Geology of Gravina Island, Alaska

GEOLOGICAL SURVEY BULLETIN 1373

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By HENRY C. BERG

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A description of the stratigraphy, lithology, general geology, and mineral resources of a structurally complex 100-square-mile island near Ketchikan, Alaska

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1973

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 72-600391

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.60 (paper cover)

CONTENTS

ILLUSTRATIONS

GEOLOGY OF GRAVINA ISLAND, ALASKA

By HENRY C. BERG

ABSTRACT

Gravina Island, near Ketchikan in southeastern Alaska, consists of two geologically distinct bedrock terranes separated by a northward-trending fault zone that extends along the Bostwick-Vallenar valley.

Bedrock northeast of the fault consists mainly of the newly named Middle or Upper Jurassic Gravina Island Formation, a monotonous assemblage of andesitic metavolcanic and flyschlike metasedimentary rocks whose base and top were not observed. The formation is characterized by greenschist-facies regional metamorphism, by complex folding and faulting, and by moderate northeastward dip of composition layering and many other planar structural features.

Bedrock southwest of the fault ranges in age from Silurian or older to Late Jurassic and includes six (three newly named) marine sedimentary and volcanic formations, three metamorphic units, and several stocklike plutons. The depositional sequence is interrupted by three unconformities. The bedded rocks generally are only slightly to moderately recrystallized; the metamorphic units locally record up to amphibolite-facies regional metamorphism. Small-scale structures indicate complex folding, but on a regional scale the bedded units form a truncated open syncline that plunges gently northward. High-angle faults abound, and there is at least one major thrust fault.

Gravina Island contains numerous mineral deposits. A few lodes on the northeast coast were worked for gold in the early 1900's, but no production has been recorded since about 1913. Recent prospecting has centered on copper lodes on the southern part of the island. Lodes are of two main types, each characteristic of one of the bedrock terranes. Northeast of the northward-trending fault zone, they are mainly disseminated sulfide deposits and sulfide-bearing quartz-calcite fissure veins that have been prospected chiefly for gold. Southwest of the fault they are mainly hematite- and sulfide-bearing quartz-dolomite-barite fissure veins now valuable mainly for their copper content.

INTRODUCTION

Gravina Island is near the southeastern end of the Alexander Archipelago (fig. 1) of southeastern Alaska. It is about 102 square miles in area, heavily timbered, and characterized by rolling uplands and muskeg-covered lowlands. The highest point, the domelike summit of Chapin Peak, is at 2,730 feet. The island is divided nearly in two by a low northward-trending U-shaped valley that connects Bostwick Inlet and Vallenar Bay and herein is informally called Bostwick-Vallenar valley. The island's glaciated valleys and rounded summits indicate that it was entirely covered by ice in Pleistocene time.

This report mainly describes the stratigraphy and lithology of the bedrock units of Gravina Island but includes summary descriptions of the island's general geology, mineral resources, and unconsolidated surficial deposits.

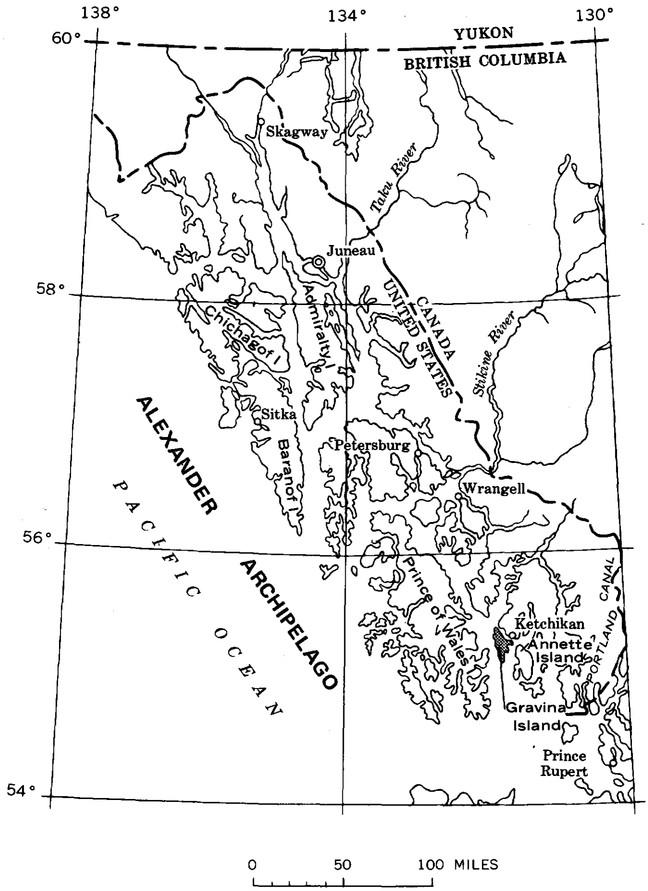

FIGURE 1. — Location of Gravina Island.

Rock nomenclature generally follows that of Williams and others (1954); classifications based on chemical analyses follow Nockolds (1954). Unless otherwise noted, mineral and rock assemblages and rock types of clasts in conglomerate are listed in estimated order of decreasing abundance. Plagioclase compositions accompanied by numerical An values were determined either by whole-rock X-ray diffraction or by measuring the refractive index of crushed fragments in high-dispersion oils; plagioclase compositions without numerical An values were determined by examination of thin sections on a flat-stage petrographic microscope.

All the rocks on Gravina Island are more or less recrystallized and, depending on the susceptibility of the original rock, foliated. Adequately preserved sedimentary or igneous textures allow most rocks to be treated as primary rather than metamorphic.

The geologic mapping, done mainly in 1969 and 1970, was by inland and coastal foot traverses, supported occasionally by helicopter and fixed-wing aircraft. The locations of traverses and helicopter landing sites are shown in figure 2.

Previous geologic investigations of Gravina Island are described in reports by Brooks (1902), Wright and Wright (1908), Smith (1915), and Chapin (1918). Certain aspects of the geology are included in regional reports by Martin (1926) and Buddington and Chapin (1929).

David L. Jones, U.S. Geological Survey, contributed significantly to my understanding of the stratigraphy and regional tectonic setting of Gravina Island and collaborated on the section on the age of the Gravina Island Formation. Others who aided materially in the progress of the mapping include William H. Condon and Robert D. Stacey, U.S. Geological Survey; Michael Nelson and James Godbe, summer geologic field assistants; Kenneth C. Eichner, Edwin L. Todd, and Jeffrey Collins of Ketchikan; and James A. Walper of Aldergrove, B.C., Canada.

GEOLOGIC SUMMARY

Gravina Island consists of two geologically distinct bedrock terranes separated by Bostwick-Vallenar valley (pl. 1). Northeast of the valley the rocks consist mainly of Middle or Upper Jurassic andesitic metavolcanic and flyschlike metasedimentary rocks. Neither the base nor the top of this lithically monotonous assemblage has been observed. Southwest of the valley the rocks range in age from Silurian or older to Late Jurassic and include a variety of bedded units and several stocklike plutons. The terranes also differ in types of mineral deposits and associated hydrothermal alteration, described under "Economic Geology."

The northeastern terrane is characterized by relatively uniform greenschist-facies regional metamorphism that apparently increases in intensity northeastward. There are too few marker beds to outline large-scale structural features, but small-scale structures indicate complex, probably composite, folding. Most foliation, composition layering, contacts, and axial planes of isoclinal small folds dip moderately northeastward. High-angle and east-

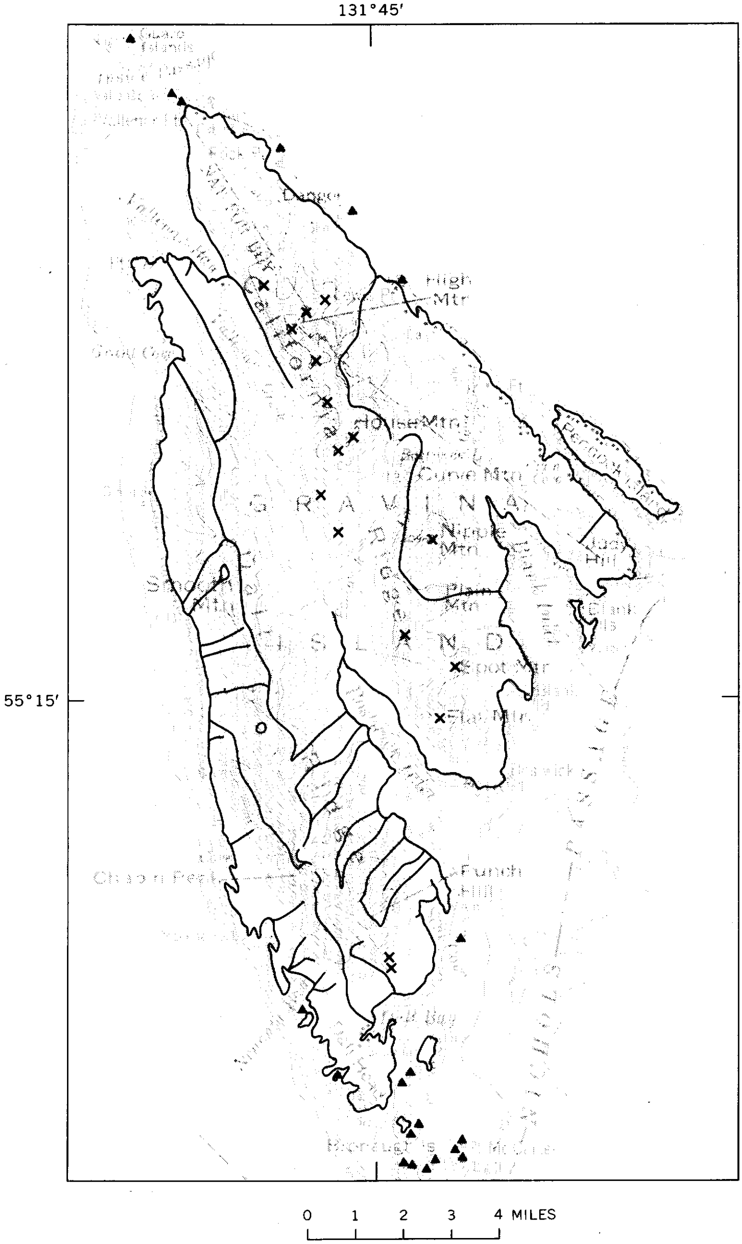

FIGURE 2. — Location of traverses (heavy lines and solid triangles) and helicopter landing sites (crosses).

ward-dipping low-angle faults also occur, but the lack of persistent marker beds precludes measurements of fault displacements.

The southwestern terrane is lithically diverse and records a complex history of marine sedimentation, volcanism, plutonism, folding, and faulting. Some of the rocks are metamorphosed to amphibolite; others are only slightly recrystallized. Small-scale structures indicate that it is at least as structurally complex as the northeastern terrane, but on a regional scale the bedded units form the western limb of an open gently northward-plunging syncline truncated near its trough by Bostwick-Vallenar valley. High-angle faults are abundant, and parts of at least one major thrust fault have been recognized.

Rocks exposed in and near Bostwick-Vallenar valley and its extensions in Bostwick Inlet and Vallenar Bay are intensely sheared and hydrothermally altered. This evidence of faulting, together with the profound differences in bedrock geology on either side of the valley, indicates that it marks a major fault zone along which the northeastern and southwestern terranes have been juxtaposed.

STRATIGRAPHY AND LITHOLOGY

SOUTHWEST OF BOSTWICK-VALLENAR VALLEY

UNDIVIDED METAMORPHOSED BEDDED AND INTRUSIVE ROCKS

An assemblage mainly of lower Paleozoic metamorphosed bedded and intrusive rocks crops out on southern Gravina Island (southern belt) and on the west coast between Grant Cove and Dent Cove (northern belt). It is mixed with apophyses of Silurian trondhjemite that are too small to map and with other, unassigned intrusive rocks. The assemblage consists chiefly of greenschist-facies rocks but includes epidote amphibolite (transitional) and possibly amphibolite-facies rocks. Its relation to the amphibolite-facies gneiss and schist unit (p. 16) on southern Gravina Island is obscured by complex faulting and poor exposures. Wherever the contact has been mapped, it is a fault.

The two belts differ in style of metamorphism. In general, the rocks of the southern belt are foliated and appear to have undergone regional metamorphism. The rocks of the northern belt also are foliated, but less conspicuously than those to the south; in addition, they are locally thermally metamorphosed, apparently by dikes and small plugs of presumably Triassic diabase and microgabbro.

No fossils have been found in the mainly lower Paleozoic assemblage. It is assigned an age of Silurian or older Paleozoic because large parts are intruded by trondhjemitic stocks interpreted as apophyses of the Silurian Annette pluton (p. 8). The age of the parts not intruded by this trondhjemite, however,

499-954 O - 73 - 2

actually is unknown; they are grouped with the Silurian or older Paleozoic rocks only because their outcrop areas happen to adjoin. Some of these undated rocks, in fact, resemble metamorphosed bedded rocks on the Metlakatla Peninsula of Annette Island (Berg, 1972) and may be as young as early Mesozoic (p. 18); these difficult-to-identify, apparently chaotically distributed rocks have not been mapped separately on Gravina Island.

For convenience, the two outcrop belts are described separately.

SOUTHERN BELT

The southern belt, which is as much as 2 miles wide, trends northeastward from the southwest coast of Gravina Island to Seal Cove and underlies parts of the Bronaugh and other nearby islands. The diversity of its lithology is reflected by the variety of field terms used to describe its constituents. In approximate order of decreasing abundance, these include schist, gneiss, hornfels, diorite, greenstone, amphibolite, phyllite, and marble.

Thin sections of the more abundant rock types show crude to nearly perfect schistosity, cataclastic structures that commonly postdate the foliation, and few relict textures. Despite the apparent diversity of megascopic rock types, the mineralogy is monotonous and fairly simple. The metamorphic minerals vary widely in abundance, however; they include albite, sodic oligoclase (An_{12-15}), quartz, chlorite, epidote-clinozoisite, colorless to moderately pleochroic green (Z) amphibole, sericite, and subordinate to minor biotite, potassium feldspar, leucoxene, sphene, apatite, and prehnite(?). Poikiloblastic green amphibole commonly is replaced by chlorite, epidote, and colorless amphibole; part of the biotite is altered to chlorite, some of which also occurs in poikiloblastic crystals enclosing quartz, feldspar, and other minerals; and part of the oligoclase is replaced by sericite, clinozoisite, and albite. Some of the epidote-clinozoisite, quartz, albite, and prehnite(?) occur in irregular veinlets and patches. Cataclastic deformation is nearly ubiquitous and is especially intense in rocks of the Dall Bay area, some of which are mylonitic.

The rocks also contain fissure veins and disseminations of dolomite, calcite, quartz, barite, hematite, and, locally, sulfide minerals. In many places the rocks are red or brown, owing in part to weathering of dolomite and sulfide minerals, in part to finely disseminated hematite, and in a few places to jasperization. Some of the rocks are pink owing to the presence of impalpable hydrothermal ferric oxide (p. 14).

The mineralogy, paragenesis, and textures indicate (1) greenschist-facies regional metamorphism, locally grading into epidote amphibolite- and possibly amphibolite-facies metamorphism,

(2) subsequent retrogressive metamorphism that is especially noticeable in the higher grade rocks, and (3) faulting, hydrothermal alteration, and formation of fissure veins. At least some of the retrogressive metamorphism probably is associated with the cataclastic deformation.

NORTHERN BELT

The northern belt is well exposed only on the west coast of Gravina Island for about 4.5 miles south of Grant Cove. Its distribution in the heavily timbered inland areas is inferred mainly from scattered outcrops.

The rocks locally are schistose, but they generally lack pronounced foliation. Rather, they commonly are relatively massive and have fairly well preserved primary textures. Recognizable originally bedded rock types include feldspar and ferromagnesian porphyries, basaltic pillow flows, and volcanic breccia; rock types of uncertain, but probably bedded, origin include greenstone, greenschist, phyllite, and marble.

The bedded rocks locally are mixed with abundant recrystallized, but generally nonschistose, dioritic intrusive rocks; the abundance of intrusive material, together with schistosity and apparent metamorphic grade of the bedded rocks, increases toward Dent Cove. Near Dent Cove, both rock types are intruded and thermally metamorphosed by dikes and small plugs of presumably Triassic diabase and microgabbro.

All the rocks are complexly faulted and are cut by innumerable fissure veins of dolomite, calcite, quartz, epidote, barite, hematite, and, locally, sulfide minerals. Many also contain microscopic veinlets and irregular replacement masses of albite, sericite, epidote-clinozoisite, calcite, dolomite, and prehnite(?). Hydrothermal alteration is indicated by delicate pink to dark-red coloration (due partly to impalpable ferric oxide and partly to abundantly disseminated hematite), by kaolinization, and in a few places by finely disseminated to patchy potassium feldspar.

Thin sections of the metamorphosed bedded rocks typically show faint to distinct relict porphyritic texture. Relict phenocrysts appear to be unoriented and consist of subhedra up to a centimeter long of sodic plagioclase and subordinate ferromagnesian minerals. The plagioclase, some of which is zoned, generally is partly replaced by sericite, clinozoisite, and kaolin; locally, it is replaced by potassium feldspar or rimmed by clear albite. The ferromagnesian minerals, some of which are pseudomorphs of pyroxene, consist chiefly of weakly pleochroic green (Z) amphibole that is partly replaced by chlorite, epidote, and colorless amphibole. The matrix generally is a microgranular to at most weakly foliated aggregate of albite(?), chlorite, epidote-clinozoisite, sericite, quartz, dolomite, calcite, prehnite(?), apatite, magnetite, and hematite.

The recrystallized dioritic intrusive rocks are medium grained and typically comprise quartz and sericitized sodic plagioclase, plus subordinate to minor green (Z) hornblende, colorless amphibole, chlorite, epidote-clinozoisite, biotite, sericite, sphene, leucoxene, apatite, zircon, calcite, dolomite, magnetite, pyrite, and hematite. Potassium feldspar, generally absent, locally constitutes a few percent of some of the rocks. Most of the rocks are hypidiomorphic granular or weakly foliated; near Dent Cove, they commonly are gneissic, with pronounced granoblastic (quartz and feldspar) and poikiloblastic (ferromagnesian minerals) textures. The granitic and schistose fabrics both are disrupted by nearly ubiquitous cataclasis that ranges in intensity from mild (slight milling) to intense (microbrecciation).

A thin section of fine-grained thermally metamorphosed dioritic(?) rock close to the contact of a presumably Triassic diabase plug just north of Dent Cove shows xenoblastic sericitized plagioclase, poikiloblastic green (Z) hornblende, anhedral clinopyroxene, and minor epidote, pyrite, and magnetite. Most of the clinopyroxene is rimmed and embayed by the hornblende, some of which is replaced by the epidote.

The history of the northern belt is complex. The earliest recognizable metamorphic event is the regional(?) recrystallization of mixed bedded and dioritic intrusive rocks to greenschist and, locally, to epidote amphibolite or amphibolite facies. The latest events include faulting, the formation of fissure veins, and at least some of the hydrothermal alteration (kaolin, hematite, some potassium feldspar). Discernable intermediate, but chronologically indeterminate, events include retrogressive metamorphism (especially of the higher grade rocks), pink hydrothermal alteration, and intrusion and local metamorphism to hornfels by presumably Triassic basic dikes and plugs.

ALTERED LEUCOCRATIC PLUTONIC ROCKS

Distinctively altered leucocratic plutonic rocks crop out near Grant Cove and triangulation station Pug and in the Dall Bay–Seal Cove area. The rocks are virtually identical with trondhjemitic parts of the Silurian Annette pluton on Annette Island and are interpreted as stocklike apophyses of it. The Gravina Island bodies also resemble the Annette pluton in that they intrude, but do not significantly metamorphose, predominantly greenschist-facies metamorphic country rocks and are overlain unconformably by middle Paleozoic bedded rocks.

The plutonic rocks typically are light greenish gray, are medium grained, and have hypidiomorphic granular texture. Some are crudely gneissic, but most are not discernibly foliated. Most consist of about 65 percent plagioclase and 30 percent quartz, plus variable, but usually small, amounts of potassium feldspar, chlorite, muscovite, biotite, epidote-clinozoisite, sphene, hematite, pyrite, dolomite, and calcite. The plagioclase is slightly to moderately sericitized albite and sodic oligoclase; relict zoning is fairly common, and many of the milky, altered crystals are rimmed by clear albite. The quartz generally is interstitial to the plagioclase but locally occurs in phenocrystlike blebs (porphyroclasts?) up to 2 cm in diameter. Potassium feldspar is generally absent; where present, however, it averages only a percent or so of the rock and only rarely makes up as much as 15–20 percent. It occurs partly as irregular sharply bounded masses interstitial to the plagioclase and quartz, partly as diffuse masses, very finely disseminated particles and veinlets, and partly as patchy replacements of plagioclase.

Evidence of cataclasis is widespread; it ranges from incipient crushing and intergranular mortaring to intense milling and microbrecciation. Dolomite and calcite veins are common, and the breccias generally are healed by orange- or brown-weathering dolomite.

Most of the plutonic rocks have a distinctly pinkish cast that apparently is due to impalpable ferric oxide hydrothermal alteration. The alteration mainly affects the feldspar and ranges in intensity from isolated pink spots and pink mottling to a nearly uniform deep pink or salmon. It is especially prominent in the Dall Bay–Seal Cove area and near triangulation station Pug. The pink hydrothermally altered material looks deceptively like potassium feldspar, for which it is easily mistaken. In fact, potassium feldspar content in most of these rocks can be determined only by selective staining tests such as those described by Bailey and Stevens (1960).

Roddick (1965, p. 138–139) suggested that pink hydrothermal alteration in plutonic rocks near Vancouver, British Columbia, is due to adsorption of ferric oxide by clay particles in kaolinized feldspar, the iron being derived from concomitant chloritization of the pluton's biotite. The pink plutonic rocks on Gravina Island resemble those near Vancouver in that the alteration probably is hydrothermal, but they differ in that the feldspar is not significantly kaolinized and that the source of the ferric iron may be external (p. 14 and 37).

PUPPETS FORMATION

The name Puppets Formation is here applied to felsic metavolcanic rocks that form conspicuous light-toned bluffs on the southeast sides of The Puppets and Punch Hill on southern Gravina Island. This area is designated the type locality (secs. 17, 19, and 20, T. 77 S., R. 91 E., and sec. 24, T. 77 S., R. 90 E.). The formation is divided into two probably intertonguing members: a massive-appearing to thinly layered recrystallized felsic volcanic unit, termed the metarhyolite member, and a recrystallized felsic volcaniclastic unit, termed the metatuff member. The metatuff member is generally at or near the base of the formation.

In the type area and on the west coast of Gravina Island, the Puppets Formation unconformably overlies Silurian or older Paleozoic rocks. In the type area, it appears to conformably underlie dolomitic limestone of probable Devonian age; elsewhere, it unconformably underlies the Nehenta Formation.

No fossils have been found in the Puppets Formation. Its stratigraphic position, however, indicates a maximum age of Silurian. Its minimum possible age is Devonian if, as seems likely, it conformably underlies the dolomitic limestone on southern Dall Ridge and if, as also seems likely, the limestone is Devonian. It is thus assigned a middle Paleozoic age.

METATUFF MEMBER

The metatuff member occurs on the southeast side of The Puppets, in Seal Cove, on islets and adjacent shoreline at the southwest mouth of Bostwick Inlet, and on the west coast of Gravina Island about 4.5 miles north of Nelson Cove. It is inferred to underlie the metarhyolite member on Punch Hill but was not actually observed there. The contact between the metatuff and metarhyolite members was not observed owing to poor exposures, but the field relations and lithology of these members suggest that they intertongue. Recrystallized tuffaceous rocks north of Smooth Mountain and at Grant Cove are provisionally assigned to this member on the basis of lithology.

The thickness of the metatuff was not measured. It is estimated to be about 150 feet thick because gently dipping, apparently homoclinal metatuff crops out (discontinuously) for a vertical distance of about 200 feet on the southeast side of The Puppets.

The metatuff is characterized by relict fragmental texture, but like the metarhyolite, it varies widely in aspect. It is similar to the metarhyolite in color, in variation in potassium feldspar content and in deuteric and hydrothermal alteration, but chemical analyses indicate that the metatuff is somewhat more mafic. This may be due in part to included extraformational material but probably is mainly primary. The silica content and alkali-lime ratio indicate that the metatuff consists of latite, rhyodacite, and subordinate rhyolite.

The metatuff can be divided into two main types: a massive apparently nonfoliated type and a slaty to phyllitic foliated type.

Typical nonfoliated metatuff occurs at The Puppets and west-coast localities; an atypical variant is on the islets at the mouth of Bostwick Inlet. On The Puppets, it contains angular clasts up to an inch long of maroon, pink, and brown metarhyolite and smaller less abundant fragments of trondhjemite, cryptocrystalline material with shardlike outlines, quartz, and albite(?). The groundmass is an aphanitic, microclastic (relict vitroclastic?), and microporphyritic aggregate of potassium feldspar, quartz, albite(?), hematite, and dolomite. On the west coast, the member is massive to slaty and consists of purple, green, and mottled purple and buff metatuff and subordinate brown-weathering tuffaceous dolomite. The metatuff has conspicuous relict fragmental texture on a scale ranging from microbreccia to coarse blocky breccia. Clasts include plutonic and metamorphic rocks derived from underlying units on Gravina Island, metarhyolite, and shardlike and pumicelike material. The groundmass is aphanitic, vitroclastic, and porphyritic and contains minute lithic fragments, albite(?), quartz, dolomite, and minor potassium feldspar. On the islets at the mouth of Bostwick Inlet, the member consists of maroon and brown flow breccia composed of spherulitic and layered metarhyolite clasts and a scant matrix of tuffaceous limestone. The rocks were rebrecciated along faults, then healed and partly replaced by dolomite, hematite, and minor sulfide minerals.

Typical foliated metatuff occurs in Seal Cove and on the shoreline of Bostwick Inlet. It differs from the nonfoliated type mainly in that it is phyllitic. In part, the foliation is due to deformation, but at least some appears to be relict eutaxitic structure. A thin section of this metatuff from the shoreline of Bostwick Inlet shows alined centimeter-long rhombic tablets of very fine grained sericite, quartz, and feldspar that could be compressed recrystallized pumice fragments; it also shows a microgranular to schistose matrix of sericite, quartz, feldspar, magnetite, apatite, and dolomite. The schistosity is defined by alined sericite, which occurs in two orientations: one parallel to the long edge of the tablets and one at a 15°-angle to it. Some of the dolomite occurs in isolated granules; some, in subparallel veinlets.

The recrystallized tuffaceous rocks on the ridges north of Smooth Mountain and at Grant Cove closely resemble parts of this member. They commonly weather greenish- or brownish-gray, but purple, pink, green, and red varieties are conspicuous locally. Relict fragmental and porphyritic textures are ubiquitous, and potassium feldspar content varies markedly. The rocks on the ridges north of Smooth Mountain typically contain relict ⅛-inch-long feldspar phenocrysts, diverse lithic fragments up to an inch long, and sparse quartz microphenocrysts. The groundmass is a crudely to strongly foliated very fine grained aggregate of sericite, quartz, albite(?), and potassium feldspar, plus minor dolomite, magnetite, hematite, pyrite, biotite, and chlorite. The potassium feldspar occurs in indistinct patches and as irregular replacements of parts of the feldspar phenocrysts, giving them a sievelike aspect in thin section. The fragmental material generally is intensely sericitized, but some can be identified as pumice(?), feldspar porphyry, felsic aphanite, and fine-grained detrital rocks. The foliation commonly is due to alined micaceous minerals, but some is distinctly cataclastic, without significant recrystallization.

At Grant Cove, purple and dark-green fragmental rocks consist of clasts up to several inches long of light-greenish-gray leucotrondhjemite and minor darker hued plutonic(?) and metamorphic rocks in a matrix of fine-grained phyllite containing sericite, quartz, albite(?), chlorite, dolomite, and hematite. In addition to the purple coloration, attributed to hydrothermal ferric iron, the rocks locally are intensely sheared and partly replaced by hematite and bright-red jasper.

METARHYOLITE MEMBER

The metarhyolite member occurs on southern Gravina Island between Nehenta Bay and Bostwick Inlet. It generally weathers light gray or light brownish gray and is distinguished by hummocky and clifflike outcrops that are either bare or only lightly covered with vegetation. From a distance the outcrops appear massive or only crudely layered, but closer inspection reveals fairly regular layering.

Small poorly exposed outcrops of light-gray metarhyolite on the ridge northwest of Chapin Peak are provisionally assigned to this member on the basis of lithology. The contact between the metarhyolite and surrounding Chapin Peak Formation, however, is not exposed, and its mode of occurrence is not known. If, as seems likely, the metarhyolite is part of the Puppets Formation, it probably is in fault contact with the Chapin Peak Formation or, less likely, occurs as large inclusions in it.

The thickness of the member is uncertain owing to its complex structure. A gently dipping apparently homoclinal section of metarhyolite is continuously exposed in a nearly 500-foot bluff on the southeast side of The Puppets, suggesting an approximate minimum thickness of about 400 feet.

The metarhyolite occurs in a variety of colors, including white, black, gray, and shades of pink, purple, red, brown, and green. Bright-red jasperized metarhyolite occurs northeast of Nehenta Bay near triangulation station Dall, and mottled purple and buff metarhyolite occurs near the base of the member on the southeast side of The Puppets.

The metarhyolite, like the metatuff, has several textural variants. Probably the most abundant consists of layers of aphanite ranging in thickness from a fraction of an inch to about a foot. Generally the layers, interpreted as relict flow bands, are most conspicuous on weathered surfaces and are obscure or even invisible on freshly broken surfaces. Another variant has relict fragmental texture. It too ranges from distinct to faint, depending on weathering and other factors, and is produced by 1-inch (or smaller) angular clasts, generally of metarhyolite, but locally of exotic rocks, in an aphanitic base. A third type of metarhyolite is distinguished by spherulitic texture. The spherulites commonly are the size of pinheads and are fairly widespread but seem to occur abundantly only in certain zones. One such occurrence, of nearly undeformed spherulites as large as golf balls, is on the northeast ridge of Punch Hill. Some of the clasts in the fragmental metarhyolite are spherulitic, and much of the layered type consists of alternating spherulitic and aphanitic layers. A fourth variant consists of apparently structureless aphanitic or flinty rock closely resembling metachert.

Thin sections of metarhyolite also show a variety of textures, which generally are much less prominent than in outcrops or hand specimens, because the uniform felsic mineralogy subdues textural contrasts. Typical metarhyolite consists of sparse microphenocrysts of quartz, potassium feldspar, and albite or sodic oligoclase in a cryptocrystalline, microgranular, decussate, or spherulitic groundmass of the same minerals, plus subordinate to minor amounts of sericite, dolomite, chlorite, apatite, clinozoisite-epidote, hematite, and pyrite. The sericite locally is conspicuous, either as subparallel zones associated with microshearing and recrystallization, as pseudomorphs after feldspar phenocrysts or lithic fragments, or as irregular replacements in parts of the groundmass. The dolomite generally occurs in veinlets and as individual crystals and clumps of crystals. The chlorite and clinozoisite-epidote probably are mainly pseudomorphs of extraformational lithic material. Quartz-calcite veins, locally containing dolomite, hematite, barite, and sulfide minerals, are common, and

499-954 O - 73 - 3

in places the metarhyolite is replaced entirely by bright-red jasper.

Etch tests and X-ray diffraction studies of the metarhyolite show a marked variation in potassium feldspar content, which ranges from zero to more than 50 percent of the rock. In part, the variation is fairly regular and abrupt, such as in alternating layers in the layered metarhyolite, but mostly it seems to be irregular and gradual. This variation is reflected in chemical analyses of the metarhyolite, in which potash-soda ratios range from about 30:1 to 1:15. According to Muffler (1967, p. C27), a comparably extreme variation in the ratio of potassium feldspar to albite in altered felsic volcanic rocks in the Keku Islets of southeastern Alaska probably results from deuteric alteration. This probably is true for most of the metarhyolite on Gravina Island, but some of the variation may result from subsequent hydrothermal alteration.

Field relations, thin-section studies, and chemical analyses indicate that most of the pink, purple, and red coloration of the metarhyolite is due to an impalpable ferric oxide hydrothermal alteration that accompanied, or closely postdated, the deposition of the Puppets Formation. This syngenetic or deuteric ferric iron is irregularly distributed but apparently is most abundant in the lower part of the formation. Similar pink alteration in many of the pre-Puppets rocks on western Gravina Island (p. 6, 7, and 9) is attributed to hydrothermal emanations from volcanic rocks of the Puppets as they covered the older rocks. The veins and local massive replacements by jasper, white quartz, dolomite, hematite, barite, and sulfide minerals postdate the pink alteration.

RECRYSTALLIZED FRAGMENTAL ROCKS

Recrystallized predominantly fragmental rocks of presumably Paleozoic age occur on the south shore of Vallenar Bay and near South Vallenar Point. They are overlain, apparently conformably, by probable Devonian rocks and unconformably by Upper Triassic rocks. The base of the unit is not exposed, and its thickness is therefore unknown. Perhaps 200 feet of beds is exposed in the Vallenar Bay area, but the beds undoubtedly are repeated by complex folding and faulting. No fossils have been found in the unit. Its maximum age, inferred from indirect stratigraphic and lithologic evidence, is Silurian; its minimum age, based on stratigraphic position, is Devonian. In this report it is assigned an age of middle Paleozoic.

The unit consists mainly of slaty to phyllitic fragmental rocks of diverse origin and relatively small amounts of metachert, dolomitic limestone and marble, and fine-grained metasedimentary rocks. Near South Vallenar Point, it also includes hornfelsic bedded rocks, greenstone, and greenschist.

The fragmental rocks comprise two main types: metatuff and polymictic conglomerate. The most conspicuous metatuff crops out about half a mile east of South Vallenar Point. It is a brightly mottled salmon and green rock containing angular clasts up to 3 inches long of potassic metarhyolite and other felsic metavolcanic rocks. The matrix is fine-grained phyllite containing sericite, quartz, albite(?), dolomite, and abundant bits of lithic material rich in potassium feldspar. That the rock appears to contain enough quartz and potassium feldspar to be classified as rhyodacite metatuff suggests at least lithic equivalence to parts of the Puppets Formation. Less conspicuous metatuff containing no potassium feldspar probably also occurs but is difficult to identify because it lacks the distinctive mineralogy and relict textures of the potassic variety.

The polymictic conglomerate most commonly is olive-, brownish-, or greenish-gray and contains clasts of metachert, dolomite, limestone, siltstone, metatuff, felsic aphanite and aplite, leucotrondhjemite, greenstone, quartz, and plagioclase. The matrix is orange-weathering siltstone and silty to gritty dolomitic limestone. A less abundant type contains only dolomite and metatuff clasts and has a dark-gray slaty argillite base. Some clasts are nearly perfectly spherical, but most are subangular; sizes range from fine grit to boulders a foot or more in maximum dimension but probably average an inch or less.

The degree of penetrative deformation of this unit varies, partly according to the competence of the beds and partly with proximity to major faults. Some of the conglomerate, for example, is slaty and has only slightly to moderately deformed clasts, but most is distinctly phyllitic and has moderately to markedly flattened clasts. In addition, much of the unit is sheared, crushed, and hydrothermally altered. Dolomitization is widespread, and the rocks locally are cut by veinlets of quartz, dolomite, barite(?), and pyrite.

LIMESTONE AND DOLOMITE

Limestone, dolomite, and, locally, metachert, phyllite, and conglomerate of Paleozoic age crop out in three places on Gravina Island: (1) near the southern end of Dall Ridge, (2) on the west coast about 4.4 miles north of Nelson Cove, and (3) between South Vallenar Point and Vallenar Bay. Small poorly exposed outcrops of dark-gray metachert on the ridges north of Smooth Mountain are provisionally assigned to this unit on the basis of lithology.

On southern Dall Ridge the unit consists chiefly of red-weathering sandy to gritty dolomitic limestone that appears to conformably overlie the metarhyolite member of the Puppets Formation. On the west coast it consists of light-brownish-gray very fine grained dolomite that is in fault(?) contact with fragmental rocks correlated with the conglomerate member of the Nehenta Formation. Near Vallenar Bay it comprises light-gray slaty limestone and minor conglomerate, dolomite, phyllite, and metachert that overlie recrystallized fragmental rocks that may be as old as Silurian.

The unit is thickly bedded or massive appearing on Dall Ridge and is thinly to moderately thickly bedded at the other localities. Its thickness, which was not measured owing to complex deformation, may be as much as 200–300 feet.

Although some of the dolomite at Vallenar Bay and on the west coast may be primary or diagenetic, most probably is hydrothermal. At Vallenar Bay dolomitization locally is accompanied by silicification and introduction of sulfide minerals. The dolomite on southern Dall Ridge commonly is ferruginous and is a result of widespread, locally intense hydrothermal alteration.

The age assigned to the unit is based on fossils collected from the west coast and Vallenar Bay localities. According to C. W. Merriam (written commun., 1969), the dolomite on the west coast (USGS Paleozoic loc. M1402) contains a spaghettilike fossil—possibly *Cladopora, Coenites,* or a related type of favositid—of Silurian to late Middle Devonian age. Fossils collected from the beds on Vallenar Bay by earlier workers (Chapin, 1918, p. 88; Buddington and Chapin, 1929, p. 94–98) were determined to be of Devonian (probably Middle Devonian) age. The limestone on Dall Ridge contains scattered poorly preserved fossils, mainly pelecypods, of uncertain age, but the angular clasts of fossiliferous Devonian limestone in the conglomerate member of the Nehenta Formation nearby (p. 22) may have been derived from this limestone before it was altered.

Most of the unit is probably Devonian. The facts that its occurrences are widely separated and that each is in contact with different types of rocks make it possible for the unit to include more than one formation. Its maximum possible age, based on fossils from Gravina Island and from probably correlative beds on Annette and Hotspur Islands (Berg, 1972), is Late Silurian. In this report, it is assigned an age of middle Paleozoic.

GNEISS AND SCHIST

Southernmost Gravina Island and parts of nearby islets and reefs are underlain by amphibolite-facies gneiss and schist containing hornblende, plagioclase (An_{25-40}), and, locally, garnet, biotite, and clinopyroxene. Variable amounts of other minerals, either of ambiguous metamorphic grade or not stable in the amphibolite facies, also occur; these include quartz, albite, sodic oligoclase, potassium feldspar, sericite-muscovite, prehnite, chlorite, epidote-clinozoisite, sphene, apatite, calcite, pyrite, and magnetite.

At megascopic scale, the rocks are conspicuously foliated and have crude to regular gneissic banding. Composition layers are a foot or so thick in places but probably average less than an inch thick. Color, governed by the proportion of felsic to mafic minerals, ranges from light gray to dark greenish black. The rocks locally are cut by fault zones carrying dolomite, calcite, quartz, barite(?), and hematite.

Thin sections typically show fine to moderately coarse grained schistose aggregates of poikiloblastic green (Z) hornblende and granoblastic plagioclase and quartz. In a few specimens, faint hypidiomorphic granular texture is preserved, as is concentric zoning in some of the plagioclase. The hornblende is partly replaced by chlorite and epidote; the plagioclase, by albite or sodic oligoclase, sericite, clinozoisite, and kaolin. Other features include irregular veinlets and replacement masses of prehnite, chlorite, albite, epidote, and quartz. The foliation is disrupted by cataclasis of up to mylonitic intensity.

The mineralogy, paragenesis, and textures indicate amphibolite-facies regional metamorphism of mafic and subordinate quartzo-feldspathic rocks, at least some of which were igneous, and widespread, generally incipient, retrogressive metamorphism. At least some of the retrogressive metamorphism probably is associated with the cataclastic deformation, but the cause of the amphibolite-facies metamorphism is uncertain. Its age also is uncertain, but available data suggest two amphibolite-facies metamorphic events. One is inferred to be Late Cretaceous because metamorphic biotite from probably correlative amphibolite-facies rocks on the Metlakatla Peninsula of Annette Island (Berg, 1972) has been dated by the K/Ar method at about 77 million years (J. C. Von Essen, written commun., 1970). The other, based on stratigraphic evidence, is Late Triassic or older, because conglomerate in the Chapin Peak Formation on southern Gravina Island contains clasts of amphibolite derived from the gneiss and schist unit. It should be emphasized that this amphibolite-facies regional metamorphism affects only the rocks on southernmost Gravina Island and on Metlakatla Peninsula and not the Paleozoic and Mesozoic rocks elsewhere on Gravina and Annette Islands.

The Paleozoic or early Mesozoic age herein assigned to the gneiss and schist unit is based partly on the inferred age of the older metamorphic event, and partly on regional geology. Using indirect evidence, Berg (1970, 1972) assigned the probably correlative rocks on Annette Island's Metlakatla Peninsula a provisional age of Silurian or older. Additional fieldwork and newly acquired K/Ar dates, however, do not support this age assignment. All that is known on Annette Island is that the unit there is intruded by a pluton whose minimum age is about 200 m.y. (see below), and that it probably underwent amphibolite-facies regional metamorphism in Late Cretaceous time. Based on the stratigraphic evidence on Gravina Island, the minimum possible age of the gneiss and schist unit is Triassic, a possibility supported by intrusive relations on Annette Island. Its maximum possible age is Silurian or older, mainly because on Gravina Island it adjoins, and resembles parts of, an assemblage of undivided metamorphosed bedded and intrusive rocks of that age (p. 5–7).

Regional geologic considerations, on the other hand, suggest that the unit (and the undated parts of the undivided assemblage referred to on p. 5–6) may be part of a recently postulated terrane of upper Paleozoic and younger rocks thought to make up much of southeastern Alaska and nearby British Columbia (Monger and Ross, 1971; Berg and others, 1972, p. D2). If it is, its possible age range is late Paleozoic to Triassic(?).

Because the available evidence is still largely inferential and indirect, the gneiss and schist unit herein is assigned an age of Paleozoic or early Mesozoic.

METADIORITE

Parts of southernmost Gravina Island and nearby islets and reefs are underlain by a metamorphosed quartz diorite-diorite pluton. The plutonic rocks are complexly mixed with metamorphosed bedded rocks, and in many places their contact is gradational. On the geologic map (pl. 1), dioritic rocks are shown where their volume is estimated to be greater than that of the country rocks.

The pluton is correlated with the South Metlakatla pluton of Annette Island (Berg, 1972), which it closely resembles in lithology and geologic setting. Using indirect evidence, Berg assigned a provisional age of middle or late Paleozoic to the South Metlakatla pluton. Additional data now available, however, including a K/Ar date of 200±6 m.y. on hornblende (J. C. Von Essen, written commun., 1970), and the same regional geologic considerations described above suggest that it is late Paleozoic or early Mesozoic.

The dioritic rocks on southern Gravina Island typically are foliated and contain widely variable amounts of poikiloblastic green (Z) hornblende and granoblastic oligoclase-andesine (An_{27-35}) and quartz. Subordinate, but locally conspicuous, minerals include albite, biotite, potassium feldspar, epidote-clinozoisite, chlorite, garnet, apatite, sphene, magnetite, and pyrite. Much of the plagioclase is replaced by sericite, clinozoisite or zoisite, and kaolin; the hornblende locally is replaced by chlorite or by colorless amphibole. The foliation commonly is disrupted by moderate to intense cataclastic deformation.

The rocks contain irregular veinlets of calcite, prehnite, quartz, albite(?), epidote, and chlorite and are cut by fault zones carrying dolomite, barite(?), quartz, and hematite. Some of the rocks have a prominent pinkish cast due to impalpable hydrothermal ferric oxide.

The mineralogy and paragenesis indicate amphibolite-facies regional metamorphism, followed first by widespread retrogressive metamorphism and then by local hydrothermal alteration and formations of fissure veins.

The cause of the amphibolite-facies regional metamorphism has not been determined. The age of at least some of this metamorphism, like that in the gneiss and schist unit, appears to be Late Cretaceous, whereas some may be older (p. 17). At least some of the retrogressive metamorphism probably is associated with the cataclastic deformation.

NEHENTA FORMATION

The name Nehenta Formation is here given to marine sedimentary and subordinate volcanic rocks that underlie western Gravina Island from Bostwick Inlet to Vallenar Bay. At no single locality is a complete, structurally simple section preserved, but good exposures of most of its members occur in the Nehenta Bay–Thompson Cove area, which is designated the type locality (secs. 23, 25, 26, and 36, T. 77 S., R. 90 E.).

The formation is divided into three members: (1) a calcareous member, distinguished by carbonaceous limestone and siltstone in its lower part and calcareous conglomerate, grit, and sandstone in its upper part, (2) a coarse conglomerate and grit member that appears to intertongue with the lower part of the calcareous member, and (3) a basaltic volcanic member that also occurs mainly in the lower part of the formation. Excellent exposures of the volcanic member occur along the coastline between Grant Cove and the cove 0.6 mile south of South Vallenar Point, which is designated as a reference area.

The formation unconformably overlies Paleozoic rocks; in most places it is overlain by the Upper Triassic Chapin Peak Formation with negligible structural, but possibly widespread erosional, discordance.

The rocks of the formation are complexly folded and faulted, and, depending upon their susceptibility to penetrative deformation, foliated. Structural complexity ranges from slight (crude fracture cleavage) in the massive parts of the coarse conglomerate and volcanic members to extreme in the lower part of the calcareous member, which characteristically is phyllitic, lineated, and compositely folded. Except for local hydrothermal alteration (mainly dolomitization in the Nehenta Bay–Nelson Cove area) and thermal metamorphism (mainly near South Vallenar Point), the rocks generally are only slightly recrystallized, and relict sedimentary and volcanic textures are common.

The thickness of the Nehenta Formation was not measured during this investigation. Buddington and Chapin (1929, p. 170) estimated that the "Upper Triassic limestone, slate, and conglomerate on Gravina Island"—essentially the Nehenta Formation of this report—are about 1,600 feet thick, but it is not known whether this figure accounts for structural repetition of beds and differences in original thickness of the members from place to place.

The Late Triassic age assignment of the Nehenta Formation is based on fossils collected from the calcareous member in the Nehenta Bay area and in Bostwick Inlet (USGS Mesozoic locs. M5093, M5094). The lower part of the member is characterized by *Halobia,* a delicately ribbed flat clam; the upper part, by *Heterastridium,* a pea-sized to golf-ball-sized spheroidal fossil of uncertain origin. According to N. J. Silberling (written commun., 1968), the *Halobia*-bearing beds are of early and middle Norian age, and the *Heterastridium*-bearing beds are of late Norian age. The known stratigraphic ranges of the two genera do not overlap.

CALCAREOUS MEMBER

The calcareous member crops out nearly continuously from Bostwick Inlet to Vallenar Bay, but only the carbonaceous beds in the lower part have been recognized throughout its outcrop length. The other rock types in the lower part and all rock types in the upper part occur mainly on southwestern Gravina Island and only sparsely north of about lat 55°15′ N.

The lower part of the calcareous member is distinguished by thinly interlayered dark-gray and dark-brown carbonaceous limestone and siltstone containing locally abundant *Halobia.* Interbedded with the carbonaceous rocks are sparsely fossiliferous olive-weathering very fine grained limestone, light-gray locally concretionary sandy to gritty limestone, and light-brownish-gray calcareous sandstone, grit, and conglomerate. The conglomerate contains granule- to cobble-sized clasts, derived in large part from underlying Paleozoic rocks, of trondhjemite, metarhyolite, limestone, argillite, and siltstone; the matrix is sandy to gritty limestone. Bedding thickness ranges from an inch or so in the carbonaceous beds to about 10 feet in some of the gray limestone.

The upper part of the calcareous member consists of thinly to moderately thickly interbedded brownish-gray calcareous grit, conglomerate, and sandstone and subordinate light-gray sandy to gritty limestone. The conglomerate is characterized by granule- to boulder-sized generally subangular clasts derived mainly from underlying parts of the Nehenta Formation; the matrix is gray siltstone and limestone.

CONGLOMERATE MEMBER

The conglomerate member occurs in the Nehenta Bay–Open Bay area and on the west coast about 4 miles north of Nelson Cove. The contact between the conglomerate and underlying rocks is not exposed in the Nehenta Bay area, but it probably forms the base of the Nehenta Formation there; on the west coast, the member appears to depositionally overlie metatuff provisionally correlated with the Puppets Formation. The conglomerate apparently intertongues with the lower part of the calcareous member, which forms the base of the formation elsewhere on southern Gravina Island.

The member, especially in coastal exposures, forms prominent to spectacular outcrops of moderately to thickly bedded fragmental rocks distinguished by abundant granitic clasts and orange- to brick-red-weathering matrix.

The prevailing rock type, which makes up the peninsulas between Open Bay, Thompson Cove, and Nehenta Bay, is orange-weathering coarse angular conglomerate containing granules to 8-foot boulders of light-gray leucotrondhjemite and minor darker hued metasedimentary and metavolcanic rocks in a matrix of cream-colored ferruginous dolomite studded with angular bits of quartz and feldspar. The leucotrondhjemite is identical with that in the Silurian Annette pluton on Annette Island (Berg, 1972) and with correlative plutonic rocks on Gravina Island (p. 8). Some of this conglomerate occurs in regular beds averaging a few feet thick, but much of it forms massive accumulations that are 10 feet or more thick and have no detectable bedding.

The islands in the southern part of Nehenta Bay and much of the adjacent mainland to the northeast are underlain mainly by beds as much as 6 feet thick of orange- and gray-weathering carbonate-cemented sandstone and pebbly to cobbly grit, pebbly limestone, and very fine grained limestone. The clasts generally are smaller and better rounded than in the prevailing rock type, but most also consist of leucotrondhjemite. The orange weathering hues are due to locally intense dolomitization. A subordinate rock type of these islands is conglomerate containing angular to subrounded clasts up to 3 feet long of light-gray fossiliferous limestone, plus leucotrondhjemite and fine-grained sedimentary and metamorphic rocks. The matrix is limestone and carbonate-cemented sandstone and grit. According to Chapin (1918, p. 92), fossils collected from this conglomerate included Devonian and Triassic types. The Devonian fossils probably were collected from clasts derived from Paleozoic rocks underlying the Nehenta Formation; the Triassic fossils probably came from the matrix of the conglomerate.

On the west coast, the member is thinly to moderately thickly bedded and consists of orange-, red-, and brown-weathering calcareous sandstone, grit, and conglomerate, sandy to gritty limestone, and minor gray limestone and dark-gray carbonaceous slate and siltstone. Clasts are similar to those in the conglomerate in Nehenta Bay, but also include locally conspicuous spheroidal pebbles of black chert and cherty argillite.

VOLCANIC MEMBER

The volcanic member occurs along the west coast of Gravina Island for about 3 miles north of Nelson Cove; between South Vallenar Point and Grant Cove; in the south arm of Thompson Cove; and in Nehenta Bay.

North of Nelson Cove, the member is interbedded with *Halobia*-bearing beds of the calcareous member; in the South Vallenar Point–Grant Cove area, it conformably underlies the *Halobia*-bearing beds and unconformably overlies Paleozoic rocks; and in Thompson Cove it overlies the conglomerate and possibly the calcareous members. In Nehenta Bay it overlies the calcareous member and apparently is in thrust contact with overlying metarhyolite of the Puppets Formation. Its thickness ranges from a few tens of feet north of Nelson Cove to probably one or two hundred feet near Grant Cove.

The member consists of altered, at least partly spilitic, basaltic and minor andesitic pillow flows and pillow breccia, massive flows and breccia, and subordinate calcareous tuff and tuffaceous limestone. Locally interbedded with the volcanic rocks are lenses and thin beds of slate, siltstone, graywacke, limestone, and calcareous grit and conglomerate.

The pillow flows and associated breccia typically are dark green and moderately to thickly bedded. Although slightly deformed pillows as much as 8 feet in diameter are preserved locally, pillows generally are flattened, shattered, and cleaved and probably average about a foot in maximum dimension. The interstices between the pillows and breccia clasts commonly are filled with light-gray fine-grained limestone. Pillows and pillow clasts are fine grained and have relict porphyritic, intersertal, and trachytic textures. Most consist of millimeter-sized relict phenocrysts of (sericitized) plagioclase and clinopyroxene in a base of altered plagioclase, epidote-clinozoisite, calcite, potassium feldspar, and cryptocrystalline secondary minerals. Calcite-chlorite(?)- and quartz-filled amygdules are common, as are veinlets of chlorite, calcite, quartz, and albite(?).

The massive flows and breccia, which occur mainly in the south arm of Thompson Cove, consist of fairly regular, locally slaty beds up to several feet thick that weather maroon, dark brown, and dark greenish gray. They lack pillow structures but otherwise are similar to the pillow flows and breccia. The massive flows are interbedded with fine-grained sedimentary rocks and with pink-, brown-, green-, and maroon-weathering slaty tuff containing scattered golf-ball-sized concretions.

The calcareous tuff and tuffaceous limestone are mutually gradational and intertongue with flows and fine-grained sedimentary rocks. They are generally slaty, are crowded with vesicles and calcite-filled amygdules, and consist of sparse to abundant fragments of altered volcanic rocks in a matrix of calcite, chlorite, plagioclase, potassium feldspar, sericite, and unidentified secondary minerals. Some of the tuff apparently is rich enough in potassium feldspar and felsic minerals to be classified as trachyandesite or dacite.

CHAPIN PEAK FORMATION

The name Chapin Peak Formation is here applied to marine basaltic volcanic and intertonguing sedimentary rocks and minor basic intrusive rocks that crop out on western Gravina Island from Bostwick Inlet nearly to Vallenar Bay. The formation is abundantly fossiliferous in places along the shore of Bostwick Inlet; it is best exposed in the Chapin Peak–Downdraft Lake area, which is designated as the type locality (secs. 12 and 13, T. 77 S., R. 90 E.).

The thickness of comparatively undisturbed exposures in the type area ranges from about 500 to 1,500 feet; variations in thickness are due partly to differences in original thickness and partly to erosion.

The formation is mapped only on Gravina Island southwest of Bostwick-Vallenar valley. In most places it conformably or possibly disconformably overlies the Upper Triassic Nehenta Formation; near Vallenar Bay, however, it may overlie rocks as old as Paleozoic. It is overlain by slaty detrital rocks with slight structural, but marked erosional, discordance.

All but a small part of the formation consists of basaltic pillow flows and pyroclastic rocks that intertongue complexly with conglomerate and grit, siltstone and argillite, and limestone. Probably less than 1 percent consists of basic intrusive rocks interpreted as feeders and hypabyssal equivalents of the extrusive rocks.

The Chapin Peak Formation is assigned a Late Triassic age on the basis of marine fossils collected from limestone beds and from limestone clasts in the conglomerate on the southwestern shore of outermost Bostwick Inlet (USGS Mesozoic locs. M5095, M5909). A partial list of the fossils, identified by N. J. Silberling (written commun., 1969) and D. L. Jones (written commun., 1969) includes:

Arcestes sp.
Cassianella sp.
Cycloceltites cf. *C. arduini* (Mojsisovics)
Gervilleia sp.
Goniomya? sp.
Halorites? sp.
Minetrigonia cf. *M. cairnesi* (McLearn)
Minetrigonia cf. *M. suttonensis* Clapp and Shimer
Palaeopharus cf. *P. buriji* Kiparisova
Pinna sp.
Placites sp.
Plicatula cf. *P. perimbricata* Gabb
Septocardia sp.
"*Variamusium*" sp.
Large trigonid? clam—genus and species unknown
Undet. nuculid, pectenacid, and other pelecypods
Undet. ornate gastropod

According to Silberling, the fossils are late, possibly latest, Norian and are younger than the Upper Triassic *Halobia*- and *Heterastridium*-bearing beds of the underlying Nehenta Formation.

BASALTIC VOLCANIC ROCKS AND INTERTONGUING SEDIMENTARY ROCKS

In the type area of the Chapin Peak Formation, approximately equal amounts of volcanic and sedimentary rocks intertongue near the base, but the volcanic rocks increase in abundance upward and make up virtually all of the upper two-thirds. In exposures along the southwestern shore of Bostwick Inlet, the sedimentary rocks are more abundant than the volcanic rocks, but it is not known whether this apparent increase in sedimentary units is due to facies change or whether only the base is exposed along Bostwick Inlet.

Bedding thickness in the sedimentary units ranges from an inch or so to about 3 feet; the pillow flows average about 10 feet thick. Most of the sedimentary and less massive volcanic rocks have distinct slaty cleavage.

The volcanic rocks consist of deuterically(?) altered basaltic and minor andesitic pillow flows and pillow breccia, limestone- and aquagene tuff-cemented volcanic breccia, and subordinate massive flows and aquagene tuff. The rocks characteristically weather dark green and dark brown; fresh surfaces are dark gray to purplish gray.

The flows and breccia clasts generally are very fine grained and have relict intergranular, intersertal, trachytic, diabasic, and, rarely, vitroclastic and porphyritic texture. Minerals identified in thin section include plagioclase, augite, calcite, chlorite, epidote, quartz, green (Z) hornblende, and prehnite(?). Vesicles and calcite- and chlorite(?)-filled amygdules are common, especially in the pillow flows. The interstices between pillows commonly contain very fine grained limestone. The aquagene tuff consists of altered basaltic fragments in a matrix of calcite, bits of volcanic rock, and chloritelike secondary minerals derived from basaltic glass.

The sedimentary parts of the Chapin Peak Formation consist mainly of limestone-cemented granule to boulder conglomerate containing angular clasts of limestone, basaltic volcanic rocks, dark-gray siltstone and argillite, and minor metamorphic rock types, including amphibolite. Less abundant, but locally prominent, rock types include thinly interbedded dark-gray siltstone and argillite, light-brownish-gray silty limestone, and light-gray very fine grained recrystallized limestone.

Most of the clasts in the conglomerate are derived from volcanic and sedimentary units of the Chapin Peak Formation; a few are from underlying Paleozoic units. Conglomerate at the base of the formation west of central Dall Ridge also contains large slabs of black, carbonaceous siltstone and phyllite derived from the apparently conformable underlying Nehenta Formation. The occurrence of these slabs suggests at least an erosional interval between the Chapin Peak and Nehenta Formations.

The silty limestone and many of the limestone clasts in the conglomerate locally contain relatively abundant moderately well-preserved fossils. The light-gray recrystallized limestone, which crops out mainly along the southwest shoreline of inner Bostwick Inlet, contains only scrappy, poorly preserved fossils. The recrystallization probably is a result of faulting nearby along Bostwick Inlet.

BASIC INTRUSIVE ROCKS

Small bodies of altered basic intrusive rocks enclosed by volcanic rocks assigned to the Chapin Peak Formation occur on the southwestern shoreline of Bostwick Inlet, on Smooth Mountain, and about half a mile northwest of Punch Hill. The bodies are interpreted as feeders and hypabyssal equivalents of some of the Chapin Peak lava flows and thus are assigned a Late Triassic age. A basic plug(?) that intrudes Silurian or older metamorphic rocks near Dent Cove is provisionally correlated with this member on the basis of lithology.

The body on Bostwick Inlet consists of altered diabase and gabbro. It is poorly exposed but apparently intrudes sheared, deuterically(?) altered pillow flows of the Chapin Peak Formation. The intrusive rocks seem to be finer grained near the flows; there are no other obvious contact effects. The intrusive rocks are incipiently sheared and hydrothermally altered, but they are not foliated; relict textures range from intergranular to coarsely ophitic. Minerals identified in thin section and by X-ray diffraction include (titan?) augite, plagioclase (An_{25-31}), chlorite, kaolin (after plagioclase), magnetite, prehnite, green (Z) amphibole (after augite), brown (Z) biotite (or stilpnomelane), brown (Z) hornblende (or biotite pseudomorphs of hornblende), and traces of quartz and apatite.

The bodies on Smooth Mountain and northwest of Punch Hill are too poorly exposed to show contact relations. The one on Smooth Mountain is enclosed by massive basaltic volcanic rocks and consists of diabase or fine-grained gabbro containing (titan?) augite, plagioclase (An_{32}), chlorite, chrysotile(?), and a trace of quartz. The rock is marked by intense cataclasis that all but obliterates relict intergranular and ophitic textures. The body northwest of Punch Hill appears to be a 200-foot-thick sill intruded into volcanic breccia and fine-grained sedimentary rocks. It is an incipiently altered, but structurally fairly intact, fine-grained intergranular to subophitic aggregate of plagioclase and (titan?) augite, interstitial chlorite and prehnite, and subordinate ilmenite and clinozoisite(?). The rock is cut by microscopic shear zones containing chlorite and potassium feldspar.

The pluglike body near Dent Cove intrudes, and apparently thermally metamorphoses, Paleozoic bedded and intrusive rocks. It is lithologically similar to the sill-like body northwest of Punch Hill but also contains a little biotite (or stilpnomelane), amphibole, epidote, albite(?), magnetite, apatite, and disseminated potassium feldspar.

SLATY DETRITAL ROCKS

The youngest sedimentary formation on Gravina Island includes two gradational members. The lower member is an elongate lens of conglomerate and grit; the upper member, which locally contains specimens of *Buchia* (Chapin, 1918, p. 96; D. L. Jones, written commun., 1969), is predominantly siltstone and argillite.

The formation, characterized by slight metamorphism and prominent slaty cleavage, occurs only on the part of Gravina Island southwest of Bostwick-Vallenar valley. In most places it overlies Upper Triassic rocks with slight structural, but marked erosional, discordance; on the southwest shore of Vallenar Bay, it appears to unconformably overlie rocks as old as Paleozoic.

CONGLOMERATE AND GRIT

The conglomerate and grit member forms an elongate lens that gradationally underlies the siltstone and argillite member. It crops out for about 3 miles and has a maximum thickness of about 350 feet.

The member consists chiefly of light-gray and brownish-gray pebble to cobble conglomerate interbedded with grit and minor sandstone and calcareous siltstone. The conglomerate is distinguished by its well-rounded and lithically diverse clasts and, locally, by the striking contrast between the light and dark pebbles. The largest clasts are about 4 feet in maximum dimension, the average probably is less than an inch long. The conglomerate has strong slaty cleavage; flattening of clasts ranges from slight to extreme (>10:1), but the rock generally breaks around, not across, the clasts. Clast types include light-gray metarhyolite and leucocratic trondhjemite; greenish- and brownish-gray vesicular and amygdaloidal intermediate and basic volcanic rocks (including fragments of pillow flows); dark-gray to black siltstone, argillite, and metachert; and dark-brownish-gray aphanitic, dioritic, metavolcanic, and very fine grained detrital rocks. The matrix is siltstone and mudstone.

Fossils have not been found in this member, but its intertonguing relation with the *Buchia*-bearing siltstone and argillite member indicates that it, too, is Upper Jurassic.

SILTSTONE AND ARGILLITE

Except for a 4-mile covered interval, the siltstone and argillite member crops out nearly continuously from Bostwick Inlet to Vallenar Bay. It consists of dark-gray and brownish-gray thinly interbedded calcareous siltstone and argillite; subordinate silty limestone, grit, and pebbly to cobbly mudstone; and minor fine-grained intermediate volcanic rocks. Locally, the pebbly mudstone contains scattered baseball-sized spherical clasts of altered quartz diorite.

In upper Bostwick Inlet, the siltstone and argillite are intruded by a few irregular dikes of altered andesite(?).

A small, mostly alluvium-covered outcrop of *Buchia*-bearing strata about 0.2 mile from the head of Bostwick Inlet is distinctly phyllitic, an exception to the member's characteristically slaty aspect attributed to intense faulting nearby along Bostwick Inlet.

The top of the siltstone and argillite member is not exposed, and precise thickness measurements are ruled out by poor exposures and complex structure. The 2-mile outcrop width of the member west of Bostwick Inlet is a result of structural repetition, not great thickness. The limited data available indicate a minimum thickness of about 500 feet.

The siltstone and argillite contain sparse, poorly preserved specimens of the pelecypod *Buchia* cf. *B. rugosa* (Fischer) (USGS Mesozoic locs. M5462–M5465) that, according to D. L. Jones (oral commun., 1970), indicate a Late Jurassic (Kimmeridgian) age.

NORTHEAST OF BOSTWICK-VALLENAR VALLEY

GRAVINA ISLAND FORMATION

The name Gravina Island Formation is here applied to the assemblage of recrystallized sedimentary and volcanic rocks that underlies Gravina Island northeast of Bostwick-Vallenar valley.

A section could not be measured owing to poor exposures, complex structure, and absence of marker beds; typical exposures are on the Blank Islands, the Guard Islands, and California Ridge. The Blank Inlet area is designated the type area. The formation is divided into three intertonguing members: a lower member of phyllitic detrital and minor metavolcanic rocks, a middle member of andesitic and subordinate basaltic metavolcanic rocks, and an upper member of phyllitic conglomerate, grit, and sandstone. The stratigraphic assignment of each member is based mainly on its structural position. Thus, the lower member structurally underlies the middle member, which in turn structurally underlies the upper member. The structural and stratigraphic positions of the members herein are assumed to generally coincide, but it should be emphasized that significant reversals and repetitions of the sequence probably occur.

The formation's thickness has not been determined; its maximum 6-mile outcrop width on Gravina Island, however, probably is due mainly to structural repetition, not to great thickness.

Neither the base nor the top of the formation is exposed on Gravina Island. On the southwest, the formation is bounded by an alluvium-covered fault zone along Bostwick-Vallenar valley; on the northeast, across Tongass Narrows, it crops out for an undetermined distance northeastward on Revillagigedo Island.

The rocks of the formation show evidence of increasing regional metamorphism from southwest to northeast, but not beyond greenschist facies. On northeastern Gravina Island, the upper member is thermally metamorphosed by Cretaceous(?) intrusive rocks. Despite recrystallization, relict sedimentary and volcanic structures generally can be identified, and fossils locally are preserved.

AGE

WRITTEN IN COLLABORATION WITH DAVID L. JONES

The age of the Gravina Island Formation is based mainly on several fossils from the lower member. Belemnites found near Blank Point by Chapin (1918, p. 98) and more recent collections from the Blank Islands (USGS Mesozoic locs. 9527 and M5839) are similar to *Cylindroteuthis* (J. A. Jeletsky, oral commun., 1971), a genus that ranges from Middle Jurassic to Early Cretaceous but is most characteristically found in Jurassic strata. Other fossils found on the Blank Islands (USGS Mesozoic locs. M5839 and 29888) are large specimens of *Entolium*? up to 8 inches in diameter. This genus ranges from Middle Triassic to Late Cretaceous (Hertlein, 1969, p. N346).

Neither *Cylindroteuthis* nor *Entolium* is sufficiently short ranging to closely establish the age of the Gravina Island Formation. The following indirect evidence, however, helps limit the probable age range.

The absence of *Buchia* from the fossiliferous strata is strong evidence that the Gravina Island beds either predate or postdate the late Oxfordian through Valanginian age range of this genus. Fossiliferous marine strata of Late Jurassic through Early Cretaceous age throughout the Pacific Coast region of North America nearly always contain *Buchia*, whatever the conditions of their deposition. Since *Buchia*-bearing beds occur on Gravina Island, as well as elsewhere in southeastern Alaska, the Gravina Island Formation probably does not merely reflect a local exclusion of this fauna.

If the absence of *Buchia* from the Gravina Island Formation does have age significance, a pre-*Buchia* (early Oxfordian or older) age is favored for the following reasons:

1. Large species of *Entolium* are unknown in post-Valanginian strata along the Pacific coast of North America, although small species up to 1 inch in diameter (*"Pecten operculiformis"*) is abundant in Hauterivian and younger deposits.

2. Belemnites are common in West Coast strata as young as Aptian, are virtually absent from Albian strata, and are unknown from Upper Cretaceous rocks. However, none of the characteristic robust forms, such as *Acroteuthis*, that occur in the Lower Cretaceous are present in the Gravina Island Formation. A Late Cretaceous age is ruled out simply by the presence of abundant belemnites.
3. Other characteristic Lower Cretaceous forms, such as *Inoceramus ovatoides*, that are the dominant faunal elements elsewhere in southern Alaska do not occur in the fossiliferous beds of the Gravina Island Formation.

In summary, the fossil evidence establishes that the age of the Gravina Island Formation lies somewhere between Middle Jurassic and the middle part of the Early Cretaceous. Mainly on the basis of indirect evidence, a pre-*Buchia* Middle or early Late Jurassic age is favored because the available fossils seem to have their strongest affinities with forms of those ages.

PHYLLITIC DETRITAL ROCKS

The lower member crops out in a discontinuous, generally coastal belt southward from Vallenar Point to near Gravina Point. It also underlies the Blank Islands and makes up a narrow coastal strip on the southwest side of Pennock Island. The member grades upward and probably laterally into the middle member by increase in metavolcanic rocks; a supposed unconformity between them described by Chapin (1918, p. 98) is discussed on page 31.

The base of the member has not been observed; it is bounded on the west by an alluvium-covered fault zone along Bostwick-Vallenar valley and has not been mapped on Gravina Island southwest of this valley. The thickness is uncertain, owing to complex structure and absence of persistent marker beds; early workers (Chapin, 1918, p. 97–98; Buddington and Chapin, 1929, p. 170), calling it a sequence of "belemnite-bearing conglomerate, graywacke, and black slate" beds, estimated it to be about 800 feet thick.

The member consists of the following interbedded lithologies: Thin-bedded locally fossiliferous greenish-gray, silvery-gray, and black pyritic phyllite and dark-gray phyllitic siltstone, graywacke, and minor silty limestone; subordinate dark-green and dark-gray phyllitic conglomerate and grit; and minor, but locally prominent, bright-green to dark-greenish-gray intermediate metavolcanic rocks.

The fossiliferous beds correspond to the belemnite-bearing graywacke and black-slate part of the sequence described by

Chapin. The fossils, discussed on pages 29–30, apparently are restricted to very thin zones (<25 ft thick) and have been found only on the Blank Islands and on the west shore of Blank Inlet about 0.4 mile south of Blank Point.

The conglomerate consists of moderately to strongly flattened angular to subrounded clasts up to 4 feet long in a matrix of dark-gray and dark-green phyllite and phyllitic grit. The clasts include porphyritic, aphanitic, and fragmental intermediate metavolcanic rocks, identical with those in the middle member of the Gravina Island Formation, and subordinate fine-grained detrital rocks. The metavolcanic clasts almost certainly were derived from rocks assigned to the middle member of the formation; it is on this basis that the lower member, despite its assumed lower stratigraphic position, is considered to at least locally intertongue with the middle member. The intermediate metavolcanic rocks in the lower member generally resemble those in the middle member.

ANDESITIC TO BASALTIC METAVOLCANIC ROCKS

The middle member underlies nearly all of Gravina Island northeast of Bostwick-Vallenar valley, most of Pennock Island, and the Guard Islands. Southwest of Bostwick-Vallenar valley, the member has not been mapped except for small, probably fault-bounded outcrops — nearly covered by seaweed and alluvium — of intensely sheared and hydrothermally altered andesitic(?) metatuff and minor metadiorite(?) along the southwest shore of Bostwick Inlet.

In most places the middle member grades downward and probably laterally into the lower member. Chapin (1918, p. 98) described an unconformity between volcanic and overlying sedimentary rocks on the northeast shore of Bostwick Inlet. This locality was not found during the present investigation, but observations of similar relations on the northeast shore of Blank Inlet indicate that the apparent structural discordance is due to differences in competence between the two rock types, not to an unconformity. The apparently anomalous sequence of sedimentary (lower member) rocks overlying volcanic (middle member) rocks described by Chapin may be the result of folding and overturning, but a likelier explanation is that his locality was in the gradational contact zone between the two members, where sedimentary and volcanic beds commonly alternate.

The member consists chiefly of locally massive, but generally distinctly foliated, greenish-hued metavolcanic rocks derived from andesitic and subordinate basaltic tuff and agglomerate. It also contains minor gray, green, and black phyllite and phyllitic siltstone that increase in abundance near the contacts with the upper and lower members. The thickness was not measured; comparable rocks nearby on Annette Island are estimated to have a maximum thickness of about 2,500 feet (Berg, 1972).

The metavolcanic rocks typically are porphyritic, are moderately to thickly bedded, weather bright green to somber shades of green and gray, and range from crudely foliated coarsely fragmental rocks to delicately laminated phyllite without detectable relict fragmental texture. The clasts are angular to subrounded, grade downward from a maximum size of about 2 feet, and generally are of the same rock type as the enclosing matrix. The amount of clast flattening ranges from slight to greater than 10:1. Nonporphyritic variants of the prevailing rock types occur but are subordinate; exotic or accidental clasts are rare, as are amygdules, which are pinhead sized and are filled with calcite and chlorite(?).

The most abundant rock type is andesitic lithic and crystal-lithic metatuff containing relict centimeter-or-smaller-sized subhedral phenocrysts of light-gray to cream-colored feldspar and light-green to greenish-black ferromagnesian minerals. The abundance and relative proportions of phenocrysts vary markedly; typically, however, phenocrysts make up 10–15 percent of the rock and, despite the apparent numerical superiority of the more easily seen ferromagnesian crystals, probably occur in approximately equal abundance. The phenocrysts comprise moderately to strongly saussuritized plagioclase, colorless augite, and moderately to weakly pleochroic green (Z) hornblende. The matrix is fine grained, is more or less foliated, and contains augite, hornblende, colorless to very pale green amphibole, chlorite, epidote-clinozoisite, albite (An_{4-7}), quartz, muscovite, prehnite, calcite, and leucoxene. The augite probably is primary, and some of the hornblende may be deuteric, but the rest of the mineral assemblage probably is due to greenschist-facies regional metamorphism.

PHYLLITIC CONGLOMERATE, GRIT, AND SANDSTONE

The upper member crops out for about 5 miles along the northeastern coast of Gravina Island. It probably is not more than a few hundred feet thick and grades downward into the middle member by increase in metavolcanic rocks. It contains a variety of phyllitic detrital rocks ranging from very fine grained to coarsely fragmental but is distinguished by a 20- to 30-foot-thick zone of dark-gray conglomerate containing prominent rounded clasts, up to a foot in diameter, of light-gray altered quartz diorite. Less prominent but numerically more abundant clast types include aphanitic and porphyritic metavolcanic rocks and fine-grained detrital rocks. The metavolcanic and fine-grained detrital clasts probably were derived mainly from the lower and middle members of the Gravina Island Formation. The source of the dioritic clasts, however, is uncertain; some are like the metadiorite at Anvil Mountain on Annette Island (Berg, 1972), whereas others resemble certain phases of the Annette pluton (Berg, 1972). Some of the clasts, especially the granitic types, are nearly spherical, but most have been moderately to markedly flattened by deformation. The matrix of the conglomerate is gray phyllite and phyllitic grit. The conglomerate, which contains a few thin layers of dark-gray limestone, grades laterally into dark-gray pebbly grit and sandstone that in turn grade into greenish-gray and dark-gray phyllite without detectable relict clastic texture.

In general, the member contains metamorphic minerals characteristic of greenschist-facies regional metamorphism. Typical mineral assemblages include chlorite, sericite, quartz, albite, epidote-clinozoisite, weakly pleochroic green (Z) amphibole and reddish-brown (Z) biotite, and calcite. Near triangulation station Sim, it is intruded by diorite and gabbro-diabase and is altered to reddish-brown-weathering, bleached, silicified, and pyritic hornfels in which biotite is locally abundant.

INTRUSIVE ROCKS

Two types of intrusive igneous rocks — olivine-bearing gabbro-diabase and porphyritic diorite — occur in small tidal outcrops near triangulation station Sim on the northeastern coast of Gravina Island.

The intrusive rocks are in contact with thermally metamorphosed and hydrothermally altered metasedimentary rocks assigned to the Middle or Upper Jurassic Gravina Island Formation, but relations among the intrusive and bedded rocks are uncertain, owing to poor exposures and intense faulting.

Small, relatively intact slivers of mixed dioritic and metasedimentary rocks in the fault zone indicate that the diorite intrudes the Jurassic beds; the contact between the gabbro-diabase and enclosing rocks was not observed, but the gabbro-diabase seems fresher and less deformed than the diorite and may postdate it.

The intrusive rocks, especially the diorite, are recrystallized and sheared but are not foliated. They are assigned a Cretaceous(?) age on the basis of provisional correlation with Cretaceous plutonic rocks that intrude Jurassic bedded rocks on Spire Island, off the northeast coast of Annette Island (Berg, 1972).

The gabbro-diabase is dark greenish gray, is medium to coarse grained, and has subophitic to ophitic texture. Minerals identified in thin section include plagioclase (An_{37-58}), clinopyroxene, orthopyroxene, olivine, and brown (Z) biotite and subordinate to minor green biotite, chlorite, magnetite, colorless to pale-green amphibole, apatite, potassium feldspar, and quartz. The pyroxenes enclose the olivine crystals, which are partly replaced by a dark-reddish-brown mineral.

The diorite, which is cut by thin veinlets of prehnite and calcite, consists of sericitized, corroded plagioclase subhedra up to 5 millimeters long in a fine-grained intergranular to granoblastic matrix of altered plagioclase, kinked and locally porphyroblastic brown (Z) biotite, chlorite, and quartz, plus minor potassium feldspar, calcite, apatite, and dark-greenish-brown (Z) amphibole.

UNCONSOLIDATED DEPOSITS

Unconsolidated deposits on Gravina Island consist mainly of alluvium, partly reworked glacial deposits, and remnants of once more extensive glacial-marine deposits. There are also a few small landslides and talus aprons. Thicknesses were not measured; accumulations as much as 10 or 15 feet thick, however, were observed, and the deposit that underlies Bostwick-Vallenar valley probably is more than 100 feet thick.

The distribution of the unconsolidated deposits was interpreted from aerial photographs by W. H. Condon. Only the largest deposits are shown on the geologic map (pl. 1); between high tide and timberline, however, bedrock nearly everywhere is mantled by soil and rock detritus that is covered by muskeg, rain forest, and brush.

ALLUVIUM

Locally stratified, generally poorly sorted silt, sand, gravel, and boulders occur sporadically along the coast, at the heads of bays and inlets, and in the river valleys. According to Chapin (1918, p. 99), the deposit in Bostwick-Vallenar valley consists largely of marine gravels that accumulated when the valley was below sea level. These gravels, which probably complexly intertongue with glacial deposits, subsequently have been partly reworked by streams and mantled by river alluvium.

GLACIAL DEPOSITS

Glacial drift, till, and moraine were not mapped, but they and their stream-reworked derivatives probably occur in the detritus that mantles bedrock nearly everywhere on Gravina Island.

GLACIAL-MARINE DEPOSITS

A small, poorly exposed deposit of stratified glacial till, gravel, and blue clay containing Quaternary marine fossils occurs about half a mile northwest of the head of Dall Bay (Chapin, 1918, p. 99). The maximum exposed thickness of the deposit is about 8 feet. It lies about 80 feet above sea level and is interpreted as a remnant of a once more extensive marine terrace deposited at sea level during the last glacial epoch. The deposit is too small to show at the scale of the geologic map (pl. 1), but others like it probably are fairly common in the lowland bordering Dall Bay.

An unconsolidated deposit mapped west of Blank Inlet may also be a marine-terrace deposit. It is at an elevation of 200–300 feet, is headed by what appears to be a low wave-cut cliff, and may correlate with the fossiliferous deposit northwest of Dall Bay.

ECONOMIC GEOLOGY

Mineral occurrences on Gravina Island, indicated on the map (pl. 1) by commodity (element) symbols, are either verified (studied or field checked during this investigation) or unverified (queried). Most unverified occurrences are replotted from published reports of early 20th-century prospecting and mining; a few, especially near Dall Bay and Seal Cove, are reported by recent prospectors. Multiple commodities at verified occurrences are listed in estimated order of decreasing abundance; leading commodities at unverified occurrences either were recovered from early ore shipments or were (are) considered by prospectors to be potentially valuable. Conspicuous (underlined) mineral occurrences (1) were productively mined in the early 1900's, (2) were the sites of appreciable early exploration and (or) development work, (3) are targets of significant recent prospecting activity, or (4) indicate relatively abundant concentrations of metallic minerals discovered during this investigation.

Lodes containing copper, gold, and other metals were known on Gravina Island before 1900 (Brooks, 1902; Wright and Wright, 1908; Berg and Cobb, 1967); several also carry barite, and one contains traces of radioactive minerals (Williams, 1956). Some were explored by fairly extensive workings, and there were a few shipments of gold-bearing ore early in the century, but there is no official record of any production since 1913. Despite the long lapse in productive mining, many of the lodes are still being prospected, especially for copper and precious metals.

The large deposit of unconsolidated sand, gravel, and silt in Bostwick-Vallenar valley constitutes a potential resource of concrete aggregate, but no attempt has been made to exploit it.

Two principal types of lodes, each characteristic of one of the bedrock terranes, are described under "Geologic Summary." Northeast of Bostwick-Vallenar valley (eastern Gravina lodes) the lodes are mainly disseminated sulfide deposits and sulfide-bearing quartz-calcite fissure veins that have been prospected chiefly for gold. The veins range from relatively large, persistent individuals to clusters of discontinuous stringers and veinlets. Southwest of Bostwick-Vallenar valley (western Gravina lodes) the lodes are mainly hematite- and sulfide-bearing quartz-dolomite-barite fissure veins first prospected for precious metals but now valuable mainly for their copper content. In addition to the vein deposits, the metallic minerals locally are disseminated in the country rocks or form small stringers and masses without any gangue minerals.

EASTERN GRAVINA LODES

Disseminated sulfide minerals and sulfide-bearing quartz veins are common on eastern Gravina Island, but early gold prospectors concentrated on deposits near the northeast coast opposite Pennock Island and also between Rock Point and triangulation station Sim. The deposits are in metamorphosed sedimentary and volcanic rocks of the Gravina Island Formation and consist of quartz (and subordinate calcite) veins containing pyrite and a little free gold, plus sporadic pyrrhotite, galena, sphalerite, arsenopyrite, and chalcopyrite. Pyrite and possibly some of the other minerals also are disseminated in the country rocks near the veins. The country rocks locally are bleached and iron stained, from decomposition of the sulfide minerals, but, except for some silicification near an intrusive contact at triangulation station Sim (p. 33), they are not significantly hydrothermally altered. The most productive of the early mines was in the Goldstream (Bell) group of claims, located near tidewater about 1.4 miles northwest of Gravina Point (Wright and Wright, 1908, p. 177–178; Berg and Cobb, 1967, p. 179). Workings consisted of two shafts, several hundred feet of drifts, and stopes from which several thousand tons of ore was mined. Early assays (Brooks, 1902, p. 62) showed up to about 1 ounce gold per ton in the sulfide-bearing veins and about 0.1 ounce gold per ton in the adjacent mineralized country rocks. The mines operated more or less continuously until about 1913, the last year of recorded production.

WESTERN GRAVINA LODES

The lodes west of Bostwick-Vallenar valley are in the Nehenta Bay–Dall Bay–Seal Cove area (also called Dall Head area), and near Dent Cove and Vallenar Bay.

The Dall Head lodes are in complexly faulted rocks ranging in age from Silurian or older Paleozoic to Late Triassic. They include quartz-dolomite-barite fissure veins, breccia fillings, and disseminated to massive replacement deposits and contain pyrite, chalcopyrite, and hematite, sporadic bornite, galena, and sphalerite, and traces of gold and silver. The country rocks near the lodes weather red, orange, and brown owing to intense hydrothermal alteration marked by the formation of quartz (including local jasper), ferruginous dolomite, iron carbonate(?), and hematite. Many of the rocks are also pink or salmon colored due to impalpable ferric oxide, but most of this alteration may have accompanied the deposition of the Puppets Formation (p. 14), predating the prevailing post-Triassic hydrothermal alteration and mineralization. Turn-of-the-century prospectors explored several of the Dall Head lodes by as much as 2,000 feet of underground workings, but there is no record of any ore production (Brooks, 1902, p. 68–73; Wright and Wright, 1908, p. 138–140). Most of the recent prospecting activity on Gravina Island has centered on the Dall Head lodes.

The lodes near Dent Cove and Vallenar Bay have not been extensively explored but seem to resemble those near Dall Head. Recent prospecting near Dent Cove reportedly has revealed disseminated chalcopyrite and pyrite and traces of molybdenite and secondary copper minerals in complexly sheared, hydrothermally altered metamorphic and intrusive country rocks. About 1.8 miles south-southeast of Dent Cove, at an elevation of about 150 feet, a water-filled adit in iron-stained metarhyolite(?) records early 20th-century exploration of a 10-foot-wide lode containing quartz, hematite, dolomite, chalcopyrite, and pyrite.

The Vallenar Bay lodes (Brooks, 1902, p. 73–74; Wright and Wright, 1908, p. 140), explored by early gold prospectors, consist of disseminated pyrite and chalcopyrite and sulfide-bearing quartz-carbonate-barite(?) fissure veins in locally silicified and dolomitized Paleozoic bedded rocks. South of Vallenar Bay, similar pyrite and chalcopyrite-bearing lodes, apparently in metamorphosed bedded and basic igneous rocks, were prospected for gold in the early 1900's. The lodes reportedly are near tidewater about 3 miles from Vallenar Bay, but their exact location is unknown.

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INDEX

[Italic page numbers indicate major references]

U.S. GOVERNMENT PRINTING OFFICE : 1973 O—499-954