

DESCRIPTION OF MAP UNITS Metaplutonic rocks Uranatina River metaplutonic unit (Jurassic and Pennsylvanian)-(Structure symbols shown on some Quaternary units refer to structures measured on outcrops Compositionally diverse, strongly schistose to blastomylonitic too small to show at map scale] metaplutonic rocks metamorphosed to low-greenschist facies. The ALL TERRANES unit forms the younger part of the Haley Creek metamorphic assemblage Unconsolidated deposits (Quaternary)—Diverse unconsolidated surfiof Plafker and others (1989) and was informally referred to as the cial deposits of mainly Holocene age, except for deposits of glacial Uranatina River metaplutonic assemblage by Wallace (1981). The Lake Ahtna and ice-contact morainal deposits that formed during unit makes up about 80 percent of the Wrangellia terrane in the both the latest major glaciation (Wisconsin) and the younger Alaska map area and is widely distributed along strike east of the Taral glaciation and lahar deposits from the Wrangell Mountains, about fault in the southern Chitina River valley about 10 km east of the 50 km to the northeast. Distribution and character of these deposits map area (Winkler and others, 1981c). The unit includes volumetrically is taken mainly from Nichols and Yehle (1969) and Williams and minor amounts of Pennsylvanian metagranodiorite and more abundant Johnson (1981) with minor modifications of ice-bedrock contacts. compositionally variable Mesozoic metaplutonic rocks, which range The chronology of glacial and glaciolacustrine sequences in the Copper in composition from ultramafic to trondhiemitic but are an estimated River basin was discussed in detail by Williams and Johnson (1981) 80 percent gneissic hornblende diorite, quartz diorite, and tonalite. and Ferrians and others (1983). The deposits consist of: Deformation took place under brittle-ductile transition conditions Alluvium (Holocene) characterized by quartz-dominated ductile flow in the more siliceous rocks and by brittle cataclastic failure in adjacent more mafic rocks Landslide deposits (Holocene) (Nokleberg and others, 1989; Pavlis and Crouse, 1989). The Pennsylvanian blastomylonitic metagranodiorite (Pg) is Alluvial fan deposits (Holocene dated by U-Pb zircon analysis at 309±11 Ma (table 1, No. 2). The metagranodiorite is coeval and probably comagmatic with variably Deltaic deposits (Holocene) metamorphosed to unmetamorphosed granodiorite, metagranite, monzonite, and syenite plutons that are widely distributed to the Terrace gravel (Holocene) east and north in the Chitina River valley and southern Wrangell Talus-cone deposits (Holocene) Mountains (Aleinikoff and others, 1988; Gardner and others, 1988; Plafker and others, 1989). Slope-wash deposits (Holocene) Supraglacial moraine (Holocene)

Rock glaciers (Holocene)

Outwash deposits (Holocene)

Glacial moraine (Pleistocene)

Lahar deposits (Pleistocene)

Lacustrine deposits (Pleistocene)

Kame and esker deposits (Pleistocene)

Fonalite (Eocene)—Very light gray, fine- to medium-grained, hypidiomorphic

granular, hypabyssal, biotite muscovite tonalite that forms a small

discordant stock about 1/2 km<sup>2</sup> in size that intrudes the Uranatina

River metaplutonic unit (map, No. 6). The unit forms bold, con-

spicuously light colored outcrops. Lithologically similar stocks and

plugs are located just east of the map area within both the Uranatina

River metaplutonic unit and the McHugh Complex. The stocks and

plugs to the east include quartz diorite and granodiorite in which

either biotite or hornblende may be the dominant mafic accessory

mineral, and muscovite may replace biotite or form from alteration

and 52.6 (±1.6) Ma are probably close to the emplacement age (table

1, No. 6). Fission track ages from the same sample and from nearby

Late Jurassic metaplutonic rocks (Jm; table 1, Nos. 4 and 6) in-

dicate rapid cooling through the annealing temperatures in the late

Eocene. This cooling is interpreted as indicative of pronounced Eocene

uplift of this part of the northern Chugach Mountains. Isotopically

dated pre-Tertiary metamorphic rocks (Ps) in the same general area

that have ages of about 52 to 45 Ma suggest widespread thermal

metamorphism related to the Tertiary plutonism (table 1, No. 5).

The tonalite stock and associated plutonic rocks are inferred to be

comagmatic with the intermediate-composition dikes (Td) on the basis

of their distribution, lithology, geochemistry, and age.. Hypabyssal

intrusive rocks, abundant west of the map area along the south margin

of the Wrangellia and Peninsular terranes in the northern Chugach

Mountains (Winkler and others, 1981c; Little, 1984) and through-

out the Chugach terrane and eastern part of the Prince William terrane

(Sanak-Baranof belt of Hudson, 1983), are probably correlative. Their

distribution, together with that of the dike unit (Td), suggest that

all these terranes were in about their present relative positions by

typically consist of fine- to medium-grained phenocrysts of plagio-

clase and hornblende ± sparse quartz phenocrysts in a very fine

grained felsic matrix. Hornblende phenocrysts are generally extensively

altered to chlorite and epidote; plagioclase phenocrysts are gener-

ally fresh and display well-developed oscillatory zoning. Thin chilled

margins are common. The mainly steeply dipping dikes and dike

swarms are a few meters to as much as 10 m thick, the largest of

which are shown schematically on the map and sections. Dikes tend

to be emplaced parallel to regional joint sets, the most prominent

of which strike approximately north-northeast to northwest. The

dikes extensively intrude the Uranatina River metaplutonic unit of

the south margin of the Wrangellia terrane, the Talkeetna Formation

of the Peninsular terrane, and all units of the Chugach terrane.

of the Epcene tonalite (Tt; table 1, Nos. 1 and 3). The dikes are

younger than the major displacements on the Border Ranges fault

and its splays in the map area; they intrude rocks both north and

south of these faults, and one dike too small to show on the map

uted in the Valdez Group west of the map area in the Valdez and

Anchorage 1:250,000-scale quadrangles (Winkler and others, 1981c;

Nelson and others, 1985); K-Ar ages of three dikes in the Anchor-

age quadrangle have comparable age ranges from about 55 to 44

vanian and older?)—Variably metamorphosed and deformed

assemblage of schistose metasedimentary and metavolcanic rocks

and minor metaplutonic rocks exposed mainly along the southern

margin of the Wrangellia terrane in thin fault-bounded sheets and

klippen. The metamorphic grade is mainly lower greenschist fa-

cies; however, the grade increases to amphibolite facies adjacent

to Late Jurassic metaplutonic rocks of the Uranatina River meta-

plutonic unit, suggesting syntectonic intrusion (Nokleberg and oth-

much as 1 km wide, compose most of the unit. The two lithologic

types are commonly interlayered and may contain callcareous beds

or lenses. The unit locally includes some undivided metaplutonic

rocks, which strongly resemble the quartz-feldspar mica schist in

outcrops within high-strain areas. The quartz-feldspar mica schist

typically shows subtle, centimeter- to meter-scale layering that appears

to reflect original bedding. Although mostly to completely recryst-

allized, a few samples appear to have a relict clastic texture. Quartz-

rich segregations commonly parallel layering. Mineral assemblages

plagioclase ± garnet, white mica, epidote, chlorite, sphene, and calcite.

The quartz-mica schist is characterized by thinly laminated (1–10

mm thick) layers of quartz schist and quartz-rich mica schist. The

rock consists of 60-90 percent strained, granoblastic quartz (mainly

less than 0.2 mm in length) and varying amounts of biotite, white

mica, chlorite, epidote, garnet, and calcite; segregation bands and

veins(?) of coarsely crystallized quartz (about 1.5 mm maximum di-

ameter) are common. In thin section, the rocks show folded schis-

tosity, local fluxion texture, moderate segregation of felsic miner-

The unit also includes greenschist composed mainly of albite, epidote,

chlorite, and actinolite ± quartz, calcite, white mica, sphene, biotite

(two samples), stilpnomelane, magnetite, and possible remnant

hornblende. The protolith is mainly mafic to intermediate-compo-

sition volcanic rocks that may have been derived from the Penn-

sylvanian to Early Permian Skolai magmatic arc that underlies much

of the Wrangellia terrane (MacKevett, 1978; Richter, 1975; Jones

White to gray marble (m) forms conspicuous deformed and folded

bands and pods throughout the unit and also in association with

the Uranatina River metaplutonic unit; the marble is the most important

marker in these two units. Individual marble beds vary markedly in

thickness along strike; maximum thicknesses are 200-300 m; in-

dividual layers are continuously traceable for as much as 5 km. Only

the largest and most continuous marble bodies are delineated on

map. The marble is typically found in association with greenschist

and quartz-rich schist, but also forms pods within predominantly phyllitic

schist or as inclusions within associated metaplutonic rocks. The

unit is massive to strongly schistose and moderately to slightly re-

crystallized. The marble is commonly composed of 90 percent or

more strongly dynamically recrystallized calcite ± minor opaque minerals

in thin stringers, quartz, tremolite, sphene, graphite, and traces of

white mica. Calc-schists locally associated with the marble beds consist

of 50-70 percent calcite, with 30-50 percent quartz, chlorite, white

Sparse small outcrop areas of metamorphosed and variably fo-

liated ultramafic and gabbroic rocks, too small to be delineated on

the map, are mainly tectonic blocks distributed along or near the

Border Ranges fault where it juxtaposes sheets of Wrangellian rocks

relatively over rocks of the Chugach terrane. The most common

types are coarse-grained hornblendite, hornblende gabbro,

clinopyroxenite, and schistose rocks that consist mainly of chlorite

The unit is undated in the map area but predates the Middle

Pennsylvanian and Late Jurassic intrusive rocks of the Uranatina

River metaplutonic unit. The Strelna is considered to be at least

as old as Early Pennsylvanian on the basis of correlation along strike

with lithologically similar strata containing age-diagnostic conodonts

in marble about 20 km east of the map area (Plafker and others,

1985a). The unit is equivalent to much or all of the metamorphosed

Skolai Group (MacKevett, 1978), (undivided) Skolai Group (Winkler

and others, 1981c), nonplutonic rocks of the Haley Creek terrane

of Winkler and others (1981c), Little Tonsina River Assemblage of

Wallace (1981) and Plafker and others (1985b), and nonplutonic

parts of the metamorphic complex of Winkler and others (1981c).

The Strelna forms the older part of the Haley Creek metamorphic

assemblage of Plafker and others (1989)

Table 2. Radiolaria from the McHugh Complex

[Identifications by C.D. Blome, U.S. Geological Survey (written commun., 1988)]

?Cecrops sp., Patulibacchium sp., and Thanarla sp. aff. T. conica Aliev

84APR169 Archaeodictyomitra(?) sp. aff. A. simplex Early Cretaceous, probably Hauterivian

mica, epidote, and albite ± tremolite, actinolite, and sphene.

als, and local crosscutting shear zones of microbreccia.

and others, 1977).

± serpentine and amphibole.

Quartz-feldspar mica schist and mica-quartz schist, in zones as

intrudes directly across the fault contact. Dikes are widely distrib-

Potassium-argon ages of 52 to 44 Ma, are comparable to those

The nearly concordant K-Ar biotite and muscovite ages of 53.8

of plagioclase (Winkler and others, 1981c).

Eocene time (Plafker and others, 1989)

Ma (Nelson and others, 1985)

WRANGELLIA TERRANE

Metasedimentary and metavolcanic rocks

Strelna Metamorphics of Plafker and others (1989) (Early Pennsyl-

Sedimentary and

**CORRELATION OF MAP UNITS** 

PENINSULAR TERRANE

Qal Qis Qf Qd Qa Qsw Qsm Qrg Qow Holocene

The metadiorite (Jm) has a Late Jurassic emplacement age of 153±4 Ma on the basis of U-Pb zircon analysis (table 1, No. 4); K-Ar ages on hornblende from dioritic and tonalitic rocks have comparable ages but a wider spread due to partial resetting (Nos. 5, 8, and 18). Early Cretaceous K-Ar ages of 110 Ma from a granodiorite in the map area (No. 7) and 133 Ma from a trondhjemite about 25 km east of the map area (Winkler and others, 1981c) are tentatively interpreted as probably reset by Late Cretaceous deformation and by early Tertiary plutonism; however, a Cretaceous igneous event is an alternate possibility (Plafker and others, 1989). Fission-track data for a metadiorite sample (No. 4) yield similar ages for sphene (48.7±8.4 Ma), zircon (42.3±3.8 Ma), and apatite (42.4±7.0 Ma), which suggest rapid uplift and cooling through the annealing temperatures of the utonic suite in the middle to late Eocene (Plafker and others, 1989) The Jurassic metaplutonic rocks are coeval and comagnatic with the Chitina Valley batholith in the Chitina River valley and southern Wrangell Mountains (Plafker and others, 1989). Late Jurassic plutonic rocks (Jgd) of comparable age, which are exposed discontinuously along the south margin of the Peninsular terrane in the map area and west of the map area in the Valdez 1:250,000-scale guadrangle (Winkler and others, 1981c), may also be part of this The unit consists of:

Mafic and intermediate-composition metaplutonic rocks (Late Jurassic)—Foliated to mylonitic plutonic rocks, dominantly diorite but including quartz diorite and tonalite, make up an estimated 80 percent of the unit. Mineral assemblages of the diorite (<5 percent quartz), quartz diorite (5–20 percent quartz), and tonalite (>20 percent quartz) consist of essentially hornblende and albitized plagioclase ± quartz, biotite, and chlorite. The unit is variably recrystallized and altered and has partial to complete replacement of hornblende by actinolite, epidote, and chlorite and of plagioclase by epidote, sericite, and calcite. Accessory minerals include apatite, sphene, and zircon(?). White to gray marble (m) is locally found as mappable bodies within the metaplutonic rocks

Frondhjemite gneiss (Late Jurassic?)—Rocks are uniformly white and consist of 75-90 percent plagioclase that is pervasively albitized, 10-25 percent quartz, and 0-10 percent muscovite ± sparse epidote and chlorite. The rocks are generally strongly foliated and (or) lineated. Primary textures are strongly modified or obliterated by intense ductile deformation and recrystallization; trondhjemite bodies are commonly flattened into the foliation or into pods and lenses aligned with the foliation and lineation of enclosing rocks. The unit crops out as two small plutons and numerous highly deformed pods, stringers, and dikes of leucocratic metaigneous rocks of dominantly trondhjemitic composition within the Uranatina metaplutonic unit and associated Strelna Metamorphics in and near the Border Ranges fault. In local low-strain zones, trondhjemite crops out as dikes that clearly cut across the enclosing rocks. More than one generation of metatrondhjemite may be present Gneissic amphibolite (Late Jurassic?)—Typically medium- to coarsegrained, moderately foliated hornblende-plagioclase amphibolite. Locally, grades into intermediate-composition metaplutonic rocks (Jm) and is intimately deformed with them. Metatrondhjemite stringers and pods are ubiquitous and are characteristically locally deformed into tight ptygmatic folds. The amphibolite is common in small areas; its protolith is uncertain. The rocks are intrusive into the metasedimentary unit (Ps) in one locality, which suggests that the unit is most likely a mafic variant of the metaplutonic unit

Metagranodiorite (Middle Pennsylvanian)—The unit consists of an estimated 45 percent plagioclase, 30 percent quartz, 15 percent potassic feldspar, 10 percent epidote, <1 percent hornblende altered to epidote, and accessory tourmaline, sphene, and stilpnomelane. The unit underlies an area estimated to be < 1 km<sup>2</sup> in a cirque just east of the Richardson Highway (map, No. 2); its distribution and contact relations are unknown. The metagranodiorite appears to be a remnant of a larger pluton engulfed by younger plutonic rocks PENINSULAR TERRANE Sedimentary and volcanic rocks Talkeetna Formation (Early Jurassic and Late Triassic?)—Domi-

nantly andesitic volcaniclastic rocks and associated hypabyssal rocks that are poorly exposed at Stuck Mountain and in isolated wooded hills just west of the Richardson Highway in the northern part of the map area. The bedded sequence is well-indurated tuff, crystal tuff, lapilli tuff, tuff breccia and breccia with clasts as large as blocksize, pebbly coarse-grained volcanogenic sandstone, and minor siliceous flows. The andesitic tuff, crystal-tuff matrix, and most fragments of the lapilli tuff are mainly composed of turbid devitrified glass containing scattered plagioclase microlites and sparse plagioclase microphenocrysts. Breccia fragments include (1) andesite porphyry containing plagioclase phenocrysts as much as 2 mm in length in a groundmass of pilotaxitic plagioclase microlites; (2) andesite containing randomly oriented plagioclase microlites, chloritic amygdules, and clots of epidote as much as 2 mm in diameter; (3) cryptofelsitic rhyodacite(?) composed mainly of cryptocrystalline silica and feldspar; and (4) chloritic devitrified andesitic basalt(?) containing sparse plagioclase microlites. Monolithologic tuff breccia on Stuck Mountain is composed of subrounded basaltic andesite clasts 1 mm to 5 cm in diameter of devitrified glass containing plagioclase microlites, very sparse clinopyroxene, and as much as 30 percent amygdules of chlorite, quartz, epidote, and sparse prehnite. The breccia matrix and interbedded tuff are lithologically similar to the basaltic andesite clasts. Subordinate dacitic to rhyodacitic flow units consist of very fine grained quartz, plagioclase, and epidote, <1 percent plagioclase microphenocrysts, and rare quartz amygdules. Locally, the felsic rocks exhibit a distinct flow banding defined by trains of finegrained epidote as much as 3 mm thick. The volcaniclastic sandstone is medium to coarse grained and consists primarily of tightly cemented angular to subrounded lithic volcanic fragments and plagioclase crystals in a tuffaceous matrix. Extensive alteration is associated with intrusive hornblende gabbro and quartz diorite bodies (Jgd). The formation is moderately folded and locally faulted; the faults generally dip northeast at angles of  $15^{\circ}$ – $55^{\circ}$ . The unit is 2–3 km thick. Well and seismic-reflection data from within the Copper River basin indicate that the unit is overlain by Middle and Upper Jurassic and Cretaceous bedded sedimentary and a lesser amount of volcanic rocks (Plafker and others, 1989; Alaska Geological Society, 1969). In the map area, the contact with the Nelchina River Gabbronorite to the south is everywhere concealed beneath unconsolidated deposits but is inferred to be a fault. These two units are juxtaposed along high-angle faults at the few localities where the contacts are exposed in the western part of the Valdez quadrangle (Winkler and others, 1981c) west of the map area. Modelling of aeromagnetic data, however, suggests that the contact dips northward at a moderate angle (Case and others, 1986). The formation was originally defined in the Talkeetna Mountains about 150 km to the west (Martin, 1926) and geographically extended into the Valdez quadrangle to include lithologically and temporally equivalent strata (Winkler and others, 1981c; Plafker and others, 1989). The rocks were emplaced in an intraoceanic arc that extended from the map area more than 1,200 km westward to the Alaska Peninsula (Barker and Grantz, 1982; Plafker and others, 1989). No unequivocal evidence exists in the map area regarding the depositional environment of this unit. Pillow breccia(?) at one locality suggests subaqueous emplacement, as does the absence of paleosols or other altered horizons characteristic of subaerial deposition. Shallow marine to subaerial deposition for much of the formation to the west of the map area is indicated by fossil content and sedimentary facies (Grantz, 1960a,b; Detterman and Reed, 1980; Imlay and Detterman,

The Talkeetna Formation is undated in the map area; a pre-Late Jurassic age is indicated by the occurrence at one locality of hornblende gabbro dikes and small intrusions (Jgd) that have a hornblende K-Ar age of 157±5 Ma (table 1, No. 14). The formation is considered to be Late Triassic(?) and Early Jurassic in age on the basis of the occurrence of a diagnostic Early Jurassic marine megafauna throughout most of its outcrop area in the Peninsular terrane (Jones and others, 1984, 1987; Winkler and others, 1981b,c) and on the presence of Late Triassic fossils in probably equivalent tuffaceous strata in the basal part of the section in the southern Kenai Peninsula. about 400 km southwest of the map area (Pogibshi unit of Kelley, 1983). Plafker and others (1989) correlate the Talkeetna Formation and correlative units of the Talkeetna arc with the lithologically and temporally equivalent andesitic arc sequence that includes the Bonanza Group and the Maude and Yakoun Formations in the Queen Charlotte and Vancouver Islands segment of the Wrangellia terrane (Sutherland-Brown, 1968; Jeletzky, 1976; Cameron and Tipper,

Hornblende gabbro and quartz diorite (Late Jurassic)—Unit exposed in a small outcrop area 1 km west of Pippin Lake (map, No. 14) and 5½ km to the north. The rocks consist of hydrothermally altered medium- to fine-grained hornblende gabbro, diabasic hornblende gabbro, and hornblende quartz diorite. All rocks contain abundant alteration veins, and some of them have prominent protoclastic textures. In the quartz diorite, minerals are dominantly altered plagioclase (55-65 percent), fresh to altered hornblende (30-45 percent), and quartz (as much as 15 percent). Minor constituents are iron oxides and apatite. The unit intrudes unmetamorphosed volcaniclastic rocks of the Talkeetna Formation; the contact is highly irregular and numerous diabasic dikes and apophyses intrude and engulf the volcaniclastic rocks. Fine-grained gabbro and diabase are found near the contact, whereas coarser grained hornblende quartz diorite is found approximately 200 m from the contact. The contact with the Nelchina River Gabbronorite is concealed, but the outcrop distribution suggests that it is an intrusive contact. The age of the unit is Late Jurassic on the basis of one hornblende K-Ar age of 157±5 Ma (table 1, No. 14). The unit is probably correlative with mafic to intermediate-composition intrusive rocks in the western part of the Valdez quadrangle that have K-Ar ages

of 154–167 Ma (Winkler and others, 1981c). The unit is equiva-

lent in age to plutonic rocks (Jm) of the Uranatina River metaplutonic

unit and the Chitina Valley bathclith in the Chitina River valley and

southern Wrangell Mountains to the east and northeast of the map

Plutonic rocks

characterizes the coeval rocks to the east Border Ranges ultramafic-mafic assemblage—East end of a belt of ultramafic and mafic plutonic rocks as much as 20 km wide that extends about 1,000 km westward along the south margin of the Peninsular terrane to the Kodiak Islands (Burns, 1985). The assemblage consists of a lower unit of ultramafic rocks and deep-level gabbro, informally named the Tonsina ultramafic-mafic sequence (Plafker and others, 1989), and an upper unit of thick shallower level gabbro named the Nelchina River Gabbronorite by Burns (in press). The Tonsina unit is inferred to be overlain by, and is possibly gradational with, the Nelchina River Gabbronorite to the north. The composite structural thickness is as much as 14 km. On the basis of associated strong magnetic anomalies, the ultramafic-mafic assemblage extends beneath surficial deposits along the southern margin of the Copper River basin between the St. Anne and Border Ranges faults (Winkler and others, 1981b,c; Case and others, 1986). The assemblage consists

apparently lacks the pervasive foliation and mylonitic fabric that

CHUGACH TERRANE

Nelchina River Gabbronorite (Middle Jurassic and older?)-Dominantly two-pyroxene gabbro, hornblende-pyroxene gabbro, and leucogabbro and minor tonalitic and dioritic phases. Color indices of the gabbronorite average about 38. Compositional layering is conspicuously developed in many places due to alternating layers of predominantly calcic plagioclase and pyroxene. Minor constituents are titanomagnetite, which averages 2-3 percent, and sparse quartz, which locally is present in amounts as much as 3 percent. Pyroxene is commonly replaced by or rimmed with amphibole. The weight percent of alumina in pyroxene is markedly lower than for the deeper level gabbros where the weight percents are 1-2 percent in clinopyroxene and about 1 percent in orthopyroxene (DeBari and Coleman, 1989).

The unit is from 5 to 10 km thick in the map area. The southern contact with the Tonsina ultramafic-mafic sequence and the McHugh Complex is concealed; about 20 km to the west, the unit is juxtaposed against the McHugh Complex along the Border Ranges fault system (Winkler and others, 1981c). Within the map area, the northern contact with the Talkeetna Formation is not exposed but is inferred to be a north-dipping normal fault (St. Anne fault) on the basis of structural levels of the units that span the boundary. The gabbronorite is in part Middle Jurassic in age on the basis <sup>40</sup>Ar/<sup>39</sup>Ar analyses of three hornblendes (table 1, Nos. 15–17). Potassium-argon data indicate that the cooling ages of the Tonsina ultramafic-mafic sequence and Nelchina River Gabbronorite in the map area are essentially coeval. The unit is correlative with twopyroxene gabbro and related rocks that extend westward from the map area as a continuous belt up to 12 km wide for at least 120 km within the Valdez and Anchorage quadrangles (Winkler and others, 1981b,c; Burns, 1985, in press)

Tonsina ultramafic-mafic sequence (Middle Jurassic and older?)— The sequence consists of a distinctive, high-pressure and hightemperature cumulate mafic and ultramafic sequence that is discontinuously exposed in low hills and stream cuts in a belt 40 km long and as much as 4 km wide. The south contact is juxtaposed against the north margin of the Chugach terrane along the Border Ranges fault system and dips generally north to northwest toward a concealed contact with the Nelchina River Gabbronorite. The sequence is variably folded and faulted and has a composite estimated thickness of 1.2 to 3.5 km. The sequence is Middle Jurassic (about 188 to 171 Ma) and older(?) on the basis of an Ar<sup>40</sup>/Ar<sup>39</sup> plateau on amphibole from hornblende gabbro and K-Ar ages on hornblende from hornblende gabbro and hornblendite (table 1, Nos. 9-11, and 13). It is probably correlative with ultramafic-mafic suites such as the Wolverine and Eklutna Complexes, the Klanelneechina and Red Mountain klippen, and related bodies, which are found along and near the south margin of the Peninsular terrane to the west (Winkler and others, 1981b; Burns, 1985). The sequence is divided into: Gabbro and gabbronorite—Layered spinel- and garnet-bearing gabbro and gabbronorite and local thin layers of ultramafic rocks between 1 and 2 km thick. Gabbroic rocks contain plagioclase, pargasitic hornblende, and Al-rich clinopyroxene, orthopyroxene, and spinel (DeBari and Coleman, 1989). Plagioclase is commonly thoroughly

Dunite and harzburgite—Variably schistose and layered dunite and harzburgite that grades upward into websterite. The unit is about 100-1,000 m thick **Serpentinite**—Lenses, pods, and sheets of serpentinite that are found locally along the Border Ranges fault system in bodies as much as 100 m wide and are also found in more restricted bodies along the Second Lake fault. The serpentinite is probably a strongly deformed equivalent of the ultramafic rocks that makes up the basal part of

Valdez Group (Late Cretaceous)—A thick, lithologically monotonous

altered, but the pyroxenes are fresh. May be interlayered with the

basal part of the Nelchina River Gabbronorite

Websterite—The unit is 100-500 m thick

CHUGACH TERRANE

sequence of schistose flysch and minor metatuff that crops out in a belt 80 km wide in the map area. The group was originally named for rocks near Port Valdez and geographically extended to include equivalent rocks that underlie much of the Chugach and Kenai Mountains Tysdal and Plafker, 1978). The north contact is the north-dipping Tazlina fault (Winkler and others, 1981c; Nokleberg and others, 1989); the south contact (south of the map area) is defined by the Contact fault, along which rocks of the Prince William terrane are thrust relatively against and beneath the Chugach terrane (Plafker and others, 1977; Nokleberg and others, 1989). Because of complex deformation and the lack of marker units, the aggregate stratigraphic thickness of the Valdez Group is not known; at least several kilometers of strata are present. The structural thickness of the Valdez Group, on the basis of geophysical data, is slightly less than 20 km (Fisher and others, 1989; Plafker and others, 1989). The metamorphic grade is mainly low-greenschist facies with local areas of biotite-grade rocks in the southern part of the map area. Metamorphic grade increases along strike to the east, culminating in the Chugach metamorphic complex, a schist and gneiss crystalline complex with sillimanite-grade migmatitic rocks (Hudson and Plafker, 1982; Sisson and others, 1989); to the west it gradually decreases to zeolite facies (Winkler and others, 1981c). The depositional age of the Valdez Group is Late Cretaceous (Maestrichtian and Campanian?), on the basis of correlation with less metamorphosed lithologically similar fossiliferous rocks about 250 km to the west in the Anchorage area and in the Kenai Mountains (Tysdal and Plafker, 1978). The Valdez Group is part of an extensive belt of accreted flyschoid deep-sea rocks that makes up most of the Chugach terrane and part of the Yakutat terrane (Plafker and others, 1977; Plafker and Campbell, 1979). The unit was accreted to the Chugach terrane in latest Cretaceous to early Paleocene time, prior to emplacement of Paleocene plutons (about 62 Ma) in lithologically

Valdez consists of: Metasedimentary rocks—Mainly metagraywacke (30–80 percent) in thin to very thick beds interbedded with subordinate metapelite and minor metavolcanic rocks and metaconglomerate. The metagraywacke is greenish gray to gray and fine to medium grained. The metagraywacke is mainly lithofeldspathic or feldspatholithic and consists of plagioclase, quartz, and altered lithic fragments ± white mica, epidote, sphene, graphite, amphibole, chlorite, and calcite. Metamorphic biotite is sparsely developed in the south one-quarter of the map area and adjacent areas to the south and east. Some of the metagraywacke is composed of as much as 90 percent intermediate-composition volcanic grains. Also recognizable in the best preserved rocks are sparse granitic and chert or felsite clasts. Fabric is characterized by a spaced incipient cleavage or variably developed schistosity. The schistose rocks commonly have well-developed fluxion texture in which matrix and lithic fragments have been pulverized and molded around strained and flattened quartz and plagioclase grains (semischist). Quartz veins are ubiquitous as segregations both parallel to foliation and crosscutting the foliation and bedding; locally, they constitute as much as 30 percent of metagraywacke outcrops. The metapelite is dark gray to black and consists mainly of

carbonaceous phyllite and lesser amounts of argillite and very fine grained mica schist. Dominant minerals are quartz, white mica, and graphite; minor minerals included in some samples are plagioclase, epidote, and calcite. The grain size of metamorphic minerals is 0.05-0.1 mm in length in the phyllite, is less than 0.05 mm in the argillite, and is as much as 0.3 mm in the schist. The finer grained metagraywackes and metapelites generally are finely laminated (1 2 mm thick). They typically contain abundant quartz segregation layers and spaced quartz cleavages that parallel the axial planes of minor folds; locally, they exhibit a well-developed crenulation cleavage. Sparse ridge-forming beds of poorly sorted pebble conglomerate and pebble-cobble conglomerate as much as 50 m thick are interbedded with the metasandstone and metapelite. The conglomerate is found mainly in the area between the headwaters of Bernard Creek and Dust Creek; a few beds as much as 1 m thick of schistose stretchedpebble conglomerate with mudstone matrix are in the extreme southern end of the map area (Valdez A-4 quadrangle, about 6 km westsouthwest of the terminus of Woodworth Glacier) Metavolcanic rocks—Metavolcanic rocks make up only a few percent

of the Valdez Group in most of the map area, although volcanic rocks and mixed volcanic and sedimentary rocks become increasingly abundant towards the Contact fault south of the map area. The metavolcanic rocks are mainly green basaltic metatuff in lenticular beds that range from a few centimeters to about 15 m thick and are as much as 4 km in strike length. The metatuff is mainly composed of strongly sheared, very fine grained, chlorite, fibrous actinolite, epidote, sparse quartz and albite, and varying amounts of pyrite, white mica, biotite, and iron oxide. The rocks are commonly microfolded and locally finely interlayered with metapelite on a millimeter to centimeter scale. Immediately south of the map area, metatuff becomes increasingly abundant and is associated with dark-green to black metabasalt, amygdaloidal pillow flows and breccia (greenstone), and diabase intrusions (Winkler and Plafker, 1981; Plafker and others, 1989) McHugh Complex (Cretaceous to Late Triassic)—A structurally cha-

otic melange-like unit of accreted oceanic rocks that crops out in an irregular belt 3-20 km wide. The complex consists of pervasively disrupted broken formation that originally was mainly tholeiitic pillowed basalt and related fragmental volcanic rocks containing subordinate amounts of argillite, tuff or tuffaceous argillite, radiolarian chert, graywacke, siltstone, and carbonate rocks. The unit was originally defined in the Anchorage area by Clark (1973) and subsequently geographically extended to comparable rocks that crop out discontinuously along the north margin of the Chugach and Kenai Mountains (Plafker and others, 1977; Winkler and others, 1981c). The metamorphic grade of most of the McHugh Complex is primarily prehnite-pumpellyite facies. In the area east of the Richardson Highway, the metamorphic grade of the McHugh Complex increases to lower greenschist facies, and the rocks are more pervasively sheared and ductilely deformed than elsewhere.

The argillaceous and tuffaceous rocks that comprise the melange matrix typically exhibit a fabric that varies from highly sheared to melange at both outcrop and thin-section scales. The argillite and metatuff are end-members of a gradational sequence that includes tuffaceous argillite and argillaceous metatuff. The argillite is dark gray to black, highly carbonaceous, and contains sparse, very fine grained fragments of chert, plagioclase, and siltstone that are commonly boudinaged and flattened. Minor constituents are white mica, calcite, chlorite, pyrite, and stilpnomelane. The mafic metatuff is gener-

albite, chlorite, quartz, calcite, white mica, and a murky irresolvable material that may be clay; minor constituents present in some samples are pyrite, stilpnomelane, relict pyroxene, and relict plagioclase microlites. Crosscutting calcite and quartz veinlets are moderately abundent in both the argillite and metauff. The basaltic rocks are dark green to dark greenish gray and characteristically form rough, reddish-weathering outcrops. The basaltic rocks are found in masses that range from a few meters to several hundred meters in thickness and contain variable amounts of chaotically intermixed ribbon chert, tuff, and argillite. The rocks are thoroughly altered to greenstone but locally retain textures and structures indicating derivation from massive flows, pillow flows, and pillow breccia. Textures include mainly microporphyritic, intergranular, and microbreccia. In thin section, recognizable minerals are relict plagioclase, clinopyroxene (commonly as euhedral microphenocrysts), chlorite, sparse epidote, and quartz in a murky, microscopically irresolvable matrix. Crosscutting veinlets consisting of quartz, calcite, and chlorite are abundant; stilpnomelane is present in a few samples, and there are pumpellyite amygdules in one sample. Volcanic rocks commonly make up more than 80 percent of the unit west of the Richardson Highway and about 50 percent east of the highway. The chert is mainly maroon, but locally pale green, pink or gray; it becomes white with increasing amounts of recrystallization. Chert commonly forms lenticular ribboned masses as much as 50 cm thick and several meters long interbedded with volcanic rock. To a lesser extent, chert is found as streaky millimeter- to centimeter-scale nonlenticular layers in argillite and tuff. Radiolarians are abundant but are usually slightly flattened and variably recrystallized, except in the extreme western part of the map area (map, No. 19). Crosscutting quartz veinlets are ubiquitous at outcrop and thin-section

Sparse marble is distributed throughout the complex; most commonly it is found as white or gray lenses and pods as much as 3 m thick and 5 m long within the metavolcanic units. In the map area, the unit is bounded on the north by the nearvertical Second Lake fault and a north-dipping segment of the Border Ranges fault system. The south contact is the Tazlina fault. Broad zones of intense faulting that lack any stratal continuity and pervasive faults of unknown offset that juxtapose contrasting rocks are present. More brittle basaltic rocks, chert, carbonate rocks, and sandstone are found as angular elongate phacoids that range from millimeters to hundreds of meters in maximum dimension, either enclosed in a sheared argillite or tuffaceous matrix or juxtaposed against other phacoids. The structural style is characterized by complex folds that are typically asymmetric to the south, as well as numerous closely spaced zones of intense deformation (Nokleberg and others, 1989). The occurrence of disrupted brittle phacoids at all scales in a sheared argillite and tuff matrix imparts a characteristic blocksin-argillite melange appearance to much of the unit. Large coherent exotic blocks derived from the Peninsular and Wrangellia terranes, such as those that characterize the McHugh Complex in the western part of the Valdez quadrangle and elsewhere in the Chugach terrane (Plafker and others, 1977; Winkler and others, 1981c), were not recognized in the map area. Similarly, the metaclastic sequences that make up much of the McHugh Complex and correlative units elsewhere in the Chugach terrane constitute a relatively minor part of the unit in the map area. The total stratigraphic thickness of the McHugh Complex is unknown because of the prevailing structural complexity and an absence of stratigraphic marker horizons; the maximum structural thickness is estimated to be about 20 km. The structural style and lithology of the complex indicate that it was probably accreted, disrupted, and mixed with terrigenous deposits

at a convergent plate margin (Clark, 1973; Moore and Connelly, 1977; Plafker and others, 1989). The depositional age of the McHugh is Late Triassic to mid-Cretaceous on the basis of age-diagnostic radiolarian assemblages found in the western part of the Valdez 1:250,000 quadrangle, 50 km or more west of the map area (Winkler and others, 1981c). In this less metamorphosed western part of the Valdez quadrangle, the McHugh contains Late Triassic, Late(?) Jurassic, Late Jurassic to Early Cretaceous, and mid-Cretaceous (Albian to Cenomanian) radiolarian assemblages (Winkler and others, 1981c), which in general get younger from north to south. Although radiolarians are abundant in chert in the map area, they are generally too recrystallized to be age-diagnostic. One sample, from the western part of the map area contains a poorly preserved radiolarian assemblage of probable Hauterivian to Aptian age (table 2). The age of accretion into the Chugach terrane predates the Late Cretaceous to Paleocene accretion of the Valdez Group that is outboard (south) of the complex, and postdates the oldest matrix rocks in the complex, which are of Late Triassic

Schist of Liberty Creek (Middle Jurassic or older)-The west end of a regionally metamorphosed and polydeformed greenschist and blueschist belt 28 km long and 13 km wide along the north margin of the Chugach terrane (Metz, 1976). The unit is mainly composed of very fine grained to fine-grained (mostly < 0.3 mm in length, rarely as much as 2 mm) greenschist-facies mineral assemblages (epidoterich, actinolite-albite schist  $\pm$  chlorite, quartz, calcite, and white mica). Intercalated with the greenschist are sparse bands and lenses of glaucophanic greenschist that range from a few millimeters to a few centimeters in width. The glaucophanic greenschist contains variable amounts of very fine grained blue amphibole (< 0.1 mm) that is mainly crossite and minor sphene and hematite; lawsonite was found at one locality (Winkler and others, 1981a,c). Rarely, the more massive greenschist exhibits faint primary structures suggestive of breccia and possible pillow breccia. Highly deformed carbonaceous (graphitic?) phyllite forms pods and irregular anastomosing layers as much as a few meters thick within some of the metavolcanic rocks. Geochemical data for the metavolcanic rocks suggest an origin as N-type mid-ocean ridge basalts (Plafker and others, 1989). These data, together with the lithology of the sequence and relict textures of the metavolcanic rocks, suggest that the schist of Liberty Creek is an oceanic assemblage of basalt flows, breccias, and tuff that contains intercalated argillaceous and sparse calcareous marine sedimentary

The schist is ductilely deformed into south-verging chevron and isoclinal folds and sparse, younger, superimposed, north-verging folds (Nokleberg and others, 1989). The unit is mostly thin to medium layered but is locally massive. Millimeter-scale crenulated lamination is characteristic. Because of the structural complexity and lack of marker horizons, the stratigraphic thickness of the sequence is unknown; structural thickness is at least 5 km in the widest part of the outcrop belt. The north contact of the unit with the Peninsular terrane is the Border Ranges fault, which is marked by a broad, near-vertical, shear

zone of schistose serpentine and strongly deformed ultramafic rocks. The south contact is the Second Lake fault, an east trending zone of strongly sheared country rock, serpentinite, and altered pyroxenite and pyroxene gabbro.

The protolith age for the unit is broadly constrained as Middle Jurassic or older. Its position in the accretionary complex indicates only that the unit is probably older than the less metamorphosed Upper Triassic to mid-Cretaceous McHugh Complex to the south. The metamorphic age is inferred to be Middle Jurassic on the basis of an Ar<sup>40</sup>/Ar<sup>39</sup> age of 186±1.5 Ma from phengite in rocks inferred to be correlative in the western part of the Valdez quadrangle (Sisson and Onstott, 1986; Plafker and others, 1989). Potassium-argon whole-rock ages from one sample of blueschist (table 1, No. 12) and two whole-rock samples less than 10 km east of the map area (Plafker and others, 1989) are interpreted as reset. The schist of Liberty Creek is tentatively correlated with the dated blueschist and greenschist of the Iceberg Lake unit in the western part of the Valdez guadrangle, on the basis of structural position, overall lithologic and geochemical similarities, and degree of metamorphism. Probable correlative blueschist units are found as small slices along the Border Ranges fault 400-600 km to the southwest in the Seldovia area and on Kodiak Island (Forbes and Lanphere, 1973; Carden and Decker, 1977; Roeske, 1986)

Contact—Approximately located; dotted where concealed

Fault—Dashed where approximately located; dotted where concealed or projected in cross section. Half arrows show direction of relative motion in cross section Thrust—Sawteeth on upper plate

Anticline, showing plunge—Dotted where concealed

Anticline, showing horizontal fold axis Syncline—Dashed where approximately located; dotted where concealed

Minor fold axis Overturned fold—Showing plunge of fold axis and dip of limbs Isoclinal fold—Showing dip of axial plane and general direction and

Horizontal isoclinal fold—Showing dip of axial plane Strike and dip of beds—May be combined Inclined, facing direction known—Dashed where estimated Inclined, facing direction unknown

Strike and dip of foliation—May be combined with other planar sym-Inclined—Dashed where estimated

Vertical—Dashed where estimated

Strike and dip of cleavage—May be combined with other planar sym-

Generalized strike and dip of folded beds or foliation Strike and dip of layering in igneous rocks Bearing and plunge of lineation—May be combined with other planar

→ → Dike, showing trend—Intermediate-composition dikes (unit Td)

**Serpentinite**—Uncertain age and affinity

Isotopically dated—Number refers to table 1 Radiolarian—Number refers to table 2

GENERAL TECTONIC AND STRUCTURAL SUMMARY This map was prepared as part of the Trans-Alaska Crustal Transect program whose objective is to provide multidisciplinary geological and geophysical coverage

iin a north-south corridor across Alaska that is centered generally along the Richardson and Dalton Highways. Details of the bedrock geology and the structural style of rocks in the map area, as well as their tectonic evolution, are presented by Plafker and others (1989) and Nokleberg and others (1989). Except as otherwise noted, the following summary is based on these two papers.

TECTONIC SETTING

In the map area, pre-Cenozoic bedrock units are divided into three fault-bounded

lithotectonic terranes that differ markedly in stratigraphy, structural style, and age (fig. 1). These terranes correspond with the Wrangellia, Peninsular, and Chugach terranes of Jones and others (1987). The Border Ranges fault (MacKevett and Plafker, 1974) forms the north boundary of the Chugach terrane (fig. 1); the Contact fault, about 25 km south of the map area, juxtaposes the Chugach terrane against Paleogene accretionary sequences (Ghost Rocks and Prince William terranes) and the allochthonous Yakutat terrane (Winkler and Plafker, 1981; Plafker, 1987). The Wrangellia and Peninsular terranes are parts of a dominantly oceanic allochthonous superterrane (composite Terrane II of Plafker and others, 1989) that was amalgamated by the Late Triassic and accreted to terranes of continental affinity north of the Denali fault system in the mid-Cretaceous to Late Cretaceous. The south margin of the Wrangellia terrane consists of a polymetamorphosed magmatic

arc complex at least in part of Pennsylvanian age (Strelna Metamorphics and metagranodiorite) and rocks of the Late Jurassic Chitina magmatic arc (mafic and intermediate-composition metaplutonic rocks). The south margin of the Peninsular terrane is underlain by rocks of the Late Triassic(?) and Early Jurassic Talkeetna magmatic arc (Talkeetna Formation and Border Ranges ultramafic-mafic assemblage) formed on Permian or older basement rocks. The Chugach terrane in the transect area consists of three successively accreted units characterized by dominantly south-verging folds and faults. From north to south these accretionary units are (1) the schist of Liberty Creek, greenschist and intercalated blueschist of unknown protolith age, which was metamorphosed and probably accreted along the Border Ranges fault (BRF2) during the Early Jurassic; (2) the McHugh Complex (Late Triassic to mid-Cretaceous protolith age), a melange of mixed

limeter- and centimeter-scale wisps within black argillite to lenticupumpellyite and lower greenschist facies and accreted along the Second Lake fault lar beds as much as 3 m thick. The tuff consists of very fine grained and Border Ranges fault system (BRF1 east of map area and BRF2 in map area) by mid-Cretaceous time; and (3) the Upper Cretaceous Valdez Group, mainly magmatic arc-derived flysch and lesser amounts of oceanic volcanic rocks of greenschist facies, which was accreted along and south of the Tazlina fault by early Paleocene time. All three terranes were affected by a regional thermal event that culminated in early middle Eocene time (48–52 Ma) and resulted in widespread greenschist-facies metamorphism and plutonism. In much of the northern part of the map area, plutonism accompanied or immediately postdated northward-verging deformation that refolded older southward-verging structures, which characterize the Chugach terrane and south margin of the Wrangellia terrane in the map area. Subsequent Cenozoic deformation included (1) local formation of orthogonal cleavage and veins possibly related o relaxation of regional compressional stresses during the Paleogene, (2) large-scale Paleogene counterclockwise oroclinal bending of Chugach and Peninsular terrane rocks about an axis that extends just west of the map area, and (3) strike-slip displacement on conjugate sets of transcurrent faults and probable reactivation of older structures related to Neogene emplacement of the Yakutat terrane to the south (Plafker, 1987; Nokleberg and others, 1989).

The major segments of the Border Ranges fault are distinguished on the map and cross sections as BRF1 for the fault contact between the Wrangellia and Chugach terranes and BRF2 for the fault contact between the Peninsular and Chugach terranes. The complex structural relation exhibited in the cross sections between these wo segments of the Border Ranges fault system result from large-scale early Teriary overthrusting of the Wrangellia terrane relative to the Peninsular and Chugach

The Border Ranges fault segment between the Chugach and Peninsular terranes BRF2) strikes east on the average and dips gently to moderately northward. The fault is marked by discontinuous zones of strongly sheared serpentinite that vary considerably in width, from as much as 125 m along part of the contact with the Tonsina ultramafic-mafic sequence to about 50 m along part of the contact with the schist of Liberty Creek. In contrast, serpentinite is absent along the sharp fault contact with the Nelchina River Gabbronorite where exposed west of the Richardson Highway. Structural relations indicate at least 20 km overthrusting of the Peninsular terrane elative to the Chugach terrane along the Border Ranges fault (segment BRF2). The Border Ranges fault segment between the Wrangellia and Chugach terranes BRF1) bounds a structural flap that is mostly flat lying to gently undulating but locally dips steeply due to post-emplacement (Eocene?) faulting and folding of the thrust surface. The fault is marked by a zone of ductilely to brittley sheared rocks ranging from a few centimeters to tens of meters wide. Sparse small lenses of highly sheared serpentinite, as much as a few tens of meters thick along the fault, may have been derived from the Tonsina ultramafic-mafic sequence. Structural relations indicate at least 40 km of westward and (or) southward thrusting of the Wrangellia terrane relative to the Peninsular and Chugach terranes along the Border Ranges fault (segment

The Second Lake fault strikes east, dips steeply or is vertical, and merges with the Border Ranges fault (segment BRF2) to the west. The fault is marked by shear zones as much as a few hundred meters wide and by discontinuous lenses of serpentinite derived from dunite that are as much as 4 km long and several hundred meters thick. The Tazlina fault juxtaposes the Valdez Group against the McHugh Complex along a contact that is characteristically a narrow, steeply north-dipping, planar surface that has local zones of sheared country rocks as much as a few meters thick.

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