an increase in pressure from low- to intermediate-pressure conditions in the northern part of this unit during intrusion and metamorphism. Similar textures in which the crystallization of kyanite postdated that of andalusite have been described for the Chiwaukum Schist of the North Cascades, Washington (Evans and Berti, 1986, and references cited therein) and the Settler Schist of the Coast Ranges, southern British Columbia (Hollister, 1969; Pigage, 1976, and other references given in Evans and Berti, 1986). In these areas in Washington and British Columbia, andalusite and kyanite formed during a single metamorphic episode that accompanied intrusion of Late Cretaceous plutons.

The boundaries between this metamorphic unit and adjacent units in the vicinity of Wrangell Island are approximate, and some parts of this unit may have been affected by younger metamorphic episodes, as well as by the earlier (mid-Cretaceous) low-grade metamorphism that affected rocks to the north and to the west. Along the southwesternmost margin of the large pluton on central Wrangell Island, parts of this unit preserve a weak to well-defined planar fabric that was produced during the earlier low-grade metamorphism (described under unit LPP/GNS (mK)).

On Revillagigedo Island, metamorphic mineral assemblages show an increase in grade from the southwest to the northeast, beginning in greenschist-facies rocks (GNS (K)) and continuing into this amphibolite-facies unit. Common mineral assemblages that show increasing grade in mafic rocks are hornblende+quartz+clinozoisite/zoisite+plagioclase±biotite±calcite, followed by garnet+biotite+hornblende+quartz+plagioclase and quartz+biotite+hornblende+garnet+plagioclase+diopside. Calcareous rocks contain, in increasing metamorphic grade, quartz+plagioclase+sphene+zoisite+tremolite+biotite+muscovite followed by hornblende+garnet+sphene+calcic plagioclase+quartz+diopside. No relict andalusite has been reported from this part of the unit. The most common assemblage in pelitic rocks is biotite+garnet+quartz+plagioclase±kyanite±staurolite (M.L. Crawford, written commun., 1984). Sillimanite occurs in pelitic rocks in a 1-km-wide zone along the southern margin of the batholith that crops out near the north end of Behm Canal, and staurolite and kyanite occur in pelitic rocks in a lower grade zone that is several kilometers wide and is located beyond the sillimanite zone (Berg and others, 1978, 1988). Some of these kyanite-bearing rocks contain late fibrolitic sillimanite and muscovite that may have formed during a late-kinematic phase of the dynamothermal metamorphic and plutonic episode and (or) during subsequent decompression of the region (M.L. Crawford, oral commun., 1985). Limited petrographic data from pelitic rocks along the northeastern margin of the pluton do not indicate the existence of similar sillimanite and kyanite zones; in that area, rocks in which kyanite and sillimanite coexist and in which either kyanite or sillimanite is the sole Al_2SiO_5 polymorph are present at approximately equal distances from the pluton (R.L. Elliott, unpub. data, 1979).

Geothermometric and geobarometric data from two samples of garnet-kyanite schist in the Ketchikan quadrangle (locs. 2 and 6, pl. 2) indicate equilibration temperatures and pressures of 600°C, 7.5–8.5 kb and 575–600°C, 8.5–9.2 kb, respectively (M.L. Crawford, written commun., 1983). These data are based on garnet-biotite equilibration temperatures (calibration of Ferry and Spear, 1978) and plagioclase-garnet-Al_2SiO_5-quartz equilibration pressures. The temperatures and pressures are derived from analysis of the outer parts of the grains and, hence, represent final crystallization equilibration for mineral rims rather than peak metamorphic conditions (M.L. Crawford, written commun., 1983). Similar moderately high final crystallization pressures have been proposed for slightly postmetamorphic or late synmetamorphic primary garnet- and epidote-bearing 90-Ma plutons that intrude this unit and the associated greenschist-facies rocks. In their study of the pluton at Bushy Point on northwestern Revillagigedo Island, Zen and Hammarstrom (1984b), applying experimental data on the composition of magmatic garnet and on pressures of crystallization of magmatic epidote, proposed that the magma began to crystallize at a minimum pressure of 13–15 kb (depth of about 40–50 km) and finally crystallized at about 6–10 kb (depth of about 20–30 km). Similar final crystallization pressures are proposed for the other approximately 90-Ma primary epidote-bearing plutons that form the Admiralty-Revillagigedo belt of Brew and Morrell (1983) (Zen and Hammarstrom, 1984a). The combination of the high- to intermediate-pressure magmatic and crystallization history inferred for the plutons and the occurrence of relict andalusite, indicative of low-pressure conditions (less than 3.8 kb; Holdaway, 1971), in their aureoles in the Wrangell Island area is indeed problematic. Also significant to this problem is the fact that narrow, low-pressure aureoles are present around some of the 90-Ma epidote-bearing plutons that intrude lower grade rocks to the north and west of the amphibolite-facies rocks on Wrangell Island and to the south and west of the amphibolite-facies rocks on Revillagigedo Island.

The 90-Ma batholiths (unit lKg with triangle pattern, pl. 1) at the northern end of this metamorphic unit, including the one on Wrangell Island around which the metamorphic isograds mark an increase in metamorphic grade toward the pluton, are probably the main cause of the metamorphism and deformation in the adjacent rocks and were emplaced during the waning stages of the metamorphism and deformation (Brew and others, 1984; Douglass and Brew, 1985; Berg and others, 1988). The synkinematic batholith near the northern end of Behm Canal and the smaller pluton that intrudes the greenschist-facies rocks to the south (tonalite of Bushy Point) yield U-Pb ages on zircon, interpreted as their emplacement ages, of approximately 90 and 94 Ma, respectively (C.M. Rubin, oral commun., 1987; Rubin and Saleeby, 1987). The Moth Bay pluton, which intrudes the greenschist-facies rocks on the southern tip of Revillagigedo Island, also may be synkinematic (J.G. Smith, oral commun., 1985), as suggested by the facts that the igneous minerals of the pluton are commonly slightly altered and bent or fractured and that, although parts of the pluton are relatively massive, it grades into fine-grained blastomylonite and mylonite schist along some margins (J.G. Smith, oral commun., 1985; Berg and others, 1988). The Moth Bay pluton has yielded a $^{40}Ar/^{39}Ar$ plateau age on hornblende of 96–97 Ma (Sutter and Crawford, 1985) and a U-Pb age on zircon of 101 Ma (Saleeby, 1987). Intrusion of the southernmost 90-Ma primary garnet- and epidote-bearing plutons within this unit, as well as most of those in the adjacent greenschist-facies unit on Revillagigedo Island, postdates the regional metamorphism and deformation of the country rocks.

K-Ar age determinations on amphibolite- and associated greenschist-facies rocks show a decrease in maximum apparent ages northward and eastward on Revillagigedo Island (Smith and Diggles, 1981; Berg and others, 1988). $^{40}Ar/^{39}Ar$ plateau ages on hornblendes from plutonic and metamorphic rocks on Revillagigedo Island, as well as from metamorphically similar rocks to the south in the area of Prince Rupert, British Columbia, show an age pattern similar to that shown by conventional K-Ar ages; they range from more than 90 Ma in the western part of the island to about 56–57 Ma near the eastern boundary of this metamorphic unit (Sutter and Crawford, 1985). $^{40}Ar/^{39}Ar$ age spectra suggest that the observed age pattern was caused by cooling associated with differential uplift and not by partial loss of ^{40}Ar during the later heating event that was associated with rocks of the Coast Mountains to the east (Sutter and Crawford, 1985). Uplift of the block consisting of these amphibolite-facies rocks and the associated greenschist-facies rocks was greatest (exposing gneissic parts of the batholith along northern Behm Canal) and occurred latest in the eastern part of the block. The eastern boundary of this block is spatially related to the Coast Range megalineament (Brew and Ford, 1978), a topographic, structural, and geophysical feature that appears to have been near the western limit of large-scale regional uplift of southeastern Alaska and adjacent parts of British Columbia beginning in early Tertiary time (Hutchison, 1970, 1982; Crawford and Hollister, 1982, 1983).

MAINLAND BELT

GNS (eTlJ)

This unit consists of greenschist-facies metatuff breccia, semischist, phyllite, marble, and crosscutting metagranodiorite and minor metaquartz diorite (Smith, 1977; Berg and others, 1977, 1978, 1988). The metaplutonic rocks are the Texas Creek Granodiorite and yield Late Triassic and Early Jurassic K-Ar ages (approximately 210 to 202 Ma) on hornblende (Smith and Diggles, 1981; Berg and others, 1988) and Early Jurassic concordant U-Pb ages (approximately 195 to 193 Ma) on zircon (Alldrick and others, 1986). Other protoliths include andesitic volcanic and volcaniclastic rocks, flysch, and minor limestone (Berg and others, 1988). Late Paleozoic and early Mesozoic protolith ages are suggested by the occurrence of a Permian fossil in limestone to the northwest that is probably correlative with marble of this unit (R.L. Elliot, oral commun., 1983) and by a probable genetic relation between the andesitic rocks of this unit and the Late Triassic and Early Jurassic Texas Creek Granodiorite (Berg and others, 1988; Alldrick, 1985).

Rocks are characterized by lower greenschist-facies assemblages that contain actinolite, chlorite, albite, quartz, clinozoisite-epidote, calcite, and opaque minerals. Relict volcanic and plutonic textures are common, and rocks generally are not schistose or otherwise penetratively deformed (Smith, 1977; Berg and others, 1988). The Texas Creek Granodiorite is locally characterized by cataclastic or mylonitic textures. Regional metamorphism and cataclasis postdate the emplacement of the granodiorite plutons. Field relations in the adjoining area in British Columbia, Canada, suggest that the metamorphism postdates sedimentary strata that are believed to range from early Middle Jurassic to middle Late Jurassic in age (Alldrick, 1985). Metamorphism is known to predate the emplacement of Eocene plutons (eTg) that produced thermal aureoles as much as 2 km wide along their contacts with the metagranodiorite (Berg and others, 1988).

GNL→I (lK) + GNI (eTlK)

Greenschist-facies garnet-chlorite-biotite schist and semischist and minor phyllite, slate, marble, and calcareous tremolite-chlorite-bearing granofels (Brew and others, 1984) crop out in the eastern Petersburg quadrangle. The protoliths and latest Cretaceous and (or) early Tertiary metamorphic history of this unit are similar to that described below for the rocks to the northwest (GNI (eTlK)), but, in addition, this unit was deformed (Hunt and Brew, 1986) and probably was metamorphosed significantly during the earlier metamorphism that was associated with the intrusion of the 90-Ma plutonic belt. Low-pressure evolving to intermediate-pressure metamorphic conditions are indicated for the first episode because kyanite occurs along with and replaces andalusite in the aureoles of the nearby 90-Ma plutons. It is generally difficult to associate a given assemblage with one or the other episode because metamorphic minerals produced during both greenschist-facies episodes are the same. Well-foliated rocks developed in the first episode were recrystallized during the later Barrovian metamorphism as were parts of some of the 90-Ma plutons (Brew and others, 1984). Part of the western part of this unit also may have been metamorphosed during the mid-Cretaceous low-grade regional metamorphism recorded in the rocks of unit LPP/GNS (mK) to the west. Some evidence (Brew and others, 1984) indicates that the eastern limit of that metamorphism was close to this area in which the 90-Ma metamorphism is overprinted by the latest Cretaceous and (or) early Tertiary Barrovian metamorphism.

LPP (eTlK)$_1$

Prehnite-pumpellyite-facies basaltic metatuff breccia, in places interlayered with metagraywacke and metapelite, crops out in the Juneau quadrangle and forms the lowest grade part of an eastward-increasing Barrovian metamorphic sequence that developed during latest Cretaceous and (or) early Tertiary time (Ford and Brew, 1973, 1977a, b; Brew and Ford, 1985). Fossils indicate that the age of the protoliths are as young as Early(?) Cretaceous (Ford and Brew, 1973). A weakly metamorphosed mid-Cretaceous pluton of intermediate composition is also included in this unit. Characteristic metamorphic minerals include albite, white mica, chlorite, pumpellyite, epidote, actinolite, and, locally, prehnite and stilpnomelane (Ford and Brew, 1977b).

The eastern boundary of this unit is defined by the first appearance of green biotite that occurs only slightly upgrade from the last appearance of pumpellyite and prehnite. The western and southern boundaries of this unit with previously metamorphosed prehnite-pumpellyite-facies rocks (units LPP (eKeJ) and LPP (eK), respectively) are approximate. The effects of low-grade metamorphism during the previous episode(s) may have extended into the area of low-grade Barrovian metamorphism, and the metamorphic effects of the later episode may have continued farther to the south into the area shown as unit LPP (eK).

The possible tectonic origins that have been proposed to explain the development of this Barrovian metamorphic sequence are discussed in the final section of this report.

GNI (eTIK)

This elongate unit forms the intermediate-grade part of the northeastward-increasing Barrovian metamorphic sequence and comprises dynamothermally metamorphosed, intermediate pressure, lower to upper greenschist-facies phyllite, slate, semischist, greenschist, chlorite-biotite schist, and greenstone. Studies of these rocks and their metamorphic history have been made in the Juneau quadrangle by Forbes (1959), Ford and Brew (1973, 1977a), Brew and Ford (1977), and Himmelberg and others (1984a, b, 1985, 1986); in the Sumdum and Taku River quadrangles by Brew and Grybeck (1984); and in the Petersburg quadrangle by Brew and others (1984) and Douglass and Brew (1985). Protoliths are considered to have been primarily clastic sedimentary rocks; mafic to intermediate volcanic, intrusive, and volcanogenic sedimentary rocks; and minor limestone and chert. Fossils found in these rocks near Juneau indicate Permian(?) and Late Triassic protolith ages; Jurassic and Cretaceous protoliths also may have been involved.

The metamorphic grade of this unit increases from southwest to northeast and ranges from lowermost greenschist facies (or perhaps prehnite-pumpellyite facies) to upper greenschist facies. Clastic and other relict textures are present only in the lowest grade part of this unit, where an early foliation, presumably formed during the low-grade late Early Cretaceous regional episode, is locally detectable (Brew and others, 1984). As metamorphic grade increases, these rocks exhibit well-defined crenulation cleavage and transposition layering; most rocks included in this unit are well foliated and lineated.

The lower greenschist-facies rocks are characterized by the assemblage albite+white mica+chlorite+quartz±epidote, and the upper greenschist-facies rocks are characterized by the assemblages muscovite+chlorite+biotite+albite+quartz±garnet and clinozoisite+albite+quartz+chlorite+calcite +muscovite±biotite±actinolite±sphene (Brew and others, 1984). The eastern (high-grade) boundary of this unit generally separates rocks in which the chlorite-garnet tieline persists from rocks to the northeast in which this tieline has been broken, and the tieline between biotite and staurolite or aluminum silicate has been established. This boundary is an isograd and is northeast dipping and, hence, is inverted. The isograds in this unit and the related unit AMI (eTIK) (Ford and Brew, 1973; 1977a; Brew and Ford, 1977) are the only inverted isograds that have been mapped to date in the Coast plutonic-metamorphic complex of Brew and Ford (1984). Farther south within the Canadian part of the complex, however, an older inverted metamorphic sequence is interpreted to have formed during metamorphism related to the intrusion and west-directed thrusting of a 98-Ma epidote-bearing pluton (Crawford and others, 1986). That pluton is part of the plutonic belt discussed earlier for units GNS (K) and AMI (IK).

Metamorphism is considered to be slightly prekinematic and primarily synkinematic with the latest Cretaceous and (or) early Tertiary mesozonal intrusion of quartz diorite, tonalite, and minor granodiorite of the great tonalite sill (Ford and Brew, 1977b; Brew and Ford, 1981; Brew and Morrell, 1983), shown as the 600-km-long synkinematic intrusive body just east of the Coast Range megalineament (Brew and Ford, 1978). Intrusion of the sill has been dated by U-Pb zircon methods at about 69 and 62 Ma in the Juneau and Sumdum quadrangles, respectively, (Gehrels and others, 1984) and at about 55–58 Ma in the Ketchikan quadrangle to the south (Berg and others, 1988). Evidence for this genetic relation is the increase in metamorphic grade toward the sill, general parallelism between the sill and isograds that define the Barrovian metamorphic sequence, and parallelism of foliation, contacts, and locally developed lineation of the sill with structural elements in the adjacent metamorphic rocks.

The inverted isograds are interpreted to have formed during northeast-southwest compression that both folded and intensified earlier folds in the mixed pelitic, volcanic, and carbonate protoliths. The isograds are not folded, which indicates that the metamorphism they record postdates the peak folding deformation. Isograds in equivalent amphibolite-facies rocks of this sequence (unit AMI (eTIK) in the Juneau quadrangle are truncated by the sill (shown by the truncation of the kyanite isograd near Juneau and about 20 km to the north, pl. 1), whose foliation, however, parallels that in the metamorphosed wallrocks. This suggests that the intrusion of the sill complex accompanied a late stage of the regional metamorphism, namely after the thermal maximum but before the end of penetrative deformation (Ford and Brew, 1977b; Brew, 1983; Brew and others, 1984). The inverted isograds are thought to have formed during the late stages of folding and compression as a thermal envelope advanced ahead of the great tonalite sill during its upward and southwestward movement in the crust; the relatively cool and wet rocks in the footwall of the advancing thermal envelope were progressively metamorphosed (Himmelberg and others, 1991).

GNI,AMI (eTIK)

This areally restricted, elongate unit is composed of the undifferentiated, intermediate-pressure greenschist- and amphibolite-facies rocks of the Barrovian metamorphic sequence whose metamorphic grade increases northeastward. The rock types and metamorphic history are the same as that described for the two nearby metamorphic units GNI (eTIK) and AMI (eTIK), but the map scale (pl. 1) is too small to allow differentiation of these two units. Isograds have not been mapped within this undifferentiated unit, which occurs north of Juneau, but a rapid eastward increase in metamorphic grade is indicated by the mineral assemblages observed (D.A. Brew, unpub. data, 1978). Immediately southeast of this undifferentiated unit spacing of metamorphic isograds increases rapidly. The isograds in that area are truncated by the contact with the great tonalite sill (shown by the truncation of the kyanite isograd, pl. 1) (Ford and Brew, 1977b). Truncation of metamorphic isograds by the sill and parallelism between foliation in the sill with that in the metamorphosed wallrocks suggest that the intrusion of the sill accompanied a late stage of the regional metamorphism, namely after the thermal maximum but before the end of penetrative deformation (Ford and Brew, 1977b; Brew, 1983; Brew and others, 1984). The latest Cretaceous and early Tertiary age of the sill establishes a similar age range for Barrovian metamorphism, as discussed for the adjacent units.

AMI (eTIK)

This unit forms the highest grade part of the Barrovian metamorphic sequence and comprises amphibolite-facies schist, paragneiss, orthogneiss, and migmatite. Common rock types include pelitic, semipelitic, and quartzofeldspathic schist and gneiss; hornblende schist; and subordinate amphibolite, quartzite, marble, and calc-silicate. These rocks have been described by Redman and others (1984) and Barker and others (1986) in the Skagway quadrangle; by Forbes (1959), Ford and Brew (1973, 1977a), Brew and Ford (1977), and Himmelberg and others (1984a, b, 1985, 1986) in the Juneau and Taku River quadrangles; by Brew and Grybeck (1984) in the Sumdum and Taku River quadrangles; and by Brew and others (1984) in the Petersburg quadrangle. Detailed mapping of migmatite at localities in the Petersburg, Taku River, and Juneau quadrangles has indicated that elongate zones of intensely deformed migmatite in those areas are composed of various combinations of hornblende-biotite quartzofeldspathic schist and gneiss, calc-silicate schist and gneiss, marble, and assorted plutonic and metaplutonic rocks of the great tonalite sill and younger intrusive units (Karl and Brew, 1984; Brew and others, 1984). Metamorphic protoliths are considered to have been primarily clastic sedimentary rocks, including a minor amount of limestone, and mafic to intermediate volcanic, intrusive, and volcanogenic sedimentary rocks. No fossils have been found in these rocks, but protolith ages are considered to be, in part, Permian, Triassic, Jurassic, and Cretaceous on the basis of regional correlations (Brew and Ford, 1984a, b, 1985).

Metamorphic grade within this unit and within the entire sequence increases to the northeast. The southwesternmost boundary of this unit is defined by the first appearance of staurolite. Mineral isograds marking the first appearance of staurolite, kyanite, and sillimanite (as well as biotite and garnet in the adjacent lower grade rocks of this facies series shown as unit GNI (eTIK)) trend north-northwest, generally parallel to the tonalite sill. As noted in the discussion of unit GNI (eTIK), isogradic surfaces dip moderately to steeply northeast (Ford and Brew, 1973, 1977a; Brew and Ford, 1977) and are either vertical or inverted. Field, petrographic, and mineral chemistry studies of the progressive metamorphism near Juneau indicate that metamorphic index-mineral isograds mark the occurrence of particular reactions and, thus, are true reaction isograds (Himmelberg and others, 1984b).

In the Petersburg quadrangle, characteristic metamorphic mineral assemblages in pelitic rocks include quartz+muscovite+plagioclase+biotite+garnet+staurolite±kyanite and, as metamorphic grade increases, sillimanite+biotite+quartz+plagioclase+garnet+ilmenite and sillimanite+potassium feldspar+muscovite+biotite+garnet+quartz+plagioclase in rocks that crop out east of the Coast Range megalineament (Brew and others, 1984; Douglass and Brew, 1985). Mafic rocks contain hornblende+biotite+quartz+garnet+plagioclase±clinopyroxene±potassium feldspar, and calcareous rocks contain calcite+wollastonite+quartz±diopside±scapolite. In the Petersburg quadrangle, fibrolitic sillimanite only rarely coexists with kyanite-bearing gneiss west of the megalineament, and prismatic sillimanite only occurs east of it (Brew and others, 1984; Douglass and Brew, 1985). Isogradic surfaces in this area appear to steepen northeastward toward the Coast Range megalineament, which locally marks the sillimanite isograd (Brew and others, 1984, p. 33).

Farther to the north in the Juneau quadrangle, characteristic metamorphic mineral assemblages, in increasing metamorphic grade, are quartz+muscovite+biotite+garnet+staurolite±plagioclase±chlorite, quartz+muscovite+biotite+garnet+staurolite+kyanite+plagioclase, and quartz+muscovite+biotite+garnet+sillimanite+plagioclase (Himmelberg and others, 1984a). Garnet-biotite geothermometry for sillimanite-zone rocks indicates equilibration temperatures of about 690°C (calibration of Thompson (1976)) or 750°C (calibration of Ferry and Spear (1978)) (Himmelberg and others, 1984a).

Minimum equilibration pressures of about 3.8 kb are indicated for the entire Barrovian sequence on the basis of the Al_2SiO_5 triple point of Holdaway (1971) above which andalusite is unstable. Preliminary sphalerite geobarometry of three massive sulphide deposits within the megalineament zone in the Sumdum quadrangle near the mouth of Tracy and Endicott Arms indicates general pressures that are consistent with values of 3.8–4.5 kb at 575°C calculated from silicate mineral equilibria of staurolite-zone rocks in the same general area (Stowell, 1985). Farther north in the Juneau quadrangle, geobarometry by several methods indicates pressures of about 9 kb for the same rocks, but the data exhibit large scatter (G.R. Himmelberg, oral commun., 1987; Brew and others, 1987).

This unit is generally well foliated and lineated; foliation in gneissic rocks is locally anastamosing or lenticular. Within the Coast Range megalineament zone, rocks are locally cataclastic or mylonitic, and many contain late-kinematic, retrograde greenschist-facies minerals, primarily chlorite, white mica, and calcite, whose development apparently accompanied shearing (Brew and others, 1984; D.A. Brew, unpub. data).

Kyanite- and sillimanite-bearing metamorphic mineral assemblages similar to those in the Juneau and Petersburg areas have recently been reported adjacent to the southern extension of the great tonalite sill north of Prince Rupert, B.C. (Gareau, 1988; S.A. Gareau, oral commun., 1988); it is possible that this unit is present south of unit AMI,L (eTIK) that crops out in the Bradfield Canal, Ketchikan, and Prince Rupert quadrangles and that is on strike with unit AMI (eTIK).

Metamorphism is considered to be slightly prekinematic and synkinematic with the lastest Cretaceous and (or) early Tertiary mesozonal intrusion of quartz diorite, tonalite, and minor granodiorite of the tonalite sill, as discussed previously for unit GNI (eTIK). The deeper levels now exposed in the western part of the Coast plutonic-metamorphic complex of Brew and Ford (1984a) clearly have been uplifted relative to those in the eastern part. Brew and Ford (1978) considered the deeper crustal levels now exposed to be due to differential uplift focused near the Coast Range megalineament. The area west of the megalineament was uplifted less than the area immediately to the east, and the easternmost side of the complex was uplifted less than the areas adjacent to the megalineament. The net result was a tilting of the complex during early Tertiary time. Crawford and others (1987) speculated that uplift of the complex in British Columbia was a result of the weakening of the crust by anatexis and the development of melt-lubricated shear zones, particularly the zone represented by the great tonalite sill, along which rapid vertical movement (tectonic surge) took place.

The eastern part of this metamorphic unit was intruded during Eocene time by epizonal plutons of intermediate composition (unit eTg) (Brew and Morrell, 1983). These Eocene plutons are surrounded by mostly low-pressure, high-temperature metamorphic rocks and by migmatites. The original eastern limit of the Barrovian metamorphism is obscurred by the Eocene intrusions, but limited evidence indicates that the low-pressure metamorphism around the Eocene plutons was superimposed over the previous intermediate-pressure metamorphism.

The tectonic setting of this Barrovian metamorphic episode is discussed in the final section of this report.

AMI,L (eTIK)

This unit comprises a heterogeneous complex of migmatite, massive to foliated or gneissic batholiths, and smaller plutons that enclose metamorphic screens and roof pendants of paragneiss (Berg and others, 1988). Dominant rock types consist of pelitic gneiss and schist and subordinate quartzfeldspathic gneiss, migmatite, and orthogneiss derived from granodiorite, quartz monzonite, and quartz diorite. Minor rock types consist of marble and calc-silicate gneiss, pegmatite, quartzite, amphibolite, and aplite (Berg and others, 1978, 1988). These rocks compose part of what has been termed the Coast Plutonic Complex by Roddick and Hutchison (1974), the Central Gneiss Complex by Hutchison (1970, 1982), and the Coast plutonic-metamorphic complex by Brew and Ford (1984a).

The paragneiss and associated rocks have been complexly folded and may have been recrystallized more than once (Berg and others, 1978, 1988). In many areas, paragneiss grades downward and laterally into gneissic granodiorite; elsewhere, it is in sharp contact with plutonic rocks or passes gradually into them through a zone of migmatite (Berg and others, 1978, 1988). Protoliths of the paragneiss sequence consist of argillaceous clastic marine sediments and minor amounts of limestone, chert(?), and felsic to intermediate or mafic volcanic or volcaniclastic rocks. A Paleozoic or Mesozoic protolith age for the paragneiss sequence has been proposed on the assumption that some of the pelitic paragneiss may correlate with the amphibolite-facies, regionally metamorphosed upper Paleozoic or Mesozoic metasedimentary rocks on eastern Revillagigedo Island (Brew and Ford, 1984b; Berg and others, 1988). An Early Cretaceous protolith age for at least some of the orthogneiss has been indicated by a U-Pb age of 127 Ma on zircon from migmatitic gneiss along Boca de Quadra in the Ketchikan quadrangle (Arth and others, 1988) and by a nearly concordant U-Pb age of 139 Ma on zircon from non-migmatitic leucogneiss near Redcap Mountain, British Columbia, some 50 km southeast of the International Boundary (Hill, 1984). On the basis of chemical data from orthogneiss in the area of Boca de Quadra, Barker and Arth (1984) suggested that in that area this unit represents the root of an andesitic arc complex.

Metamorphic mineral assemblages in paragneiss generally consist of quartz+muscovite+biotite+plagioclase+garnet+sillimanite (Berg and others, 1978, 1988; M.L. Crawford, written commun., 1984). Cordierite occurs locally in pelitic rocks in the Ketchikan quadrangle (Berg and others, 1988) and in the Bradfield Canal quadrangle (R.L. Elliott, unpub. data, 1979). Cordierite-bearing assemblages (c, pls. 1,2) in the Bradfield Canal quadrangle commonly contain the assemblage cordierite+sillimanite+hercynite+garnet+plagioclase+biotite±orthoclase±muscovite (R.L. Elliott, unpub. data, 1979). Paragneiss and associated rocks also have been reported to contain minor amounts of the metamorphic minerals potassium-feldspar, clinopyroxene, and hornblende (Berg and others, 1988). Cummingtonite occurs in mafic schist in the Bradfield Canal quadrangle (table 2 and pl. 2; R.L. Elliott, written commun., 1985). Metamorphic mineral assemblages indicate amphibolite-facies metamorphism. Small amounts of retrograde minerals, actinolite, albite(?), chlorite, epidote, and sericite attest to widespread incipient retrograde metamorphism (Berg and others, 1988).

Intermediate- to low-pressure amphibolite-facies conditions are indicated by mineral-assemblage data and geobarometric and geothermometric calculations determined for one sample in the northeastern Ketchikan quadrangle. Kyanite has not been observed within this unit in Alaska. Andalusite (together with sillimanite and garnet) occurs at one locality within this unit adjacent to a 50-Ma pluton (loc. 3, Bradfield Canal quadrangle, table 2, pl. 2) (R.L. Elliott, written commun., 1985) and indicates that low-pressure metamorphic conditions, at least locally, accompanied Eocene plutonism. Pressure and temperature calculations on a sample of sillimanite-garnet-biotite-quartz-plagioclase schist (loc. 6, Ketchikan quadrangle, table 2, pl. 2) indicate metamorphic equilibration conditions of 3.5–4.5 kb and 650 °C (calibration of Ferry and Spear (1978)) (M.L. Crawford, unpub. data, 1983).

Intrusion of the foliated quartz diorite (part of the great tonalite sill of Brew and Ford (1981); discussed in the description of unit GNI (eTIK)), which forms the western margin of this metamorphic unit, occurred sometime during amphibolite-facies metamorphism. The quartz diorite commonly is at least weakly foliated, and in the extreme case it is gneissic. This foliation generally strikes north or northwest and is parallel to the outcrop trend and to the internal structure of the adjoining metamorphic rocks. Much of the quartz diorite also has cataclastic textures, such as undulose quartz and granulated grain boundaries (Berg and others, 1988). A Late Cretaceous and (or) early Tertiary emplacement age for the quartz diorite and the rest of the elongate belt of similar plutonic rocks is indicated by U-Pb ages on zircon of about 58–55 Ma in the Ketchikan quadrangle (Berg and others, 1988) and of about 62 and 69 Ma in the Juneau and Sumdum quadrangles, respectively (Gehrels and others, 1984).

Few detailed mapping and petrologic studies have been conducted within this metamorphic unit, but it appears to be similar to rocks across the International Boundary to the south in British Columbia (M.L. Crawford, oral commun., 1985). In that area, metamorphic reactions, thermobarometric data, and isotopic data indicate that the Central Gneiss Complex in the Prince Rupert area (between about lat 54° and 55°) was uplifted and eroded at a rate of about 1 mm/yr between about 60 and 48 Ma, beginning at a depth of about 20 km and terminating at about 5 km (Hollister, 1982; revised in Crawford and others, 1987). The emplacement of the elongate 60-Ma Quotoon pluton, which is the continuation of the (Alaskan) great tonalite sill, apparently occurred at deep levels during the early stages of uplift, and emplacement of intermediate and felsic plutons along the east margin of the metamorphic unit occurred at high levels during the end stages of uplift. According to the Canadian work, metamorphism continued throughout the period of uplift under evolving pressure and temperature conditions (Hollister, 1982; Crawford and Hollister, 1982, 1983). On the basis of similarities of style and conditions of metamorphism exhibited in rocks exposed west of the megalineament in British Columbia to those suggested by early metamorphic relicts found in rocks exposed east of the megalineament, Crawford and Hollister (1982, 1983) suggested that early metamorphism of the Central Gneiss Complex (which is correlative with this metamorphic unit) may have been synchronous with the approximately 90-Ma metamorphism of the western terrane (represented in the Ketchikan area by units GNS (K) and AMI (IK)). After much of the hinged uplift of the western terrane took place, which began about 90 Ma and continued to about 56 Ma (Sutter and Crawford, 1985), a structural break (the megalineament) between the western terrane and the Central Gneiss Complex was established (Crawford and Hollister, 1982, 1983; Crawford and others, 1987). As discussed above for unit AMI (eTIK), intrusion of the synmetamorphic elongate sills along the west margin of the Central Gneiss Complex is interpreted to have had a causal relation to the proposed drastic uplift by greatly increasing crustal thickness in the region (Hollister, 1982), weakening the crust, and serving as a lubricant in the major shear zone along which the large and rapid vertical uplift took place (Hollister and Crawford, 1986; Crawford and others, 1987).

The boundary between this poorly studied metamorphic unit (AMI,L (eTIK)) in Alaska and the lithologically similar unit farther northwest (AMI (eTIK)) has been drawn to separate the northern rocks in which kyanite occurs (and, hence, intermediate-pressure conditions are indicated) from rocks of this unit in which kyanite has not been identified and for which intermediate- to low-pressure conditions are indicated by thermobarometric data on one sample and the limited occurrence of cordierite. Future identification of kyanite within unit AMI,L (eTIK) would not be unexpected, however, because relict kyanite (Crawford and Hollister, 1982, 1983) and unreacted kyanite (S.A. Gareau, oral commun., 1988) have been identified in rocks equivalent to this unit in British Columbia. Although the proposed metamorphic histories of both of these units involve the association of metamorphism with the Late Cretaceous and (or) early Tertiary intrusion of the tonalite sill, differences in interpretation, such as the duration and number of separate metamorphic episodes, between the Alaskan work to the north (unit AMI (eTIK)) (Brew, 1983; Douglass and Brew, 1985) and Alaskan work in this area (unit AMI,L (eTIK)) (R.L. Elliot, unpub. data, 1980), as well as Canadian work to the south (for example, Hollister, 1982; Crawford and Hollister, 1982, 1983; Crawford and others, 1987), also warrant at least a temporary boundary between these two similar units.

TECTONIC INTERPRETATION OF METAMORPHISM IN THE WESTERN METAMORPHIC BELT DURING LATE CRETACEOUS AND EARLY TERTIARY TIME

The tectonic environment of the widespread plutonometamorphic episode that occurred along the western edge of the Coast Mountains in early Late Cretaceous and early Tertiary time (affecting units of the western metamorphic belt with age designations of (IK) and (eTIK)) was dominated by crustal thickening due to the accretion of an outboard terrane(s) to the west. Exactly what was accreted is not agreed upon, however. Monger and others (1982, 1983) proposed that the plutonometamorphic belt developed as a welt resulting from the accretion of the amalgamated Wrangellia and Alexander terranes against the previously accreted Stikinia and other terranes in Cretaceous and Tertiary time. Brew and Ford (1983) interpreted stratigraphic and paleomagnetic evidence to suggest that the Alexander and Stikinia terranes were one and the same and that a rift developed in the megaterrane as it migrated northward. According to their model, that rift was filled with Gravina belt (Berg and others, 1972) flysch and volcanic rocks during Late Jurassic and Early Cretaceous time. Brew and Ford (1983) proposed that the plutonometamorphic belt formed as a result of the closure of the rift and the resultant crustal thickening during accretion of the Chugach terrane that lies to the west and southwest of the Alexander and Wrangellia terranes.

Workers in the southern extension of this metamorphic belt near Prince Rupert, British Columbia, concur with the terrane accretion model of Monger and others (1982). They have proposed that the crustal thickening resulted from west-directed tectonic stacking of crustal slabs along east-dipping thrusts, in places possibly lubricated by intrusion of melt (parent magma of intermediate, epidote-bearing plutons and sills) generated at the base of the crust (Hollister and Crawford, 1986; Crawford and others, 1987). Thrusts possibly correlative with those that were synchronous with 100- to 90-Ma plutonism near Prince Rupert have been identified on Revillagigedo Island in Alaska (M.L. Crawford, oral commun., 1987).

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Table 2.—*Metamorphic mineral-assemblage data*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)[1]	Contributors	Rock type[2]	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage[3]	Metamorphic facies indicated by given assemblage[4]	Metamorphic-facies unit in which assemblage occurs[4,5]	Sample No., if available
Skagway								
109	1	E.M. MacKevett	OT	AS	PL+CL+QZ+CA±HE±MU±EP	GNS	GNS (eKITR)	
109	2	-----do.-----	BA	AS	HO+BI+PL±HE	AMP	AMP (eKITR)	
109	3	-----do.-----	BA	AS	HO+QZ+PL±BI±HE±TR	AMP	-------do.-------	
109	4	-----do.-----	OT	AS	BI+QZ+MU±CA±CL±PL	GNS	GNS (eKITR)	
Mt. Fairweather								
116	1	D.A. Brew	BA	OC	HO	AMP	AMP (eTK)	
116	2	-----do.-----	PE	AS	GA+BI+QZ+CP	AMP	GNS/AMP (eTK)	66ABd709
116	3	-----do.-----	PE	AS	CP+QZ+KF+HO+BI+DI	AMP	AMP (eK)	
116	4	-----do.-----	PE	AS	BI+CL+QZ+CA+PL(?)	GNS	LPP (eKeJ)	
116	5	-----do.-----	PE	OC	QZ+BI+CP+GA+ST+AN	AML	GNS/AMP (eTK)	
116	6	-----do.-----	BA	OC	HO+CP+QZ	AMP	AMP (eTK)	
116	7	-----do.-----	PE	OC	QZ+BI+CP	AMP	GNS/AMP (eTK)	
116	8	-----do.-----	BA	OC	CP+HO	AMP	AMP (eK)	
116	9	-----do.-----	BA	OC	GA+HO+CP	AMP	-------do.-------	
116	10	-----do.-----	OT	AS	CP+QZ+SH+CL+CA+MU	AMP	-------do.-------	
116	11	-----do.-----	BA	OC	HO+CP	AMP	-------do.-------	
116	12	-----do.-----	CA	OC	CA+GA+WO	AMP	-------do.-------	
116	13	-----do.-----	BA	AS	HO+CP+QZ+CL+ZO+SH±BI	AMP	-------do.-------	
Juneau								
117	1	A.B. Ford	BA	AS	CP +HO+BI±QZ±EP±CA±GA±CZ±DI±SH	AMI	AMI (eTIK)	
117	1	-----do.-----	PE	AS	QZ+BI±WM±PL±CB±GA±ST±KY±SI	AMI	-------do.-------	
117	2	G.R. Himmelberg	PE	AS	QZ+MU+BI+GA+SI+PL	AMP	-------do.-------	
117	2	-----do.-----	PE	AS	MU+BI+SI+CN+PL	AMP	-------do.-------	
117	3	-----do.-----	PE	AS	QZ+MU+BI+GA+ST+KY+PL	AMI	-------do.-------	
117	4	-----do.-----	PE	AS	QZ+MU+CL+BI+GA+ST	AMP	-------do.-------	
117	4	-----do.-----	PE	AS	QZ+MU+BI+GA+ST+PL	AMP	-------do.-------	
117	5	-----do.-----	PE	AS	QZ+MU+CL+BI	GNS	GNI (eTIK)	
117	5	-----do.-----	PE	AS	QZ+MU+BI+GA+PL	GNS	-------do.-------	
117	6	-----do.-----	PE	AS	QZ+WM+CL+PL+CD	GNS	-------do.-------	68ABd145A
117	6	-----do.-----	PE	AS	WM+CL+PL+CD+BI+AM±QZ±CA	GNS	-------do.-------	68ABd159A,B
117	7	-----do.-----	PE	AS	QZ+MU+CL+BI	GNS	-------do.-------	
117	7	-----do.-----	PE	AS	QZ+MU+BI+EP+CA+DO	GNS	-------do.-------	
117	8	A.B. Ford	BA	AS	AB+CL+AC±CZ±CA±EP±BI±WM±ZO±QZ	GNS	-------do.-------	
117	8	-----do.-----	PE	AS	QZ+CB±AB±CL±WM	GNS	-------do.-------	
117	9	-----do.-----	BA	AS	HO+PL±BI±QZ±GA±SH±CA	AMI	AMI (eTIK)	
117	9	-----do.-----	PE	AS	QZ+BI+PL±GA±ST±KY±SI±WM±CB	AMI	-------do.-------	
117	9	-----do.-----	CA	AS	CA±DO±QZ±PL±DI±SC±HO±SH±TR	AMI	AMI (eTIK)	
117	10	-----do.-----	BA	AS	AC+PL+CL±EP±CZ±CA±QZ±SH±BI	GNS	GNI (eTIK)	
117	10	-----do.-----	PE	AS	QZ+BI+WM±CB	GNS	-------do.-------	
117	11	-----do.-----	BA	AS	AB+CL+EP±AC±QZ±PU±SH±CA	LPP?	LPP (eTIK)$_1$	
117	12	R.A. Loney	BA	AS	CL+EP+AB±QZ	GNS	GNS (eK)	
117	13	-----do.-----	PE	AS	WM+CL+AB±QZ	GNS	-------do.-------	
117	13	-----do.-----	OT	AS	AB+QZ+BI+CL±EP±GA±HO	GNS	-------do.-------	
117	14	D.A. Brew	PE	OC	AB+CA+CL+EP	LPP?	LPP (eKeJ)	56ALy26
117	15	-----do.-----	PE	AS	CL+EP+MU+AB+QZ	LPP?	-------do.-------	
117	16	-----do.-----	CA	AS	CA+DI+GA+WO	AMP	AMP (eK)	
117	17	R.A. Loney	BA	AS	CP+HO±QZ±BI	AMP	GNS,AMP (eK)	
Sitka								
124	1	D.A. Brew	BA	AS	EP+QZ+AB+ZO+SH±AC±HO	GNS	LPP,GNS (eTeK)	
124	2	-----do.-----	PE	OC	QZ+CP+KF+BI+MU±GA	AMP	AMP (eK)	
124	3	-----do.-----	BA	AS	EP+CL+CA+MU±AC	LPP?	LPP (eKeJ)	
124	4	-----do.-----	CA	OC	CA±DI±GA±EP±WO±TR	AMP	AMP (eK)	
124	5	-----do.-----	PE	AS	CA+CL+QZ+CM	LPP?	LPP (eKeJ)	
124	6	-----do.-----	BA	AS	MU+AB+EP+CL+CA±AC	LPP?	-------do.-------	
124	7	-----do.-----	PE	AS	CL+EP+AB+QZ	LPP?	-------do.-------	
124	8	-----do.-----	BA	AS	CP+HO±BI±QZ	AMP	AMP (eK)	
124	9	-----do.-----	BA	AS	QZ+EP+ZO+CL±PH±CA	GNS	LPP/GNS (eTITR)	
124	10	-----do.-----	BA	AS	CL+ZO+EP+PH+LU+AB±AC±TR	LPP	LPP/GNS (eTeK)	
124	11	-----do.-----	BA	AS	CL+ZO+EP+QZ+FS±PH	GNS	-------do.-------	
124	12	-----do.-----	PE	AS	QZ+EP+ZO±CL±BI	GNS	-------do.-------	

Table 2.—*Metamorphic mineral-assemblage data—Continued*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)[1]	Contributors	Rock type[2]	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage[3]	Metamorphic facies indicated by given assemblage[4]	Metamorphic-facies unit in which assemblage occurs[4,5]	Sample No., if available
124	13	D.A. Brew	BA	AS	EP+TR+GL+AB+QZ+BI	GNH	LPP/GNS (eTeK)	
124	14	-----do.-----	CA	AS	CA+GA+CL+AB+EP+QZ	GNS	-------do.-------	
124	15	-----do.-----	BA	AS	QZ+AB+CL+EP±AC±TR	GNS	LPP/GNS (eTlTR)	
124	16	-----do.-----	BA	AS	AB+CL+TA+EP+QZ+PH	LPP?	LPP,GNS (eTeK)	
124	17	-----do.-----	BA	AS	AB+EP+CL	GNS	LPP/GNS (eTlTR)	
124	18	-----do.-----	BA	AS	AB+TR+CL+EP±QZ±PH	GNS	-------do.-------	
124	19	-----do.-----	BA	AS	AC+CP+MI+CL+EP±PH	GNS	-------do.-------	
124	20	-----do.-----	BA	AS	EP+TR+AB+CL	GNS	LPP,GNS (eTeK)	
124	21	-----do.-----	BA	AS	MI+CL+CA+QZ+AB	GNS	-------do.-------	
124	22	-----do.-----	PE	AS	AB+QZ+CL+MU+GA+ZO	GNS	-------do.-------	
124	23	-----do.-----	BA	AS	EP+CL+CA+AB+CS+SH	GNH	-------do.-------	
124	24	-----do.-----	PE	OC	CL+EP+AB+MI	LPP?	-------do.-------	
124	25	-----do.-----	BA	AS	EP+AC+CL+AB+QZ	GNS	LPP/GNS (eTlTR)	
124	26	-----do.-----	BA	AS	EP+CL+AB+PH+CM±CA	LPP?	LPP,GNS (eTeK)	
124	26	-----do.-----	PE	AS	CL+EP+PH+CA+MU+CM	LPP?	-------do.-------	
124	27	-----do.-----	PE	AS	QZ+AB+MU+AC+EP+CL±HO	GNS	LPP/GNS (eTlTR)	
124	28	-----do.-----	PE	AS	CL+MU+QZ+PL	GNS	LPP,GNS (eTeK)	
124	29	-----do.-----	BA	AS	CP+HO	AMP	AMP (eKlTR)	
124	30	-----do.-----	BA	AS	QZ+CP+BI+HO+GA	AMP	-------do.-------	
124	31	-----do.-----	CA	AS	CP+DI+ZO	AMP	-------do.-------	
124	32	-----do.-----	BA	AS	AB+MU+CL+EP+PH	LPP	LPP,GNS (eTeK)	
124	33	R.A. Loney	BA	AS	CL+EP+CA+TA±TR±AB±QZ	GNS	GNS (eK)	
124	33	-----do.-----	PE	AS	CL+WM+AB+QZ	GNS	-------do.-------	
124	34	D.A. Brew	PE	AS	QZ+AB+MU+CL±EP±PH	LPP	LPP,GNS (eTeK)	
124	35	-----do.-----	PE	AS	AB+CL+MU+QZ	LPP	-------do.-------	
124	36	-----do.-----	PE	AS	(2) BI+QZ+AB+EP+CL+MU±CP	GNS	LPP,GNS (eTeK) + GNL (eT)	61APy641
124	37	-----do.-----	PE	AS	(2) QZ+CP+BI+GA+TO+CO+MU	AMP	LPP,GNS (eTeK) + AML (eT)	61ABd709
124	38	-----do.-----	BA	AS	AM+AB+EP+MU+PH+QZ+CA±CL	LPP	LPP,GNS (eTeK)	
124	39	-----do.-----	PE	AS	QZ+AB+AC+CL±PH	LPP	-------do.-------	
124	40	-----do.-----	PE	AS	QZ+CL+CA±MU±EP±SH±AB	LPP?	LPP,GNS (eTeK)	60ABg564
124	41	-----do.-----	OT	AS	(2) QZ+CP+BI+MU+GA	AMP	LPP,GNS (eTeK) + AML (eT)	62ALy247
124	42	-----do.-----	PE	AS	(2) QZ+CP+BI	AMP	LPP,GNS (eTeK) + AML (eT)	62ABd338A
124	43	-----do.-----	BA	AS	(2) QZ+CP+BI+HO+GA	AMP	-------do.-------	62ALy230
124	44	-----do.-----	PE	AS	(2) QZ+CP+BI+MU+GA+ST+SI+TO	AMP	-------do.-------	62ABd316
124	45	-----do.-----	BA	AS	(2) QZ+CP+BI+HO	AMP	-------do.-------	62AMp230
124	46	-----do.-----	PE	AS	(2) QZ+CP+BI+GA	AMP	-------do.-------	62APy293
Sumdum								
125	1	R.A. Loney	BA	AS	AB+AC+EP+CL+CA±SH±QZ	GNS	LPP (eK)	
125	2	-----do.-----	PE	AS	CL+CA+WM±EP±PH	LPP?	-------do.-------	
125	3	S.L. Douglass	OT	AS	BI+CL+CZ+PL+AC+SH	GNS	GNI (eTlK)	
125	4	-----do.-----	OT	AS	QZ+MU+BI+EP+CL+PL	GNS	-------do.-------	
125	5	-----do.-----	PE	AS	QZ+MU+BI+PL	AMP	AMI (eTlK)	
125	6	-----do.-----	PE	AS	QZ+MU+BI+ST+PL+CL	AMP	-------do.-------	
125	7	-----do.-----	PE	AS	QZ+PL+ST+GA+BI+CL	AMP	-------do.-------	
125	8	-----do.-----	PE	AS	QZ+PL+ST+GA+BI+CL	AMP	-------do.-------	
125	9	-----do.-----	OT	AS	QZ+PL+BI+GA+HO+EP+CL	AMP	-------do.-------	
125	10	-----do.-----	OT	AS	QZ+PL+HO+EP+CL	AMP	GNI (eTlK)	
125	11	-----do.-----	OT	AS	BI+QZ+MU+CL	GNS	-------do.-------	
125	12	-----do.-----	OT	OC	BI+HO+CL	AMP	GNI (eTlK)	
125	13	-----do.-----	OT	OC	BI+AC+CL	GNS	-------do.-------	
125	14	-----do.-----	OT	OC	GA+BI+HO	AMP	AMI (eTlK)	
125	15	L.J.P. Muffler	PE	AS	AB+QZ+MU+CL+CA±EP	GNS	LPP/GNS (mK)	
125	16	-----do.-----	BA	AS	CL+AB+QZ+MU+EP±KF±CA	GNS	-------do.-------	
125	17	S.L. Douglass	OT	OC	QZ+BI	GNS	GNI (eTlK)	
125	18	-----do.-----	OT	OC	GA+KY+BI	AMI	AMI (eTlK)	
125	19	-----do.-----	OT	OC	GA+BI+HO	AMP	-------do.-------	
125	20	-----do.-----	OT	AS	CL+WM+QZ	LPP	LPP/GNS (mK)	
125	21	-----do.-----	OT	AS	GA+QZ+MU+PL	AMP	AMI (eTlK)	
125	22	-----do.-----	CA	AS	DI+QZ+BI+SC+SH	AMP	-------do.-------	
Port Alexander								
130	1	D.A. Brew	PE	AS	QZ+AB+CL+MU+EP±PH±SH	LPP	LPP,GNS (eTeK)	61ABd344
130	2	-----do.-----	PE	AS	(2) CP+QZ+CL+BI+MU+EP±SH±CA±TO	GNS	-------do.-------	61ABg345 61APy312

Table 2.—*Metamorphic mineral-assemblage data—Continued*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)^1	Contributors	Rock type^2	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage^3	Metamorphic facies indicated by given assemblage^4	Metamorphic-facies unit in which assemblage occurs^{4,5}	Sample No., if available
130	3	D.A. Brew	BA	AS	(2) EP+CA+AC±AB±CP	GNS	LPP,GNS (eTeK) + GNL (eT)	63ABd26B
130	4	-----do.-----	PE	AS	(2) CP+QZ+BI+CO+MU	GNS	-------do.-------	62ABd33 61APy319A
130	5	-----do.-----	PE	AS	QZ+AB+CA+EP+CL+SH±PH	LPP	LPP,GNS (eTeK)	62ABd302
130	6	-----do.-----	PE	AS	(2) CP+QZ+BI+CA+EP+MU	GNS	LPP,GNS (eTeK) + GNL (eT)	63AMp15 63AMp23
130	6	-----do.-----	PE	AS	(2) QZ+CP+BI+MU+CL±EP	GNS	-------do.-------	63AMp14 63AMp13
130	7	-----do.-----	PE	AS	(2) QZ+CP+BI+MU+GA+SI+TO	AMP	LPP,GNS (eTeK) + AML (eT)	63AMp244
130	8	-----do.-----	PE	AS	(2) QZ+CP+BI+GA+ST+SI±TO	AMP	-------do.-------	62ALy319A
130	9	-----do.-----	PE	AS	(2) QZ+CP+BI+GA±TO	AMP	-------do.-------	62ALy317
130	10	-----do.-----	BA	AS	(2) QZ+AB+HO+EP±CL	AMP	LPP,GNS (eTeK) + GNL (eT)	63AMp340B
130	11	-----do.-----	BA	AS	QZ+CP+HO+BI±GA±TO	AMP	LPP,GNS (eTeK) + AML (eT)	62ABd426
130	12	-----do.-----	PE	AS	(2) QZ+CP+BI+CO+MU+GA±AN±KF	AML	LPP,GNS (eTeK) + GNL (eT)	62ABd448
130	13	-----do.-----	BA	AS	(2) AC+EP+CL+CA±SH	GNS	-------do.-------	62APy195A
130	14	-----do.-----	PE	AS	(2) BI+QZ+CP+KF+SI±OP	2PX?	LPP,GNS (eTeK) + AML (eT)	63AMp37
130	15	-----do.-----	PE	AS	(2) CP+QZ+BI+AN+MU	AML	-------do.-------	62ABd82
130	16	-----do.-----	PE	AS	(2) QZ+BI+AB+EP+SH+MU+CA	GNS	LPP,GNS (eTeK) + GNL (eT)	62ABd109
130	17	-----do.-----	PE	AS	(2) AB+QZ+BI+CL+EP+GA+TO	GNS	-------do.-------	63AMp41
130	18	-----do.-----	PE	AS	(2) BI+QZ+CP+ST+AN+GA+MU+TO	AML	-------do.-------	62ALy132A
130	19	-----do.-----	BA	AS	AB+MU+AC+EP±PH±CL	LPP	LPP,GNS (eTeK)	62ABd193D
130	20	-----do.-----	PE	AS	(2) QZ+AB+BI+MU+EP+TO	GNS	LPP,GNS (eTeK) + GNL (eT)	62AMp52
130	21	-----do.-----	PE	AS	(2) QZ+AB+BI+MU	GNS	-------do.-------	62ALy66
130	22	-----do.-----	PE	AS	(2) AB+BI+QZ+EP+MU±TO±SH	GNS	-------do.-------	63AMp108
130	23	-----do.-----	PE	AS	(2) CP+QZ+BI+EP+CL+GA+TO±MU±SH	GNS	LPP,GNS (eTeK) + AML (eT)	63ABd108
130	24	-----do.-----	PE	AS	(2) QZ+BI+MU+CP+CO+TO±CL	AMP	-------do.-------	63ABd50
130	25	-----do.-----	PE	AS	(2) QZ+AB+BI+MU+EP+CL±CA±SH±TO	GNS	LPP,GNS (eTeK) + GNL (eT)	62ALy103
130	26	-----do.-----	BA	AS	(2) AC+QZ+AB+SH+EP+BI	GNS	-------do.-------	62ABd169
130	27	-----do.-----	PE	AS	(2) QZ+CP+BI+MU+GA+ST+CL+TO	AMP	LPP,GNS (eTeK) + AML (eT)	62ABd52
Petersburg								
131	1	S.L. Douglass	OT	AS	BI+CZ+CL+QZ+PL	GNS	LPP/GNS (mK)	80EK141A
131	2	-----do.-----	OT	AS	(1) PL+QZ+CL+WM (2) BI+CZ+QZ+PL+AC+WM	GNS GNS	-------do.-------	80SK582A
131	3	-----do.-----	OT	AS	EP+CL+WM+QZ+PL	LPP/GNS	-------do.-------	80SK584A
131	4	-----do.-----	OT	AS	GA+EP+BI+QZ+PL+HO+CL	GNS	GNI (eTIK)	81RK300A
131	4	-----do.-----	CA	AS	GA+EP+QZ+CA+PL+CL	GNS	-------do.-------	81RK300B
131	5	-----do.-----	OT	AS	MU+PL+CL+BI+QZ+GA+EP	GNS	-------do.-------	81RK303A
131	6	-----do.-----	OT	AS	AC+SH+CL+EP+PL+MU+CA+QZ	GNS	-------do.-------	81RK297A
131	7	-----do.-----	PE	AS	(1) KY+ST+GA+PL+QZ+BI+MU (2) BI+EP+CL+QZ	AMI GNS	AMI (eTIK)	81SK157B
131	8	-----do.-----	PE	AS	(1) KY+GA+PL+HO+QZ+BI+MU (2) CL+EP+BI+SH	AMI GNS	-------do.-------	81SK156A
131	9	-----do.-----	PE	AS	QZ+MU+KY+ST+PL	AMI	-------do.-------	79DB202A
131	10	-----do.-----	PE	AS	CL+WM	GNS	GNI (eTIK)	81SH076A
131	11	-----do.-----	PE	AS	SI+BI+QZ+CP+GA+CO(?)	AMP	AMI (eTIK)	79AF123
131	12	-----do.-----	PE	AS	ST+KY+GA+CP+QZ+BI	AMI	-------do.-------	81TM092
131	13	-----do.-----	PE	AS	(1) KY+MU+BI+ST+QZ+CP+GA (2) BI+PL+QZ+CL+MU+SH	AMI GNS	AMI (eTIK)	81TM088A
131	14	-----do.-----	OT	AS	CZ+MU+GA+CL+BI+PL+QZ	GNS	GNI (eTIK)	81TM005A
131	15	-----do.-----	OT	AS	QZ+WM+EP+CL	GNS	-------do.-------	81SH096A
131	16	-----do.-----	OT	AS	CL+CA+SH+WM+CB+EP+QZ+PL+BI	GNS	-------do.-------	81PB055A
131	17	-----do.-----	PE	OC	KY+GA+BI+CP+QZ	AMI	AMI (eTIK)	81RK309
131	18	-----do.-----	PE	AS	CP+QZ+SI+MU+BI	AMP	-------do.-------	78RM246
131	19	-----do.-----	PE	AS	GA+CP+QZ+BI+MU+KY	AMI	-------do.-------	81DB122
131	20	-----do.-----	PE	AS	(1) CP+KF+BI+GA+SI (2) CL+WM+BI	AMP GNS	-------do.-------	82DB213B

Table 2.—*Metamorphic mineral-assemblage data*—*Continued*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)[1]	Contributors	Rock type[2]	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage[3]	Metamorphic facies indicated by given assemblage[4]	Metamorphic-facies unit in which assemblage occurs[4,5]	Sample No., if available
131	20	S.L. Douglass	BA	AS	(1) HO+GA+CP+QZ+CB (2) AC+EP+CL+QZ	AMP GNS	AMI (eTlK)	82DB213D
131	21	-----do.-----	PE	AS	(1) BI+CL+GA+QZ+PL+CB (2) BI+CL+QZ+MU+CD	GNS GNS	-------do.-------	82SK094A
131	22	-----do.-----	PE	AS	(1) QZ+BI+GA+PL+CB (2) CL+MU+BI+EP	GNS GNS	GNL→I (lK) + GNI (eTlK)	78DB250A
131	23	-----do.-----	PE	AS	(1) BI+QZ+PL+CB+GA+MU (2) BI+QZ+PL+CL+MU	GNS GNS	-------do.-------	78AF173A
131	24	-----do.-----	CA	AS	(1) HO+QZ+PL+CA+EP+CB (2) HO+QZ+PL	AMP AMP	-------do.-------	81TM105B
131	25	-----do.-----	BA	AS	HO+CZ+BI+QZ+CA+PL	AMP	-------do.-------	81SH080A
131	26	-----do.-----	PE	AS	(1) BI+QZ+MU+CL+CB+AB (2) BI+GA+EP+CL	GNS GNS	-------do.-------	82SH092A
131	27	-----do.-----	PE	AS	(2) SI+KY+GA+ST+QZ+MU+CP+BI+CB	AMI	LPP/GNS (mK) + GNL→I (lK)	81DB096A
131	28	-----do.-----	PE	AS	(2) KY+SI+AN+BI+QZ+PC+GA+MU+CB	AMI	-------do.-------	82DB105B
131	29	-----do.-----	PE	AS	(1) WM+QZ+CL (2) BI+CL+AB+QZ+MU	LPP/GNS GNS	-------do.-------	82RK803A
131	30	-----do.-----	PE	AS	(1) MU+BI+QZ+AB+EP (2) GA+BI+QZ	GNS GNS	-------do.-------	82DB218B
131	31	-----do.-----	PE	AS	(1) WM+CB+CL+EP+CA+QZ (2) BI+CL+QZ+AB	LPP/GNS GNS	-------do.-------	79RS001A
131	32	-----do.-----	PE	AS	(2) AN+SI+ST+GA+BI+MU+QZ	AMP	-------do.-------	78RS117C
131	33	-----do.-----	PE	AS	SI+MU+BI+QZ+CP±AN	AML	AMI (lK)	78RM270B
131	34	-----do.-----	PE	AS	KY+ST+BI+MU+QZ	AMI	-------do.-------	82RK791A$_2$
131	35	-----do.-----	PE	AS	KY+QZ+ST+BI+CP+GA±AN	AMI	-------do.-------	82RK786B
131	36	-----do.-----	PE	AS	KY+GA+ST+BI+CL+CP+MU+QZ	AMI	-------do.-------	81RK321C
131	37	-----do.-----	PE	AS	SI+BI+ST+MU+GA+QZ+CP	AMP	-------do.-------	81SH122A
131	38	-----do.-----	OT	AS	(1) WM+QZ+CL+CB (2) ST+BI+GA+QZ+PL+CL+CB	LPP/GNS AMP	LPP/GNS (mK) + GNL→I (lK)	82PB104A
131	39	-----do.-----	OT	AS	(1) CL+WM+QZ+CB+AB (2) BI+GA+QZ+AB	LPP/GNS GNS	-------do.-------	82SK117A
131	40	-----do.-----	PE	AS	(2) QZ+MU+BI+CB±AN	AMP	-------do.-------	78DB154A
131	41	-----do.-----	PE	AS	(1) BI+QZ+CP+ST+CB (2) CL+MU+CA	AMP LPP/GNS	AMI (lK)	82PB110
131	42	-----do.-----	PE	AS	(1) BI+QZ+CP+GA+KY (2) CL+MU	AMI LPP/GNS	-------do.-------	82RK820A
131	43	-----do.-----	PE	AS	BI+GA+ST+AM+QZ+PL	AMP	-------do.-------	82PB114A
131	44	-----do.-----	CA	AS	(1) CP+QZ+HO+GA+DI (2) ZO+GA+SH	AMI	-------do.-------	82DB248B
131	44	-----do.-----	PE	AS	(1) BI+QZ+GA+SI+PL (2) CL+MU	AMI LPP/GNS	-------do.-------	83DB248A
131	45	-----do.-----	PE	AS	(1) PL+BI+QZ+KY+GA+SI (2) MU+CL	AMI LPP/GNS	-------do.-------	82SK136A
131	46	-----do.-----	PE	AS	(1) QZ+CP+BI+KY+GA+ST+SI (2) MU+CL	AMI LPP/GNS	-------do.-------	81TM138A
131	46	-----do.-----	CA	AS	(1) QZ+HO+GA+DI (2) CA+QZ+AM+GA+ZO+SH	AMI GNS	-------do.-------	81TM138C
131	47	-----do.-----	PE	AS	(1) QZ+BI+CP+ST (2) CL+MU	AMP LPP/GNS	-------do.-------	81SK190A
131	48	-----do.-----	PE	AS	QZ+BI+CP+KY+SI+ST+GA	AMI	-------do.-------	81SK140A
131	49	-----do.-----	BA	AS	BI+CP+QZ+HO+EP	AMP	-------do.-------	82KR105A
Bradfield Canal								
132	1	R.L. Elliott	PE	OC	AN+SI	AML	AMI (eTlK)	79RS335
132	2	-----do.-----	PE	AS	GA+CO+SI+MU+KF	AMP	AMI,L (eTlK)	79MH138
132	3	-----do.-----	PE	AS	AN+SI+GA	AML	-------do.-------	79SK639
132	4	-----do.-----	PE	OC	KY+GA	AMI	AMI (lK)	79ER224
132	5	-----do.-----	BA	OC	CU+PX	AMP	-------do.-------	79DB730

Table 2.—*Metamorphic mineral-assemblage data—Continued*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)[1]	Contributors	Rock type[2]	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage[3]	Metamorphic facies indicated by given assemblage[4]	Metamorphic-facies unit in which assemblage occurs[4,5]	Sample No., if available
132	5	R.L. Elliott	PE	AS	GA+SI+CO(?)	AMP	AMI (IK)	78RM413 79DB368
132	6	-----do.-----	BA	OC	GA+CU/HO	AMP	-------do.-------	78RM414
132	7	-----do.-----	PE	OC	MU+CO(?)	AMP	AMI,L (eTIK)	79SK707
132	8	-----do.-----	PE	AS	GA+SI+HR+KF+CO(?)	AMP	-------do.-------	78ER119
132	8	-----do.-----	BA	OC	CU	AMP	-------do.-------	79DB354
132	9	-----do.-----	PE	AS	GA+MU+SI(?)	AMP	AMI (IK)	79MH174
132	10	-----do.-----	PE	OC	SI	AMP	AMI,L (eTIK)	79RK295
132	11	-----do.-----	BA	AS	CX+CU/HO	AMP	-------do.-------	79ER071
132	12	-----do.-----	BA	OC	CU/HO	AMP	-------do.-------	79ER070 79JD959
132	13	-----do.-----	PE	AS	GA+KY+SI	AMI	AMI (IK)	79SK676
132	14	-----do.-----	PE	AS	SI+MU+GA	AMI	-------do.-------	79RK169 79RK170
132	15	-----do.-----	PE	AS	MU+GA+KY	AMI	-------do.-------	79MH186
132	16	-----do.-----	PE	AS	GA+KY+SI	AMI	-------do.-------	78SK394 79ER192
132	17	-----do.-----	PE	AS	CO+GA+HR+SI	AMP	AMI,L (eTIK)	78ER165
132	18	-----do.-----	BA	AS	CU+CX+HO	AMP	-------do.-------	79ER066
132	19	-----do.-----	PE	AS	GA+CO+MU	AMP	-------do.-------	79JD882
132	20	-----do.-----	PE	AS	GA+SI+CO(?)	AMP	AMI (IK)	79ER193
132	21	-----do.-----	BA	OC	CU/HO	AMP	AMI,L (eTIK)	79ER064
132	22	-----do.-----	PE	AS	CO+KF	AMP	-------do.-------	79JD886
132	22	-----do.-----	PE	AS	GA+SI+CO+KF+HR	AMP	-------do.-------	79JD886
132	23	-----do.-----	BA	OC	GA+CU	AMP	-------do.-------	79GJ068
132	24	-----do.-----	PE	AS	GA+SI+CO+KF	AMP	-------do.-------	79SK763
132	25	-----do.-----	BA	OC	CX+CU/HO	AMP	-------do.-------	79ER029
132	25	-----do.-----	BA	OC	CX+CU	AMP	-------do.-------	79ER027
132	26	H.C. Berg	BA	AS	BI+AC+PL+QZ±CL±EP±SH±GA±PH±CA	GNS	GNS (eTIJ)	
132	27	R.L. Elliott	PE	OC	SI	AMP	AMI,L (eTIK)	79RK057
Craig								
136	1	G.D. Eberlein	OT	AS	AB+CL+EP±CA±QZ	GNS ?	LPP (DS)	
136	1	-----do.-----	OT	AS	AB+CL+EP±CA±AC	GNS	-------do.-------	
136	2	-----do.-----	OT	AS	PL+CL±EP±WM±BI±CA	GNS	GNS (O€) + LPP (DS)	
136	2	-----do.-----	BA	AS	AC+CL+AB+EP±CA±QZ	GNS	-------do.-------	
136	3	T.K. Bundtzen	OT	AS	(1) HO+CP+GA+QZ	AMP	-------do.-------	72C149
136	4	G.D. Eberlein	CA	AS	CA±AM±BI	GNS	-------do.-------	
136	4	-----do.-----	BA	AS	AB+EP+CL±MU±CA	GNS	-------do.-------	
136	4	-----do.-----	OT	AS	QZ+WM+CB±CA±AM±CL	GNS	-------do.-------	
136	4	-----do.-----	BA	AS	ZO+WM+AM+EP+CL±QZ±FS	GNS	-------do.-------	
136	5	-----do.-----	OT	AS	QZ+AB+CA+CL±WM	GNS	-------do.-------	
136	5	-----do.-----	OT	AS	QZ+AB+CL+CA±EP	GNS	-------do.-------	
136	6	T.K. Bundtzen	BA	AS	AC+AB+BI+CL+QZ	GNS	LPP (DS)	DT72-51A
136	6	-----do.-----	BA	AS	TR+AB+BI+WM+CL	GNS	-------do.-------	DT72-51C
136	7	G.D. Eberlein	OT	AS	QZ+AB±WM	GNS	-------do.-------	
136	7	-----do.-----	OT	AS	QZ+AN+WM+CL±SH	GNS	-------do.-------	
136	7	-----do.-----	OT	AS	QZ+AB+CL±WM±EP±SH	GNS	-------do.-------	
136	7	-----do.-----	BA	AS	CL+AB+EP±WM±QZ±SH	GNS	-------do.-------	
136	8	-----do.-----	BA	AS	AB+CZ+CL+WM+QZ±EP	GNS	LPP (DS)	
136	9	-----do.-----	OT	AS	QZ+AB±SH±BI±CA±AM	GNS	GNS (O€ + LPP (DS)	
136	10	-----do.-----	CA	AS	CA±QZ	GNS	-------do.-------	
136	10	-----do.-----	OT	AS	QZ+AB+CL+EP±HO±GA	GNS	-------do.-------	
136	10	-----do.-----	OT	AS	CL+CA	GNS	-------do.-------	
136	11	-----do.-----	BA	AS	AB+EP+CL+QZ±AC	GNS	-------do.-------	
136	11	-----do.-----	OT	AS	QZ+WM±CL±EP	GNS	-------do.-------	
136	12	-----do.-----	OT	AS	QZ+AB+EP+CL±SH	GNS	-------do.-------	
136	13	-----do.-----	BA	AS	AB+CL+EP+PL±SH±QZ	GNS	-------do.-------	
Ketchikan								
137	1	M.L. Crawford	PE	AS	BI+GA+QZ+MU+PL+KY+SI	AMI	AMI (IK)	
137	2	-----do.-----	PE	AS	KY+ST+GA+PL+BI+MU+QZ	AMI	-------do.-------	
137	2	-----do.-----	PE	AS	BI+GA+QZ+KY+ST	AMI	-------do.-------	
137	2	-----do.-----	BA	AS	QZ+CZ+HO+BI+CA	AMI	-------do.-------	
137	3	J.G. Smith	PE	AS	PL+QZ+BI+GA+±KY	AMI	-------do.-------	
137	3	-----do.-----	BA	AS	PL+HO±GA	AMI	-------do.-------	
137	4	M.L. Crawford	PE	AS	BI+QZ+KY+PL+MU	AMI	-------do.-------	
137	4	-----do.-----	CA	AS	HO+GA+SH+CP+QZ+DI	AMI	-------do.-------	
137	5	H.C. Berg	PE	AS	CP+QZ+BI±KF±GA±SI±MU±HO±SH	AMP	AMI,L (eTIK)	
137	6	M.L. Crawford	PE	AS	SI+GA+BI+QZ+PL	AMP	-------do.-------	

Table 2.—*Metamorphic mineral-assemblage data—Continued*

Quadrangle name and reference No. (plates 1,2)	Locality No. (plate 2)[1]	Contributors	Rock type[2]	Assemblage (AS) or occurrence (OC)	Metamorphic mineral assemblage[3]	Metamorphic facies indicated by given assemblage[4]	Metamorphic-facies unit in which assemblage occurs[4,5]	Sample No., if available
137	6	M.L. Crawford	PE	AS	BI+GA+SI+MU+QZ+PL	AMP	AMI,L (eTIK)	
137	7	J.G. Smith	PE	AS	PL+QZ+BI+MU±GA	GNS	GNS (K)	
137	8	M.L. Crawford	PE	AS	QZ+MU+BI+PL+GA+SI	AMP	AMI,L (eTIK)	
137	9	J.G. Smith	PE	AS	QZ+PL+BI+GA±SI	AMP	-------do.-------	
137	10	M.L. Crawford	PE	AS	QZ+MU+BI+PL+SI+CB	AMP	-------do.-------	
137	11	J.G. Smith	CA	OC	QZ+CA±TR±PY	AMP	AMI (IK)	
137	11	-----do.-----	BA	AS	PL+HO+BI±QZ±GA	AMP	-------do.-------	
137	12	M.L. Crawford	CA	AS	QZ+PL+SH+ZO+TR+BI+MU	GNS/AMP	-------do.-------	
137	13	M.L. Crawford	CA	AS	QZ+GA+EP+BI+CL+MU	GNS	GNS (K)	
137	14	-----do.-----	CA	AS	MU+SH+CA+DO+QZ+ZO+CL	GNS	-------do.-------	
137	15	-----do.-----	BA	AS	HO+QZ+PL+ZO	AMP	AMI (IK)	
137	16	J.G. Smith	PE	AS	QZ+BI+MU+GA	AMP	-------do.-------	
137	16	-----do.-----	BA	AS	PL+HO+EP+BI±GA±PY	AMP	-------do.-------	
137	17	H.C. Berg	BA	AS	AB+AC+CL+EP+CZ+QZ+MU+PH	GNS	GNS (K)	
137	18	-----do.-----	BA	AS	(1) AC+CL+EP+AB+MU+QZ±CA±HE (2) AB+MU+EP+CZ+CA+QZ+HE+KF+CM+PH	GNS GNS	GNS (DS) + GNS (K)	
137	19	-----do.-----	BA	AS	(1) AB+CL+EP+CZ+AC±QZ±MU±CA±BI	GNS	-------do.-------	
137	20	-----do.-----	BA	AS	(1) CL+MU±AB±QZ±BI±CA±AC±KF (2) AB+QZ+EP+CZ±CL±MU±PH±CA±AC	GNS GNS	-------do.-------	
137	21	J.G. Smith	PE	AS	QZ+MU+BI+GA	GNS	GNS (K)	
137	22	-----do.-----	PE	AS	MU+BI+PL+QZ+GA	AMP	-------do.-------	
137	22	-----do.-----	BA	AS	HO+PL+EP+SH±BI	AMP	-------do.-------	
137	23	M.L. Crawford	PE	AS	BI+GA+MU+KY+ST+QZ+PL	AMI	AMI (IK)	
137	24	-----do.-----	BA	AS	GA+BI+HO+QZ+PL	AMP	-------do.-------	
137	25	J.G. Smith	PE	AS	CP+QZ+BI+GA+KY	AMI	-------do.-------	
137	25	-----do.-----	BA	AS	CP+BI+HO±QZ±GA	AMP	-------do.-------	
137	26	-----do.-----	PE	AS	CP+QZ+BI+GA±SI	AMP	AMI,L (eTIK)	
137	27	M.L. Crawford	PE	OC	SI+GA+QZ+BI	AMP	AMI (IK)	
137	28	-----do.-----	PE	AS	(1) QZ+PL+GA+KY+MU+SI	AMI	-------do.-------	
137	28	-----do.-----	PE	AS	KY+ST+GA+PL+BI+MU+QZ	AMI	-------do.-------	
Prince Rupert								
142	1	H.C. Berg	CA	OC	AB+QZ+CL+CA+MU	GNS	GNS (K)	
142	2	J.G. Smith	BA	AS	AB+CL+EP+QZ+CA+SH	GNS	GNS (DS) + GNS (K)	
142	3	-----do.-----	PE	AS	QZ+PL+BI+MU±GA	AMP	AMI (IK)	
142	3	-----do.-----	BA	AS	HO+PL+BI+GA	AMP	-------do.-------	
142	4	M.L. Crawford	PE	AS	BI+QZ+PL+GA+MU+SI	AMP	AMI,L (eTIK)	
142	5	J.G. Smith	PE	AS	PL+QZ+BI±GA	AMP	-------do.-------	
142	6	M.L. Crawford	PE	AS	KY+GA+BI+QZ+PL	AMI	AMI ((IK)	
142	7	-----do.-----	BA	AS	QZ+BI+HO+GA+PL+DI	AMI	-------do.-------	

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[1] Localities numbered consecutively within each 1:250,000-scale quadrangle.

[2] Rock types: BA, basic; CA, calcic; OT, other; PE, pelitic.

[3] Metamorphic minerals, arranged in order of decreasing abundance:

AB,	albite (An 0-10)
AC,	actinolite
AM,	amphibole
AN,	andalusite
BI,	biotite
CA,	carbonate
CB,	carbonaceous and (or) graphitic material
CD,	chloritoid
CL,	chlorite
CM,	clay minerals
CN,	corundum
CO,	cordierite
CP,	calcic plagioclase (An 11-100)
CS,	crossite
CU,	cummingtonite
CX,	clinopyroxene
CZ,	clinozoisite
DI,	diopside
DO,	dolomite
EP,	epidote
FS,	feldspar
GA,	garnet
GL,	glaucophane
HE,	ematite
HO,	hornblende
HR,	hercynite
KF,	potash feldspar
KY,	kyanite
LU,	laumontite
MI,	mica
MU,	muscovite
OP,	orthopyroxene
PH,	prehnite
PL,	plagioclase (An 0-100)
PU,	pumpellyite
PX,	pyroxene
PY,	pyrophyllite
QZ,	quartz
SC,	scapolite
SH,	sphene
SI,	sillmanite
ST,	staurolite
TA,	talc
TO,	tourmaline
TR,	tremolite
WM,	white mica
WO,	wollastonite
ZO,	zoisite

(1) First phase of a polymetamorphic episode or early phase of a single evolving metamorphic episode (shown by arrow).

(2) Second phase of a polymetamorphic episode, late phase of an evolving metamorphic episode (shown by arrow), or subsequent recrystallization due to an event not shown on map.

[4] Refer to text for explanation of symbols.

[5] In a few cases, the area of the metamorphic-facies unit in which assemblage occurs is too small to show on map.

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