# Stratigraphy and Petrography of the Pybus-Gambier Area Admiralty Island Alaska

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*By* ROBERT A. LONEY

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# STRATIGRAPHY AND PETROGRAPHY OF THE PYBUS-GAMBIER AREA, ADMIRALTY ISLAND, ALASKA

By Robert A. Loney

## ABSTRACT

The Pybus-Gambier area comprises about 215 square miles of uninhabitated land on the southeastern coast of Admiralty Island, southeastern Alaska. The pre-Tertiary section consists of more than 20,000 feet of intensely folded sedimentary, volcanic, and metamorphic rocks, all probably of marine origin ranging in age from Devonian to Early Cretaceous, the pre-Tertiary strata are unconformably overlain by more than 10,000 feet of gently dipping nonmarine coarse-grained sedimentary rocks, and basalt and andesite flows of Tertiary age. Diorite plutons and associated contact metamorphic rocks occur in the little-known northwestern part of the area.

The structure of the pre-Tertiary rocks is complex and is largely the result of the superposition of two and, in places, three episodes of folding, all of which appear to have been caused by subhorizontal northeast-southwest compression. The gently dipping Tertiary strata have been broken into fault blocks by subvertical north- and northeast-striking normal and reverse faults.

The section is here subdivided into nine formations, eight of which are named for the first time, as follows: Gambier Bay Formation of Middle(?) Devonian age, composed of greenschist, phyllite, marble, and metachert; Hood Bay Formation of Devonian(?) age, composed of dark carbonaceous thin-bedded chert, argillite, limestone, and graywacke; Cannery Formation of Permian age, composed of thin-bedded chert, argillite, and graywacke; Pybus Dolomite of Permian age, composed of fossiliferous cherty dolomite; Hyd Formation of Late Triassic age, composed of a basal chert breccia, a limestone member, a thin-bedded argillite member, and a spilitic volcanic member; Seymour Canal Formation of Late Jurassic and Early Cretaceous age, composed of argillite, graywacke, and conglomerate; Brothers Volcanics of Late Jurassic and Early Cretaceous age, composed of andesitic flows and breccia; unnamed conglomerate and sandstone of late Eocene age; and Admiralty Island Volcanics of late Eocene and Oligocene age, composed of basaltic and andesitic flows.

A marked angular unconformity occurs at the base of the Tertiary section, and unconformities of less angularity occur at the base of the Cannery Formation, at the base of the Hyd Formation, and at the base of the Seymour Canal Formation. In general, pre-Seymour Canal deformation seems to have been mild, but the intensity of the post-Gambier Bay and pre-Cannery deformation is not known with certainty. The complex structure of the pre-Tertiary rocks seems to be chiefly the product of the post-Seymour Canal and pre- late Eocene deformation.

The episodes of folding in the Gambier Bay Formation were accompanied by metamorphic recrystallization not found in either younger or coeval (Hood Bay

**Formation) pre-Tertiary rocks. If these episodes are contemporaneous with those in nonmetamorphic pre-Tertiary rocks, then the metamorphism dies out both vertically and laterally, and may be part of the regional decrease in metamorphism westward away from the Coast Range batholith, which is located about 25 miles to the east.**

# INTRODUCTION

## LOCATION AND PHYSICAL GEOGRAPHY

The Pybus-Gambier area is on the southeast coast of Admiralty Island about 60 airline miles south-southeast of Juneau in southeastern Alaska (fig. 1). Admiralty Island, which is about 100 miles in length, is the northeasternmost large island of the Alexander Archipelago.

The area comprises the Sitka B–1 and the Sumdum B–6 15-minute quadrangles, of which about 215 square miles is land. The highest and most rugged part of the Pybus-Gambier area is southwest of Pybus Bay, where one peak rises to 3,853 feet above sea level. Elsewhere, except for a few peaks in the northwest, the topography is subdued and rarely rises above timberline (between 1,500 and 2,000 ft). Below timberline, the country is covered by a dense forest of spruce and hemlock that contains scattered muskeg bogs.

The coastline of the area is deeply indented in the south by the northwest-trending Pybus Bay, and in the north by the more westward-trending Gambier Bay. Numerous small islands dot the two bays, and a few occur offshore in Stephens Passage. In a general way the elongations of the bays and the alinement of islands within them reflect the structural grain of the underlying rocks.

The area is drained by numerous small short rivers, many of which occupy in their lower reaches broad U-shaped valleys characteristic of glacial channels. The floors of the valleys contain scattered deposits of glacial clay and gravel together with recent alluvial deposits. The only glacial ice remaining in the area is a small patch glacier west of Little Pybus Bay near the south border of the area.

In longitudinal profile the larger streams commonly have a steep-gradient channel in their upper courses, where they are cutting a narrow V-shaped valley in bedrock. In their middle courses the streams flow with a low gradient over largely glacial and alluvial deposits, but in a few places they cut narrow gorges in bedrock. Before entering their lower courses, the streams commonly cut steep-gradient gorges with falls and rapids in bedrock. In their lower reaches the streams again assume a low gradient and flow over alluvial deposits and, in places, bedrock before reaching salt water.

The Pybus-Gambier area has the moist, moderate climate character-

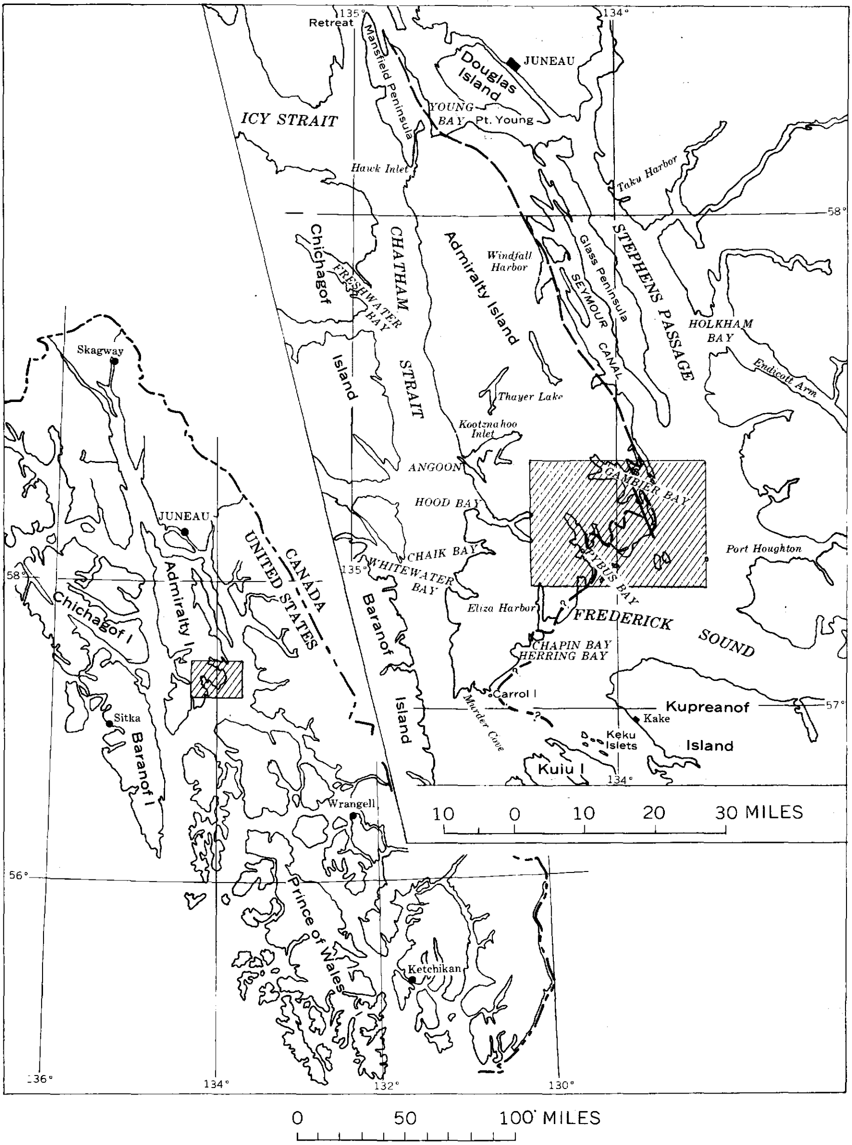


**FIGURE 1.—Index map of southeastern Alaska showing location of the Pybus-Gambier area and contact (dashed line) between Triassic rocks (west) and Jurassic and Cretaceous rocks (east).**

istic of southeastern Alaska in general. The nearest weather stations are at Five Fingers Light, just beyond the southeastern corner of the area, and at Angoon on the west coast of Admiralty Island about 10 miles west of the northwestern corner of the area.

The following data from these two stations illustrate the local climate (U.S. Weather Bureau, 1959):

| | |
|---|---|
| Five Fingers Light: | |
| Mean annual temperature (10-year record) | 43.3°F |
| Mean annual precipitation (9-year record) | 68.8 in. |
| Angoon: | |
| Mean annual temperature (35-year record) | 42.2°F |
| Mean annual precipitation (27-year record) | 41.34 in. |

The heaviest precipitation occurs at these stations during the late summer, fall, and winter months.

The area contains no permanent settlements, and the only evidence of human habitation seen is a few partly ruined cabins, some of which are occupied seasonally by fishermen, hunters, and trappers. No roads or trails exist in the area, and all transportation to and from the area is by air or water; no regularly scheduled transportation of any kind is available.

## PREVIOUS GEOLOGIC INVESTIGATIONS

The first geological map of the Pybus-Gambier area was that produced by C. W. Wright (1906) as a result of his reconnaissance of Admiralty Island. His map in a general way delineated the outcrop belts of Paleozoic, Mesozoic, and Tertiary rocks in the area, but erroneously showed the conglomerate and sandstone unit of Eocene age at Little Pybus Bay as Mesozoic. Wright also mapped the volcanic rocks of The Brothers islands as correlative with the Tertiary volcanic flows of southern Admiralty Island. In the present paper, the volcanic rocks of The Brothers are called the Brothers Volcanics and are considered to be Upper Jurassic and Lower Cretaceous.

Kindle (1907, p. 332) visited Pybus Bay; he gave a brief description of the "Lower Cretaceous beds" (Seymour Canal Formation of this report) and the underlying "Upper Carboniferous limestone" (Pybus Dolomite of Permian age), and also made fossil collections.

Kirk (1918, p. 514–515; unpublished data) studied the stratigraphy of the area around Pybus Bay and collected fossils. He thought that the "conglomerate" overlying "high Carboniferous beds" and underlying "Upper Triassic beds" was probably a tillite, and an indication of Permian glaciation. In the present work this "conglomerate" is considered to be the basal breccia of the Hyd Formation of Late Triassic age and to be derived directly from the underlying Pybus Dolomite of Permian age. No indication of glacial origin was found.

Burchard (1920, p. 55), in connection with his study of the marble resources of southeastern Alaska, examined and made fossil collections from the "cherty magnesian limestone" at several localities at Pybus Bay; his fossil collections were determined by G. H. Girty to be of Artinskian age (Permian). This formation is herein called the Pybus Dolomite; the Permian age has been substantiated by recent collections.

Martin (1926, p. 376–379) visited Pybus Bay and studied the stratigraphy of the Mesozoic rocks as part of his work on the Mesozoic stratigraphy of Alaska.

## PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

The geologic mapping was undertaken as part of the regional geologic mapping program of the U.S. Geological Survey in southeastern Alaska. The Pybus-Gambier area was selected for detailed study because it appeared to contain one of the most complete and best exposed stratigraphic sections on Admiralty Island. Knowledge of this section was a desirable and effective preliminary to the reconnaissance mapping of Admiralty Island as a whole.

The Pybus-Gambier area contains excellent and extensive shoreline exposures. A large proportion of these are tidal outcrops exposed only at lower tide level, hence the geologic map (pl. 1) includes these low-tide exposures. Stream channels afford another important source of geologic data but, as a rule, exposures in these are much inferior in quality to those along the shores. Except for the rugged mountains in the southwestern part of the area, ridge crests and other interstream areas are largely covered by heavy forest and contribute only scattered and commonly poor information.

The mapping was done on 1:15,840 scale, U.S. Geological Survey multiplex compilation sheets of the Sitka B–1 and the Sumdum B–6 topographic quadrangle maps supplemented by 1:40,000-scale vertical aerial photographs. A few days of preliminary reconnaissance was done in the area during the summer of 1957, but the bulk of the fieldwork was done in the summer of 1958 and in part of the summer of 1959. During the summer of 1958, I was assisted by Arthur L. Kimball who, by his knowledge of woodsmanship and boatsmanship, contributed greatly to the success of the summer's work. That summer's fieldwork was accomplished by small boat and foot traverses from base camps. In the summer of 1959 I was assisted by Douglas Barnes and also had supporting assistance from a helicopter based on the U.S. Geological Survey motor vessel *Stephen R. Capps*, Robert D. Stacey, master. Henry C. Berg, John S. Pomeroy, and D. W. Hinckley of the U.S. Geological Survey assisted me during the summer of 1959 in the reconnaissance mapping of the northwestern part of the Pybus-Gambier area.

I wish to thank Professors Charles M. Gilbert, Lionel E. Weiss, and J. Wyatt Durham of the University of California at Berkeley

for reviewing parts of the manuscript and offering suggestions for its improvement. Dr. Weiss visited the area during the summer of 1959.

## GEOLOGIC SETTING

The pre-Tertiary rocks of southeastern Alaska comprise abundant volcanic rocks associated with marine argillite and volcanic graywacke (Buddington and Chapin, 1929; Lathram and others, 1959, 1960; Loney and others, 1963) and form part of the eugeosynclinal Fraser Belt of Kay (1951, p. 35). This belt has been divided by Payne (1955; see also Miller and others, 1959, pl. 2) into tectonic elements called "geosynclines" and "geanticlines." As seen today, the "geosynclines" are belts of Mesozoic rocks and the "geanticlines" are belts of Paleozoic rocks. The Pybus-Gambier area lies astride the boundary between two of the most important tectonic elements: the Seymour geosyncline on the east and the Prince of Wales geanticline on the west.

Recent reconnaissance mapping on Admiralty Island north of Gambier Bay has shown that the boundary between Mesozoic and Paleozoic rocks, that is, between the Seymour geosyncline and the Prince of Wales geanticline, is not a straight north-northwest-trending line as shown by Payne (in Miller and others, 1959, pl. 2), but is instead irregular in detail (Lathram and others, 1960). On the other hand, in the same region the contact between the Triassic rocks and the Jurassic and Cretaceous rocks within the Seymour geosyncline trends much more uniformly north-northwest for more than 50 miles. Farther south in the vicinity of False Point Pybus, the contact between the Triassic and the Jurassic and Cretaceous rocks bends sharply westward and thence follows a sinuous southwesterly course through Pybus Bay, becoming lost to the south beneath Tertiary rocks (fig. 1).

The northeastern extremity of the Admiralty trough of early Tertiary age (Payne, 1955; Miller and others, 1959, p. 22, pl. 2) occupies the southwestern part of the area and overlaps both the Prince of Wales geanticline and the Seymour geosyncline. This trough contains nonmarine volcanic and sedimentary deposits of early Tertiary age which cover the southern part of Admiralty Island and extend south onto parts of Kupreanof and Kuiu Islands. Miller and others (1959, p. 22, 25–26) suggest that the Mesozoic and Paleozoic rocks underlying this trough may be favorable for petroleum.

Most of the Seymour geosyncline was involved in the regional metamorphism associated with the Coast Range batholith (Miller and others, 1959, p. 16–19). This metamorphism dies out to the west away from the batholith. The Pybus-Gambier area, situated at the western margin of the geosyncline, lies near the western limit of this metamorphism. In addition, numerous granitic plutons, considered by some to belong to the same episode of plutonism as the Coast Range batholith (Buddington and Chapin, 1929, p. 173; Dutro and Payne, 1957), intrude both the Seymour geosyncline and the Prince of Wales geanticline. Such plutons on Admiralty Island are commonly surrounded by contact metamorphic aureoles. The area of plutonism and contact metamorphism in the northwestern part of the Pybus-Gambier area represents a southern extension of an important region of plutonism centered around Thayer Lake (Lathram and others, 1960).

## SUMMARY OF STRUCTURE

### STRUCTURE OF THE PRE-TERTIARY ROCKS

The structure of the pre-Tertiary rocks is the result of the superposition of two and in places three episodes of intense folding. The complex structure is briefly summarized below; most of the conclusions presented are based on a detailed structural analysis to be published elsewhere (Loney, 1964). A generalized diagrammatic interpretation of the structure is presented on plate 2. The distorted geologic sections of this diagram are used instead of more accurate, conventional ones because the fold axes in the pre-Tertiary rocks are commonly curved and change orientation abruptly; hence their orientation beneath the surface cannot be reliably predicted. The scarcity of marker beds in most of the thicker formations adds further difficulty to the construction of accurate and significant sections.

The intense folding occurred after the deposition of the Seymour Canal Formation and the Brothers Volcanics in Early Cretaceous time and before the deposition of the unnamed conglomerate and sandstone unit in late Eocene time. Three generations of folds, each having northwesterly striking steeply dipping axial planes, indicate three episodes of subhorizontal, northeast-southwest compression (shortening). The geometry of the fold axes is much more complicated than that of the axial planes because, as the deformation progressed, each successive generation of folds was superposed upon more and more complexly deformed strata and, in superposed folding, a fold axis of different orientations results from each preexisting orientation of the surface being folded (Weiss, 1959, p. 95–98). Additional complexity results from the deformation and rotation of earlier folds by later ones. Earlier deformation must have occurred, as indicated by the various unconformities in the stratigraphic column, but only broad warping could be related to such deformation.

The episodes of intense folding recognized in the unmetamorphosed pre-Tertiary strata are correlated with similar events in the metamorphic Gambier Bay Formation, where they were more intense and are accompanied by metamorphic crystallization. This correlation is in part based on the fact that the generation of folds in these metamorphic rocks have orientations that indicate northeast-southwest compression similar to that indicated for the folds in the unmetamorphosed rocks. The metamorphism of the Gambier Bay Formation may have been caused by its deeper burial during deformation. It is also possible that this metamorphism occurred in late Paleozoic time before the deposition of the Cannery Formation; however the existence of the unmetamorphosed and probably coeval Hood Bay Formation in the western part of the area indicates that no widespread metamorphic terrane existed prior to the deposition of the Cannery Formation.

The first episode of intense folding produced isoclinal folds in bedding. In the Gambier Bay Formation a foliation developed parallel to the axial planes of the folds. The foliation is defined by the planar preferred orientation of platy and prismatic minerals and streaks of mylonitic material. Slip movement along the foliation surfaces resulted in the disruption of the bedding. Because of this disruption and the abundance of originally thick bedded rocks, the large-scale structure of the bedding in this formation is poorly known. Mineral streaking on the foliation and striations on the bedding also formed during the first folding; these lineations represent the intersection of bedding and foliation and are parallel to the axes of the first folds. Axial-plane foliation also formed in the argillite of the Seymour Canal Formation, but here it formed as fracture cleavage with little visible recrystallization.

The folds of the first episode of folding (first folds) east of the False Point Pybus fault zone have gentle to moderate plunges, either to the north-northwest or to the south-southeast, and subvertical axial planes that strike uniformly north-northwest. These folds generally have straight limbs and relatively small sharp hinges; as a rule one limb is subvertical and the other has a dip ranging from 60° to 70°. No evidence of later folding exists here, and the original orientation of the first folds does not appear to have been much affected by later deformation.

West of the False Point Pybus fault zone folds similar in form to the first folds east of the fault zone have been deformed by large-scale second folds. In the Gambier Bay Formation the second folds are known chiefly from their form in the axial plane foliation of the first folds because of the scarcity of recognizable continuous bedding. Here the second folds range from minute crenulations to large-scale antiforms and synforms [1] that are the largest known folds in the rocks of the Gambier Bay Formation. In general, these large folds plunge moderately to the southeast; their hinges are indicated on the geologic map (pl. 1) by large-scale bends in the foliation.

In the unmetamorphosed pre-Tertiary rocks west of the fault zone, the limbs and axial planes of the first folds have been deformed into large-scale second folds having subvertical axes and northwest-striking subvertical axial planes. The hinges of these second folds are indicated on the geologic map (pl. 1) by sharp bends in the trace of marker beds such as the Pybus Dolomite and the Hyd Formation in the Pybus Bay area. The trends of first-fold axes also bend around these second hinges, but in doing so they maintain gentle to moderate plunges similar to those east of False Point Pybus fault zone. In flexural slip folding, the bending of an earlier fold axis or lineation about a vertical axis changes its trend but not its plunge (Weiss, 1959, p. 98–100).

A third episode of folding is confined to the thinly foliated phyllite and greenschist of the Gambier Bay Formation. These third folds are chiefly small-scale chevron or kink folds that appear to have no large-scale counterparts. In general the third-fold axes plunge moderately to the south and have subvertical axial planes whose strikes range from northeast to west and average about north-northwest. The kink folds evidently form only in thinly foliated or laminated fissile rocks (Hoeppener, 1955, p. 33), and the lack of such rocks in the unmetamorphosed pre-Tertiary probably explains the absence of third folds in these rocks. The general southward plunge of the axes of the third folds appears to have been controlled by the predominance of moderately southward dipping foliation surfaces upon which they were superposed.

A series of northwest-striking thrust or reverse faults displace all the above folds in the pre-Tertiary strata, but in general do not cut the gently deformed Tertiary rocks. These faults generally dip steeply eastward, and appear to involve the upward movement of the eastern block over the western. However, the separations of marker beds across some of these faults could be explained equally well by strike-slip movement. The faulting in the False Point Pybus and Pybus fault zones has resulted in a complex jumble of broken folds in part delineated on the map (pl. 1) by the Pybus Dolomite. Between

[1] "Antiform" and "synform" are purely descriptive terms introduced by E. B. Bailey (in Bailey and others, 1939, p. 120–121) for folds whose hinges are respectively convex upward and convex downward. The terms do not imply that the folded strata become either older or younger toward cores of folds, and are used in this paper for folds in complexly layered rocks to avoid the stratigraphic connotation sometimes applied to the term "anticline" and "syncline."

the two zones are several northwest-striking faults about which much less is known. The strike of this series of faults is about normal to the direction of compression inferred from the orientation of the folds, and it may have formed at the same time as the folds (Anderson, 1951, p. 13–14).

Subvertical northeast-striking faults are also common in the pre-Tertiary rocks. These faults also occur rarely in the Tertiary rocks, and for this reason they are tentatively considered to be younger than the northwest-striking faults. Many of the minor faults show distinct left- and right-lateral separation of marker beds, and may be wrench faults associated with the northeast-southwest compression that formed the folds and the northwest-striking thrust faults. The major faults, however, such as the Gambier fault and the fault south of Snug Cove can best be explained by vertical displacements in which the southeastern blocks moved downward relative to the northern blocks.

Numerous small strike faults, most too small to show on the map, characterize the outcrops of the Pybus Dolomite in Pybus Bay. The faulting, involving both normal and reverse movements, has resulted in a complex of small faulted folds. These faults may have formed as the result of the repeated folding of the brittle dolomite.

### STRUCTURE OF THE TERTIARY ROCKS

The slightly deformed sedimentary and volcanic rocks of Tertiary age are disposed in an irregular north-trending troughlike structure whose axial trace approximately coincides with the trace of the Eliza fault. West of this fault the beds dip gently eastward, and east of it they dip gently southwest and west. Flexures are rare in these rocks, and most of the present structure seems to have been the result of block faulting involving largely dip-slip movements on steeply dipping north-striking faults, and on less abundant northeast- and northwest-striking faults.

## GENERAL FEATURES OF STRATIGRAPHY

The pre-Tertiary section of the Pybus-Gambier area consists of formations ranging in age from Devonian to Cretaceous (table 1). Sedimentation was not continuous, however, for hiatuses have been recognized between most of the formations. In large part, the section consists of fine-grained sedimentary rocks of marine origin that seem to have been derived mostly from volcanic sources, but it also contains marine limestone, dolomite, and basic volcanic rock. The most abundant rock type is dark-colored argillite interbedded with thin beds of chert or fine-grained graywacke, which are graded and crossbedded on

TABLE 1.—*Composite stratigraphic section of the Pybus-Gambier area, Admiralty Island, Alaska*

| SYSTEM OR SERIES | FORMATION | DESCRIPTION | THICKNESS (FEET) |
|---|---|---|---|
| Quaternary | Unconsolidated deposits | Glacial clay and gravel, and alluvial gravel | 0–50 |
| | UNCONFORMITY | | |
| Tertiary | Admiralty Island Volcanics | Andesite and basalt flows | 9500+ |
| Tertiary | Unnamed unit | Conglomerate and sandstone | 0–2000 |
| | ANGULAR UNCONFORMITY | | |
| Lower Cretaceous and Upper Jurassic | Brothers Volcanics | Brothers Volcanics; andesitic flows and breccias, and minor graywacke | 2000+ |
| Lower Cretaceous and Upper Jurassic | Seymour Canal Formation | Seymour Canal Formation; argillite, dark-gray, and graywacke and conglomerate | 8000+ (estimated) |
| | DISCONFORMITY | | |
| Upper Triassic | Hyd Formation | Thin-bedded grayish-black chert, argillite, and limestone (Spilitic lavas, pillow types common...... 0–500+) | 0–280+ (total 1300+ (estimated) including volcanic rocks) |
| Upper Triassic | Hyd Formation | Limestone, dark-brown, medium-bedded | 0–500+ |
| Upper Triassic | Hyd Formation | Breccia, white chert (0–30+ ft); Breccia, red and green chert (0–350 ft) | 0–380+ |
| | DISCONFORMITY | | |
| Permian | Pybus Dolomite | Dolomite, yellowish-gray and bluish-white chert nodules and beds | 0–1000 |
| Permian | Cannery Formation | Thin-bedded, dark-gray and green argillite, chert, and minor graywacke and pillow lava | A few 1000 |
| | ?—?— UNCONFORMITY | | |
| Devonian(?) and Devonian | Gambier Bay Formation | Gambier Bay Formation; greenschist, phyllite, marble, and metachert | Unknown |
| Devonian(?) and Devonian | Hood Bay Formation (intertongues with Gambier Bay Formation) | Hood Bay Formation; thin-bedded, grayish-black chert, siliceous argillite and minor marble, graywacke, and basic volcanic rock (probably coeval with Gambier Bay Formation) | A few 1000 |

a small scale and resemble closely the turbidities of Kuenen (1953; 1957).

With the single exception of the miogeosynclinal cherty Pybus Dolomite of Permian age, the pre-Tertiary strata represent a long,

736-005 O—64——2

discontinuous episode of flysch sedimentation (Tercier, 1947; Pettijohn, 1957, p. 615–618) that was ended in the Cretaceous by strong deformation and uplift. Nonmarine coarse-grained sedimentary rocks of Eocene age were deposited after the deformation and are typical postorogenic molasse-type deposits (Pettijohn, 1957, p. 618–622). These deposits rest with marked angular unconformity on the older rocks and are overlain by nonmarine volcanic flows of the Admiralty Island Volcanics.

Deformation and the lack of marker beds have prevented the accurate determination of stratigraphic thicknesses in all but the thinnest pre-Tertiary formations. In many thick units, vertical lithologic change cannot be distinguished from lateral change. The following stratigraphic descriptions, therefore, are lacking in accurately measured sections, but the total thickness must be at least a few tens of thousands of feet. A more precise estimate than this would be without adequate basis.

## DEFINITIONS

The rock classification used in this report is that of Williams and others (1954), unless otherwise stated. The grade scale used is the Wentworth scale as modified by Dunbar and Rodgers (1957). The color terminology of this paper follows that of the Rock-Color Chart (Goddard and others, 1951).

All gradations between chert and nonsiliceous argillite occur among the rocks of the Pybus-Gambier area. The term "chert" is applied to those extremely fine grained rocks that fracture with a glossy conchoidal or smooth angular surface and that cannot be scratched by a knife blade. The term "siliceous argillite" is applied to fine grained rocks that cannot be scratched or can be scratched only slightly with a knife blade, but which fracture with a dull, rough surface.

The rocks of the area have been studied by optical petrographic methods only, and very fine grained minerals have not been identified with certainty. Argillite and graywacke are especially rich in such minerals, and it has been necessary to use certain mineral names arbitrarily. Thus, fine-grained colorless micaceous minerals having a strong birefringence are called sericite. The name "chlorite" is applied to pale-green, commonly pleochroic micaceous minerals having a low birefringence. These two terms probably include other micaceous minerals.

The feldspar determinations are based largely upon the four-axis universal stage method of Turner (1947). The actual determinations were based upon curves newly derived by Slemmons (1962).

## DEVONIAN AND DEVONIAN(?) SYSTEM

### GAMBIER BAY FORMATION

#### STRATIGRAPHY

The name Gambier Bay Formation is here proposed for the low-grade metamorphic rocks exposed along the shores of western Gambier Bay and in the area immediately to the south and west. The type locality of the formation is the exposure along the shore of western Gambier Bay from Snug Cove on the south to the vicinity of the triangulation station "Butt" on the north. The formation underlies the area west of Gambier Bay and north of the eastern part of the Gambier fault. The northwestern part of the map area has been examined only by reconnaissance, but the phyllite, greenschist, and marble there are tentatively correlated with the metamorphic rocks bordering Gambier Bay.

Among the formations mapped, the Gambier Bay Formation is identified by the metamorphic foliation of its rocks, which are fine-grained greenschist and phyllite in which individual minerals are generally too small to be identified in hand specimen. The chief types of rock in the formation are chlorite-epidote-calcite phyllite or schist, quartz-albite, phyllite, marble, and phyllitic slate. (See "Petrography," p. 15 for details.) All the rocks have been intensely deformed. Some are phyllonitic and contain abundant relict mineral grains considerably larger than the metamorphic mineral grains present; metamorphic crystallization has not eliminated all of the mylonitic layers associated with the larger relict grains.

The pervasive foliation that penetrates these rocks on an intergranular scale is chiefly defined by the preferred orientation of platy minerals and by mylonitic layers. Lenticular masses of marble and basic volcanic fragments are alined with their longest dimensions about parallel to the foliation. Field evidence indicates that this foliation is parallel to the axial planes of folds in the bedding. The foliation surfaces contain abundant small folds and crenulations. The rocks invariably break along the foliation.

Primary bedding is inconspicuous, partly because of the original, dominantly thick-bedded character of the rocks and partly as a consequence of intense folding that was accompanied by slip along the foliation and resulted in the disruption and transposition of the bedding. Bedding is commonly visible as discontinuous streaks of contrasting composition on the foliation surfaces (fig. 2). These streaks represent the intersection of bedding and foliation and are parallel to the axes of the first folds. Only rarely, chiefly in thin-bedded

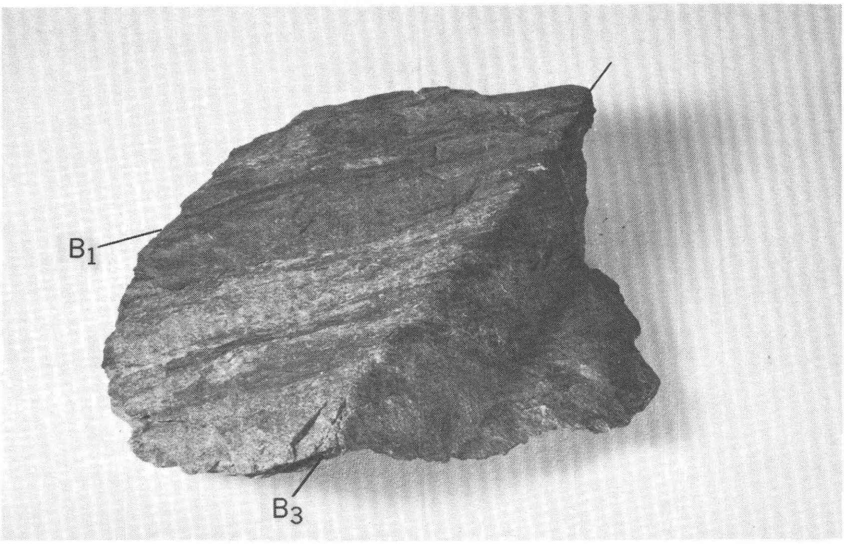


FIGURE 2.—Hand specimen of phyllite about 8 inches across showing streaking ($B_1$) on first generation axial plane foliation; $B_1$ represents the intersection of bedding and foliation and is parallel to the axes of the first folds; note kink fold of the third generation ($B_3$), which has deformed $B_1$ and foliation; Gambier Bay Formation.

phyllitic slate, can continuous beds be traced around fold hinges. In such rocks, precise measurement of stratigraphic thickness is meaningless.

Poorly preserved fossils indicative of Devonian age (probably Middle Devonian; W. A. Oliver, J. Berdan, and Helen Duncan, written communications, 1959 and 1960) occur in the prominent marble unit of the Gambier Bay Formation. (See "Fossil localities and lists," p. 94.) The Gambier Bay Formation, as mapped, may also contain minor amounts of rocks of Permian age inasmuch as its upper contact with the Cannery Formation of Permian age represents the limits of visible metamorphism and may cut across the unconformity that separates the original lithogenetic units. Structural evidence suggests that the metamorphic features by which the Gambier Bay Formation is recognized may have been acquired after the deposition of the overlying Cannery Formation (see p. 8); the "contact" between the two formations may thus be a zone of transition from metamorphic to nonmetamorphic rocks. In view of the above considerations, the age of the Gambier Bay Formation is here considered to be Middle(?) Devonian. There is no evidence for the existence of Carboniferous rocks anywhere on Admiralty Island.

Reconnaissance mapping (Lathram and others, 1960) indicates that the exposures of the Gambier Bay Formation at Gambier Bay are the southeastern end of a discontinuous belt of metamorphic rocks extending from Gambier Bay northwestward along the west side of Admiralty Island to Point Retreat at the northernmost tip of the island. Barker (1957) named the metamorphic rocks in the Point Retreat area the Retreat Group; he considered the group to be possibly Triassic to Cretaceous in age. However, he had no fossils either from the metamorphic rocks or from the overlying rocks upon which to base his age correlation. The Retreat Group, considered by Lathram and others (1960) to be Silurian and Devonian, is probably correlative with the Gambier Bay Formation, but certain correlation is impossible because the two units crop out in localities separated by a broad area of plutonism and contact metamorphism centered around Thayer Lake (Lathram and others, 1960). Known fossil control is confined to the southern area of outcrop.

The Gambier Bay Formation also resembles in a general way the Wales Group of southern southeastern Alaska, a name applied by Brooks (1902, p. 40–52) to "crystalline white limestones and argillites or phyllites, with closely associated greenstones" cropping out on Prince of Wales, Long, and Dall Islands. Buddington and Chapin (1929, p. 45–49) considered this group to be "probably of pre-Ordovician to Devonian" age.

## PETROGRAPHY

The rocks of the Gambier Bay Formation are here divided into several categories, within each of which considerable variation occurs. Both massive-appearing and fissile rock types occur interlayered with one another; however, both types possess the same microscopic intergranular foliation. In general, the more micaceous mineral constituents a rock contains, the more fissile is its aspect. In the field, massive-appearing chlorite-epidote-calcite phyllite and schist appear to be the most abundant rock types, whereas fissile rocks are less prominent. However, the more fissile rocks may be at least as abundant as the massive ones, but they are much less resistant and, hence, less commonly crop out.

The presence of the mineral assemblages quartz-muscovite-chlorite-albite, quartz-talc-calcite, talc-dolomite, and chlorite-calcite indicates that the rocks of the Gambier Bay Formation belong to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Fyfe and others, 1958, p. 219–223). The common occurrence of relict pyroxene, hornblende, and calcic plagioclase grains, however, indicates that equilibrium was seldom attained in these rocks.

### CHLORITE-EPIDOTE-CALCITE PHYLLITES AND SCHISTS

These rocks are among the most abundant in the Gambier Bay Formation. In outcrop the chlorite-epidote-calcite phyllites are massive-appearing, homogeneous and medium bluish gray to dark greenish gray. The weathered surface is roughly granular, and euhedral pyroxene crystals, ranging in length from 0.5 mm to 2 mm, sometimes project from it. Compared to the more fissile rocks, the phyllites lack structural detail. They are phyllonites which contain an abundance of relict augite and, in places, hornblende. The relict grains make up as much as 60 percent of the total rock and are several times larger than the metamorphic grains. Thus the augite and hornblende grains appear to be the remnants of a coarser grained igneous rock, possibly a pyroxenite, whose grain size has been reduced to varying degrees by metamorphic deformation. The resulting rock is phyllitic in appearance, but was formed by the reduction rather than increase of grain size (Turner, in Williams and others, 1954, p. 206–208). In some specimens, metamorphic crystallization has been so slight that the rocks resemble mylonite.

Microscopically these phyllonites consist of abundant relict grains of nonpleochroic yellow augite and, in some specimens, hornblende in a strongly foliated matrix consisting of chlorite, epidote, calcite, talc, and fine mylonitic material; the foliated matrix bends around the relict grains (fig. 3). The relict grains are commonly fractured, and trails of smaller fragments form streaks parallel to the foliation. The augite grains have overgrowths of amphibole which project, commonly across the foliation, in sawtooth fashion from surfaces of the pyroxene grains, and in a few places the amphibole fills fractures within the pyroxene grains. The amphibole overgrowths are colorless except for the part in contact with the augite grains, which is strongly pleochroic as follows: X=deep blue, Y=bluish green, and Z=pale yellow. The colorless amphibole is tremolite, and the bluish amphibole is a sodic variety. Turner (1935, p. 340–341) has also reported tremolite or actinolite and blue amphibole occurring as overgrowths on relict augite in the greenschists of New Zealand. Universal stage measurements indicate that the yellow augite has an angle $Z \wedge c$ in the range 40°–45°, and $2V_z$ in the range 56°–68°. The cause of the yellow color is unknown.

Chlorite is faintly pleochroic, pale yellowish green, and shows an anomalous low brownish birefringence.

Epidote occurs as stubby euhedral crystals and as anhedral grains, both of which tend to form clots slightly elongate parallel to the foliation around the margins of the pyroxene grains. The pleochroism is Z=yellow, Y=greenish yellow, and X=pale yellow.

Calcite occurs interstitially and in equant patches scattered throughout the matrix. Minor amounts of albite and quartz occur as fine mosaic patches and rare veins in all specimens examined.

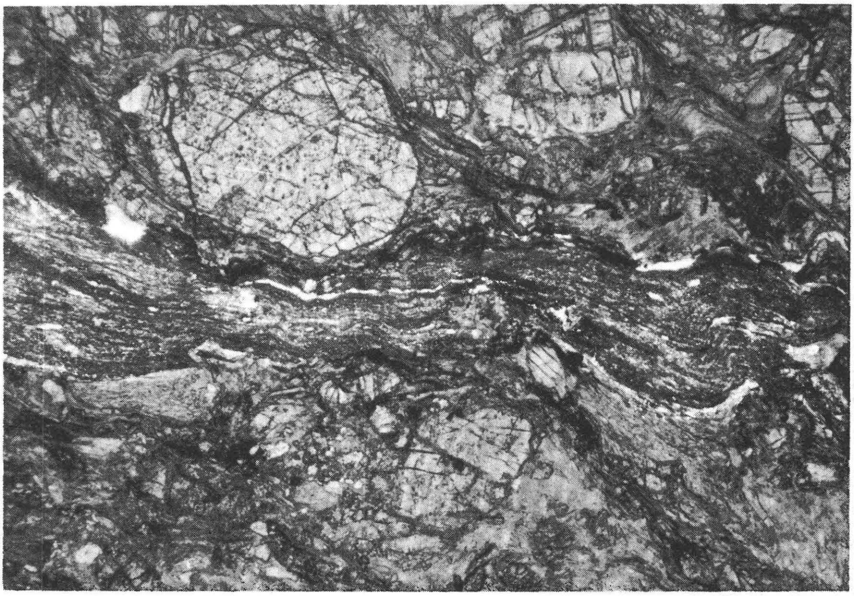

FIGURE 3.—Photomicrograph of phyllonite showing foliated matrix, chiefly of chlorite, epidote, and mylonitic material, bending around relict augite crystals (plain light, ×35).

### QUARTZ-ALBITE-MUSCOVITE (SERICITE)-CHLORITE PHYLLITES

The quartz-albite-muscovite (sericite)-chlorite phyllites are thinly fissile and range through all gradations from sericitic phyllites to chloritic greenschists. The color ranges from lustrous medium dark green to lustrous grayish green depending on whether sericite or chlorite dominates. The amount of quartz and albite varies, but is minor in the most thinly foliated types. These rocks possess a thin regular foliation, and commonly show an abundance of fine structural detail such as small folds and lineations. As pointed out above, they may be one of the most abundant rock types in the Gambier Bay Formation, but because of their nonresistant character they do not crop out prominently.

Only the coarsest grained specimens were examined in thin section. These consist of thin (0.018–0.3 mm) lenticular layers of slightly undalose mosaic quartz separated by layers of muscovite and chlorite that show a strong planar preferred orientation. An unknown amount of albite, mostly untwinned, is scattered through the quartz-rich layers. Minor amounts of calcite and magnetite occur in all the sections examined. Angular quartz and lesser amounts of twinned plagioclase grains are scattered along the foliation in all sections; these grains may be relict clasts.

Microfolds involving all the above minerals deform the foliation in all thin sections studied. In hand specimen, crenulations and striations parallel to the axes of these microfolds can be seen on the foliation surfaces.

Muscovite, much of which can be termed sericite, occurs as fine irregular elongate crystals which average about 0.04 mm in length. It ranges from colorless to pale green and is commonly interlayered with chlorite. In general, chlorite does not have the strong preferred orientation of muscovite but tends to form feathery aggregates, parts of which diverge from the foliation. The chlorite is pale yellowish green and slightly pleochroic, but in one specimen more strongly pleochroic crystals are common in which X and Y=green and Z=pale yellowish green.

### QUARTZ-ALBITE-TALC-CHLORITE QUARTZITES AND PHYLLITES

The quartz-albite-talc chlorite quartzites and phyllites are fine-grained, highly quartzose rocks ranging from greenish gray to grayish yellow. In outcrop they appear slightly translucent and irregularly foliated. The rocks of this category are generally composed of light-colored lenses ranging from a few millimeters to a few centimeters in length and separated by a darker, strongly foliated matrix. Locally, the lenses weather out in splintery pencillike forms.

The light-colored lenses consist largely of microcrystalline quartz and contain variable amounts of albite. Because albite is mostly untwinned, accurate estimates of its relative amount could not be made. The darker foliated layers are rich in talc and chlorite, both of which show a strong planar preferred orientation. The proportion of these two minerals varies; in some rocks talc predominates over chlorite, and in others chlorite predominates over talc. Both minerals occur also in the quartz-rich lenses within and between the quartz grains. The chlorite is generally pleochroic pale yellowish green, and has a very low anomalous blue birefringence. Less abundant minerals commonly present are sphene, epidote, calcite, tremolite, and pyrite.

Quartz ranges from 40 to 90 percent of the rock, depending upon what percentage of the rock is made up of the quartz-rich lenses. Quartz grains range from less than 0.018 to 0.1 mm in diameter, the small grain size suggesting that the rocks originally may have been chert. The few larger angular quartz grains scattered through the quartz-rich layers suggest relict clasts.

One specimen contains abundant larger grains of slightly sericitized, complexly twinned plagioclase ($An_{10-15}$ ranging from 0.07 mm to 1 mm in diameter. The margins of the grains are granulated and are surrounded by fine mosaics of quartz and albite. The chlorite and talc appear to have replaced and embayed the plagioclase along its margins. This rock is not so clearly divided into lenslike masses as are the other rocks in this category, and the foliated zones are more closely spaced and regular; it appears to have been derived either from an igneous rock or from a feldspathic sedimentary rock.

### MARBLE

A fine-grained dark marble, slightly mottled with white, is prominent in the Gambier Bay Formation. Marble beds are very rare, and it is possible that there is only the one marble unit in the formation. However, structural complexity prevents an accurate count of the number of units present.

The marble consists of nearly 99 percent calcite in an irregular mosaic of grains having irregularly sutured borders. Most grains average about 1.0 mm in length and 0.09 mm in width and are elongate parallel to a clearly defined foliation. Small grains that cluster along the borders of the larger grains, especially along the borders parallel to the foliation surfaces, suggest granulation and recrystallization. Patches of equant grains break up the foliated pattern in places. The dark color of the marble is probably caused by the thin coating of opaque carbonaceous dust on the borders of the grains.

The calcite grains themselves show abundant broad lamellae which are commonly bent and lensoidal (fig. 4). The form of the lamellae resembles that in the calcite grains of the Yule marble, which were artificially deformed by extension at 800° C, 5 kilobars (Griggs and Handin, 1960, pl. 11).

Minor amounts of quartz and albite occur in small patches of equant grains. Sparse tremolite needles are scattered through one specimen.

### CALC-SCHISTS

The calc-schists are lustrous fine-grained pale-olive foliated rocks containing augen and streaks of light-gray marble, and they occur chiefly but not entirely as layers in marble. Poorly preserved fossils have been observed in the thicker marble augen.

The calc-schists consist of lenticular layers of calcite, quartz, and albite separated by strongly foliated cloudy talc-rich layers, in which the talc forms indistinct feathery masses containing much fine unresolvable material. In most specimens, calcite is the dominant constituent, amounting to as much as 50 percent of the total rock, but in at least one specimen the carbonate is dolomite. Talc, quartz, albite, and chlorite in varying proportions make up the remainder of the rocks, and pyrite cubes partially altered to limonite are minor constituents in all of them.

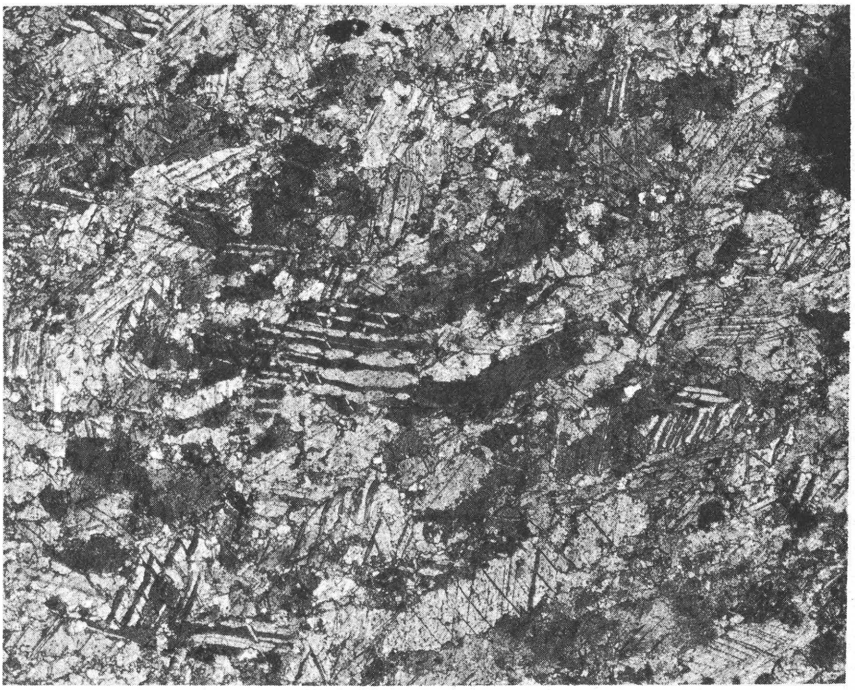

FIGURE 4.—Photomicrograph of marble, Gambier Bay Formation, showing bent and lensoidal lamellae; note grains near center and near upper left corner (crossed nicols, ×35).

The calcite generally occurs as anhedral aggregates in layers and lenses ranging in thickness from 1.0 to 25.0 mm. Grain size of the calcite aggregates is extremely variable.

Quartz and albite occur together as mosaics of anhedral grains, but, because the albite ($An_{0-6}$) is largely untwinned, it is difficult to estimate the proportions of the two minerals. In one specimen, quartz occurs as augen, 2.0 to 4.0 mm long, in spherulitic chalcedonic aggregates along with calcite and albite.

Chlorite is a minor constituent in all specimens examined except one, in which it forms about 20 percent of the total rock; it occurs in all the specimens as nonpleochroic very pale green, irregular elongate crystals oriented about parallel to the foliation. The birefringence of the chlorite is a low anomalous brown.

### ALBITE-CHLORITE-CALCITE-QUARTZ ROCKS

Albite-chlorite-calcite-quartz rocks are uncommon but distinctive and are characterized by an abundance of closely packed, dusky-yellow, platelike laths of altered feldspar ranging from 4.0 to 25.0 mm in length. The laths are set in a fine-grained matrix which ranges from grayish olive to dark greenish gray. The lighter colored varieties are foliated, but darker varieties, which are the most common, show no visible foliation. The large plagioclase grains set in a fine-grained metamorphic matrix indicate that the rock has undergone partial reduction in grain size, and hence is on the way to becoming a phyllonite.

The laths are composed of a cloudy mixture of chlorite, epidote, albite, ($An_{0-8}$) calcite, and quartz. Most of this mixture is very fine grained ($<0.02$ mm in diameter), but in places albite anhedra as much as 0.9 mm in diameter occur. The interstices between the laths are filled with a granular mixture of quartz and albite containing much interstitial chlorite and patches of calcite. In one specimen, anhedral grains of apatite are scattered throughout; in another, sphene is an important accessory.

## HOOD BAY FORMATION

### STRATIGRAPHY

The name Hood Bay Formation is here proposed for the sequence of dark-hued carbonaceous chert, siliceous argillite, graywacke, limestone, and minor altered basic volcanic rock that is typically exposed along the two rivers flowing westward into the head of the North Arm of Hood Bay. Similar rocks are also exposed along the southwest shore of Pybus Bay northward from Donkey Bay. The lower contact is not exposed, and older formations are unknown in the Pybus-Gambier area. The Hood Bay Formation is unconformably overlain by the Cannery Formation of Permian age, but this contact is largely covered and its details are unknown.

Rocks of the Hood Bay Formation crop out in a roughly triangular area west of Pybus Bay and south of the Gambier fault. To the southwest, the Hood Bay Formation is buried unconformably by the Admiralty Island Volcanics of Tertiary age. To the northeast, rocks of the Hood Bay Formation are in fault contact with the Cannery and younger formations in a complex manner along the Pybus fault zone, which follows the main arm of Pybus Bay. In general, the topography of the country underlain by the Hood Bay Formation consists of rounded mountains and hills without prominent features.

The Hood Bay Formation lacks distinctive persistent members and has been isoclinally folded, so that the measurement of accurate stratigraphic thickness is impossible. Although the formation crops out over a relatively large area, its total stratigraphic thickness may be only a few thousand feet, and the lithology must be described in general terms and without implication as to stratigraphic sequence.

The predominant rocks of the formation are thin-bedded grayish-black radiolarian chert and siliceous argillite. Dark-gray limestone, calcareous argillite, and fine-grained graywacke are locally interbedded with the argillite. The general dark color of all the rocks is the result of disseminated fine carbonaceous material and fine pyrite crystals. The lithologic aspects of the formation as a whole suggest a black shale or euxinic facies, as described by Pettijohn (1957, p. 622–626). Flows of altered basic volcanic rock crop out in one locality and represent a minor rock type of the formation.

The lithostratigraphic correlation of the Hood Bay and Gambier Bay Formations is indicated by the following geologic evidence:

1. The two formations have similar stratigraphic positions. Both underlie the Cannery Formation of Permian age, and both are stratigraphically the lowest formation in their respective areas of outcrop.
2. The two formations have separate areas of outcrop.
3. The metamorphic Gambier Bay Formation contains subordinate rock types, such as dark-gray phyllite, metachert, and marble that could have been derived from the dark argillite, chert, and limestone of the Hood Bay Formation.
4. The large-scale intertonguing of Hood Bay and Gambier Bay lithologies is strongly suggested by the interlayering of metasedimentary and metavolcanic rocks in the metamorphic terrane that lies along the west coast of Admiralty Island north of the area. This terrane is considered by Lathram and others (1960) to be correlative with the Gambier Bay Formation. It contains thick units of dark-gray highly quartzitic graphitic phyllite and schist, which probably represent the grayish-black carbonaceous chert and argillite of the Hood Bay Formation, interbedded with thick units of greenschist, which is probably equivalent to the greenschist that dominates the Gambier Bay Formation. The zone in the Pybus-cambier area in which this intertonguing might be observed is largely covered by younger rocks. However, the minor volcanic flows in the Hood Bay Formation may represent thin tongues of the volcanic pile in the Gambier Bay Formation to the northeast.

Poorly preserved fossils indicative of a middle Paleozoic age (Helen Duncan and J. T. Dutro, Jr., written communication, 1960) were collected from limestone and calcareous argillite in the Hood Bay Formation. (See "Fossil localities and lists," p. 94.) Because the geologic evidence listed above for the lithostratigraphic correlation of the Hood Bay and Gambier Bay Formations, the Hood Bay Formation is here considered to be of probable Devonian age.

The difference in the degree of metamorphism of the Gambier Bay and Hood Bay Formations requires explanation, in view of the above correlation. Structural evidence suggests that the deformation and metamorphism of the Gambier Bay Formation occurred at the same time as the intense folding of the younger pre-Tertiary rocks, probably in the Cretaceous. (ee p. 8.) The metamorphism of the Gambier Bay Formation may have been the result of its deeper burial during deformation. If this assumption is correct, the nonmetamorphic character of the Hood Bay Formation indicates a decrease in metamorphism in a southwesterly direction from Gambier Bay, and the "contact" of the Gambier Bay Formation both upward and laterally must be a zone of transition from metamorphic to nonmetamorphic rocks. (See p. 14 for further discussion.)

Limestone, argillite, and graywacke of Silurian or Devonian age occur on Carroll Island and vicinity, near the southern tip of Admiralty Island (Lathram and others, 1960, fig. 1). These rocks are lighter in color than the Hood Bay Formation and contain no interbedded chert. The fossil evidence indicates that these rocks are more probably Silurian than Devonian (W. A. Oliver, Jr., written communication 1959).

Buddington and Chapin (1929, p. 82–91, 97, 103–109) described sedimentary and volcanic rocks of Devonian age on Kupreanof and Kuiu Islands, and the Keku Islets about 30 miles to the south of the Pybus-Gambier area. (See fig. 1.) The lithologic sections described, however, do not correspond closely to the uniformly dark-colored siliceous fine-grained rocks of the Hood Bay Formation.

Another section of Devonian and possibly Silurian sedimentary rocks occurs near Freshwater Bay on Chichagof Island about 45 miles northwest of the Pybus-Gambier area (Loney and others, 1963, fig. 1). Here a thick sequence of interbedded medium-gray graywacke, dark-gray slate, and conglomerate of possible Silurian age underlies another thick sequence of Devonian limestone and minor graywacke (Kennel Creek Limestone and Cedar Cove Formation), which is in turn overlain by a thick sequence of Upper Devonian volcanic rocks (Freshwater Bay Formation). The rocks of this section are, in general aspect, quite unlike those of the Hood Bay Formation.

## PETROGRAPHY

### CHERT AND SILICEOUS ARGILLITE

Chert and siliceous argillite generally occur in grayish-black interbeds ranging from 0.5 to 3.0 inches in thickness. The ratio of chert to argillite is generally about 1 : 1, but ranges locally from 3 : 1 to 1 : 3.

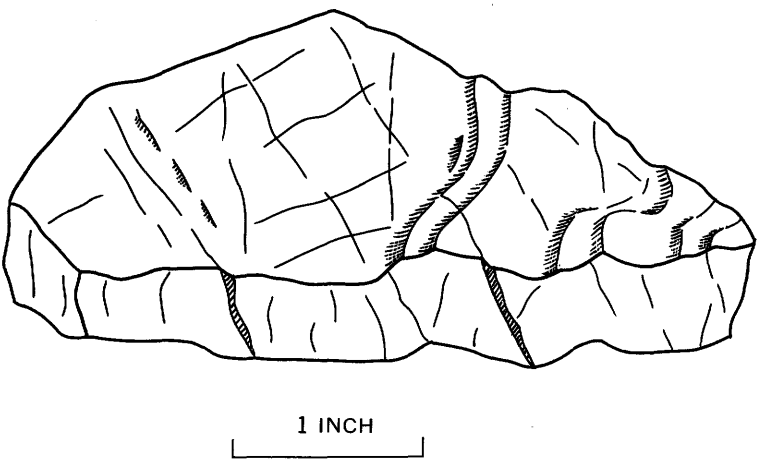


FIGURE 5.—Sketch of chert specimen showing displaced and recemented segments separated by cuestalike ridges; Hood Bay Formation.

Where siliceous argillite is predominant, it commonly occurs in homogeneous beds that range from 0.5 to 1.0 foot in thickness and contain thin units of thinly bedded chert averaging 0.5 foot in thickness. In some localities, dark-gray limestone nodules ranging from 2 to 12 inches in length are sparsely scattered through the massive argillite beds. All gradations between chert and nonsiliceous argillite occur.

The chert typically contains abundant quartz veinlets that average about 1.0 mm in thickness and intersect the bedding at angles of about 90°. On the weathered surfaces, these veinlets appear as ridges intersecting one another at various angles.

A common feature of the chert beds is illustrated by figure 5, which shows a fragment of a chert bed divided into segments that have been rotated slightly with respect to one another. Small subparallel cuestalike ridges bound the rotated fragments, and the sense of rotation is commonly the same in any one outcrop. The beds appear to have been broken, slightly rotated, and recemented. The zone of cementation is commonly not visible and usually does not coincide with the conspicuous quartz veinlets. These features are less apparent in the siliceous argillite because this rock tends to break irregularly and not parallel to the bedding.

The outcrops of thinly bedded chert and argillite are commonly stained reddish brown, particularly along shear zones that are common in the Hood Bay Formation. This stain probably results from the oxidation of pyrite, which is a common accessory mineral in the chert and argillite.

In thin section the typical chert is seen to consist of abundant microcrystalline quartz, sparsely scattered patches of chlorite and euhedral pyrite, and abundant dark-brown unresolvable dust. Scattered sparsely along a few layers are masses of spherulitic and microgranular quartz which are circular or elliptical in outline and average about 0.02 mm in diameter, the largest measuring as much as 0.2 mm in diameter. These masses are very similar to the radiolarian tests in bedded cherts of California figured by Taliaferro and Hudson (1943, p. 251–256, figs. 12, 15, 17–22).

Quartz occurs in both spherulitic and granular forms, and in both its average grain size is extremely small (less than 0.002 mm in diameter). Clots of coarser grains, generally elongate parallel to bedding, occur sparsely throughout the rock.

Small colorless micalike flakes are sparsely scattered through the rock roughly parallel to the bedding, but show no marked preferred orientation. The flakes are length slow, and show a first-order yellow birefringence.

Veins seen in thin section are mosaics of anhedral quartz crystals containing small patches of calcite and chalcedonic quartz. In addition, numerous stylolitic seams containing dark-brown material cut the rock at high angles to the bedding.

### LIMESTONE AND CALCAREOUS ARGILLITE

Dark-gray massive fine-grained limestone is a prominent but minor constituent of the Hood Bay Formation. It occurs chiefly in lenses 30 to 40 feet thick that can be traced only a few hundred feet along strike. The massive limestone is commonly associated with thinly bedded dark-gray calcareous argillite and very thinly laminated dark-gray and grayish-black limestones. The entire calcareous section including the massive limestone beds is commonly less than 50' feet thick and is overlain and underlain by thin-bedded chert and siliceous argillite.

On weathered surfaces the massive limestone is medium gray, mottled with dark gray, and is commonly cut by numerous white calcite veins. A crude parting occurs parallel to the bedding, and freshly broken limestone has a distinct sulfurous odor. In one locality, the limestone contains scattered small clots of black asphaltic material. Calcite is the chief carbonate mineral in the limestone, as indicated by the copper nitrate ($Cu(NO_3)_2$) stain method (Rodgers, 1940). Solution of powdered limestone in warm dilute hydrochloric acid yielded 15.0 percent by weight insoluble residue consisting largely of extremely fine carbonaceous material.

### GRAYWACKE

Graywacke is a subordinate constituent of the Hood Bay Formation, but locally it is the dominant rock type. It occurs mostly as beds

1 to 2 inches thick in the thinly bedded chert and siliceous argillite sections. In the few localities where it is abundant, graywacke forms beds 0.5 to 2.0 feet thick interlayered with thinner beds of chert or argillite.

The graywacke ranges from medium gray to medium dark gray and from very fine sand to medium sand. Coarse-grained beds are extremely rare. The thinner beds of graywacke commonly show graded bedding. Thicker beds, 1 to 2 feet thick, are generally homogeneous; some appear to grade laterally into argillite.

A typical graywacke is composed of subangular grains of quartz, plagioclase, argillite, chert, and calcite amounting to about 80 percent of the total rock, embedded in a dark-brown cloudy matrix composed of sericite, chlorite, calcite, microgranular quartz and albite, and abundant fine opaque dust. Slight preferred orientation of the sericite and chlorite crystals in the matrix and the slight granulation and elongation of the larger clastic grains combine to produce an incipient foliation in the rock.

Quartz grains, composing about 45 percent of the rock, average about 0.15 mm in diameter and generally show undulatory extinction under crossed nicols. The quartz grains have been corroded and penetrated along their margins by the micaceous matrix, and many of them show overgrowths of clear quartz which tend to elongate the grains parallel to the incipient foliation.

Plagioclase grains (15 percent of the rock) are partly sericitized and commonly complexly twinned. Universal stage determinations indicate compositions from $An_{28}$ to $An_{38}$.

Chert and argillite grains (about 15 percent of the rock) resemble in texture and composition the chert and siliceous argillite of the Hood Bay Formation. They are elongated parallel to the foliation and have frayed ends projecting along the foliation.

Calcite grains, forming about 5 percent of the rock, have irregular shapes and indistinct borders. A few show structures faintly suggestive of fossils.

## PERMIAN SYSTEM

### CANNERY FORMATION

#### STRATIGRAPHY

The name Cannery Formation is here proposed for thinly interbedded chert, argillite, and graywacke typically exposed in and around the mouth of Cannery Cove on the southwest shore of Pybus Bay. The formation crops out almost continuously along this shore from a point about 3½ mile southeast of Cannery Cove northwestward to the north shore of Donkey Bay. Similar strata underlie a large

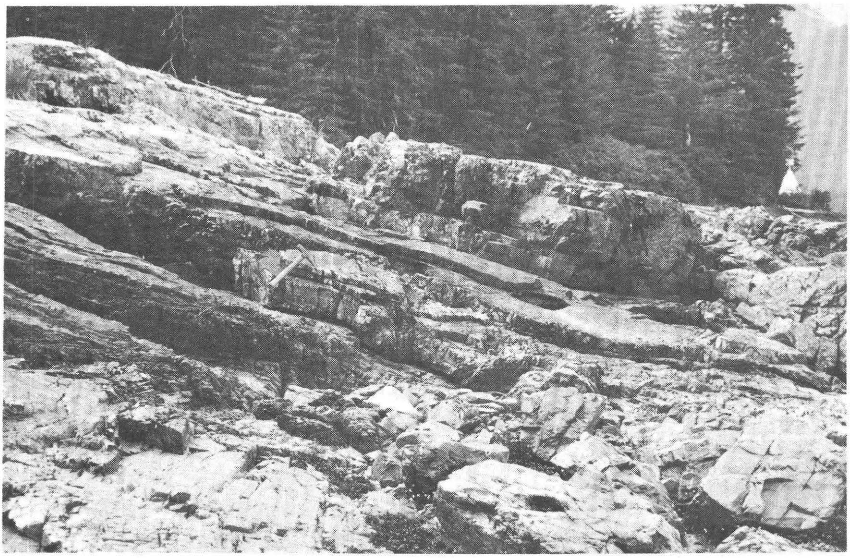

FIGURE 6.—Thin-bedded chert and argillite of the Cannery Formation at Cannery Cove, Pybus Bay.

area north of Pybus Bay and extend as far as the south shore of Gambier Bay.

Throughout most of the Pybus-Gambier area the Cannery Formation consists of thin-bedded siliceous argillite, graywacke, and chert (fig. 6) and local intercalations of thick-bedded calcareous, volcanic graywacke and altered pillow lavas and breccias. In contrast to the Hood Bay Formation, the color of the thin-bedded chert, argillite, and graywacke is highly variable, but shades of green and gray dominate. Some of the chert contains radiolarian tests.

At Gambier Bay in the vicinity of Church Point and Gain Island, the color of the chert and argillite in the Cannery Formation changes to shades of bright green and red, and the chert acquires a coarser crystalline sugary texture indicative of metamorphic recrystallization. The overlying basal breccia of the Hyd Formation contains fragments of this metachert on the island north of Gain Island and on the north shore of Gambier Bay, where the Cannery Formation is missing. The matrix of this breccia is also recrystallized, a fact that indicates that the metamorphism of both the breccia of the Hyd Formation and the chert of the Cannery Formation occurred after the deposition of the breccia. The metamorphism may be related to the intrusion and extrusion of younger volcanic rocks in the Hyd Formation that overlie the breccia.

Among the larger clasts in the graywacke, quartz is rare but feldspar and volcanic rock fragments are abundant. The feldspar consists of

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both andesine and albite grains, the latter being cloudy and generally sericitized, as is commonly the habit of plagioclase grains that have been albitized (Coombs, 1954). The presence of albite veins and of scattered albite and analcime crystals in the graywacke matrix and in the argillite suggest that the albite in these grains is not detrital but has developed by diagenetic alteration of the graywacke. Other diagenetic minerals occurring in the graywacke are quartz, chlorite, sericite, calcite, and probably various clay minerals.

Fossil bryozoan debris found in calcareous graywacke at several localities in the Cannery Formation indicates an age probably no older than Permian (Helen Duncan, with L. G. Henbest, written communications, 1959 and 1960; see also "Fossil localities and lists"). The stratigraphic position of the Cannery Formation below the Pybus Dolomite of Permian age eliminates the possiblity that the Cannery is younger than the Pybus Dolomite. The Cannery Formation, therefore, is here considered to be Permian in age.

The Cannery Formation overlies the Hood Bay Formation to the southwest and the Gambier Bay Formation to the north. The contact with the Hood Bay Formation must be an unconformity, but it has not been directly observed (p. 21). The contact with the Gambier Bay Formation may represent the limits of visible metamorphism and may cut across the original unconformable contact between the two lithogenetic units (p. 14 and 23).

The Permian Pybus Dolomite generally overlies the Cannery Formation, but the contact between them is poorly exposed. Fossil evidence is not sufficient to indicate whether or not a hiatus separates the two formations. Bedding attitudes in the Cannery Formation close to this contact commonly diverge from those of the Pybus Dolomite; this divergence may be of tectonic origin. The two formations are so different in competence that slip along their contacts during intense folding would be expected; the two formations are commonly separated by strike-fault zones.

Southwest of Pybus Bay, the Cannery Formation is buried unconformably beneath nonmarine sedimentary and volcanic rocks of Tertiary age. In places near Gambier Bay to the north, the Hyd Formation of Triassic age lies unconformably upon the Cannery Formation, as at Church Point and on Gain Island. At the latter place the contact between the two formations is an erosion surface having a local relief of about 2 feet. South and west of Gambier Bay, the exact distribution of the Cannery Formation cannot be mapped because of the similarity of the thinly bedded rocks of the Cannery and Hyd Formations, which, when the intervening Pybus Dolomite is absent, are difficult to distinguish from one another.

Despite the large area of outcrop north of Pybus Bay, the total stratigraphic thickness of the Cannery Formation there is probably no more than a few thousand feet because of tight folding and common stratigraphic repetition. In the absence of distinctive members, the thickness cannot be accurately measured in an area of poor exposures such as this. The reason for the narrowing of the outcrop of the Cannery Formation southwest of Gambier Bay is unknown, but it may be tectonic. Furthermore, the contact of the Cannery Formation and the Gambier Bay Formation may not be a simple sedimentary contact, for, as described on page 14, the Gambier Bay Formation is distinguished on the basis of its metamorphic characteristics and hence may include in places parts of the original lithogenetic Cannery Formation.

Rocks that may be correlative with the Cannery Formation have been reported in a series of outcrops along the eastern side of Admiralty Island (Lathram and others, 1960). Like the Cannery Formation, they consist principally of thinly bedded argillite, graywacke, and chert, and Permian fossils have been found in them at Windfall Harbor and in the mountains south of Point Young. Permian fossils in similar lithology have also been found on the mainland about 100 miles northwest of the Pybus-Gambier area in the vicinity of William Henry Bay along the east flank of the Chilkat Mountains (Lathram and others, 1959). However, the poor quality of the collections from the Cannery Formation in the Pybus-Gambier area does not afford the basis for precise biostratigraphic correlation with the above localities.

Permian fossils have also been reported (Buddington and Chapin, 1929, p. 119, 122–127) from marble in a sequence of phyllite, mica schist, chert, and slate on the mainland east of Admiralty Island at Taku Harbor and on the Snettisham Peninsula, and also from a dominantly clastic section of Kuiu Island and the Keku Islets south of Admiralty Island. These rocks were assigned by Buddington and Chapin to the "lower division of the Permian."

## PETROGRAPHY

### THIN-BEDDED CHERT AND ARGILLITE

The thin-bedded chert and argillite are the most abundant rocks in the Cannery Formation, making up about 60 percent of the total. They generally occur in rhythmic interbeds ranging from 0.25 to 3.0 inches in thickness. Very thin (<1.0 inch) beds of graywacke, commonly green, are scattered sparsely through most sections of chert and argillite.

The chert occurs in a variety of colors, the most common of which are dark gray, medium dark gray, greenish black, dark greenish gray, greenish gray, and grayish green. It weathers dark greenish gray and olive gray and is typically crossed by a network of fractures.

Most of the chert examined under the microscope is seen to consist of a cloudy mass of submicroscopic to microgranular quartz containing sparse lenticular clusters of coarser equigranular quartz and, in places, albite alined parallel to bedding. Scattered sparsely through the rocks are angular clasts of quartz and plagioclase, which average about 0.25 mm in diameter. Most specimens contain very small chlorite and sericite patches and flakes disseminated throughout the thin sections.

One-third of the specimens examined contain ovoid or spherical clear masses of microgranular quartz similar to those that represent recrystallized radiolarian tests in the chert of the Hood Bay Formation. (See p. 25.) The radiolarian tests range from 0.08 to 0.18 mm in diameter. The bedding planes in the chert are commonly marked by extremely thin, dark laminae. The layers between the dark laminae pinch and swell and impart a microscopically lenticular appearance to the rock. Clasts of quartz and plagioclase, as well as radiolarian tests, commonly have indistinct margins that appear to merge into the matrix.

The brightly colored, sugary-textured chert from the vicinity of Gain Island in Gambier Bay is seen in thin section to consist chiefly of a sutured mosaic of quartz averaging 0.03 mm in diameter, which is mottled with scattered patches of mosaics having a larger grain size. The rock also contains sparsely scattered sericite flakes.

All the chert contains abundant veinlets of mosaic quartz and albite; calcite veinlets are less common, although calcite commonly forms a minor constituent of the quartz-albite veinlets. In the vicinity of the calcite veinlets the chert commonly contains much interstitial calcite that appears to have replaced the minerals of the matrix. One specimen contained veinlets composed of a complex of calcite, quartz, albite, and analcime crystals.

In thin section all gradations are seen, from chert to siliceous argillite to argillite. The transition from chert to argillite appears to have been brought about by a decrease in quartz and an increase in chlorite and sericite. The argillite tends to contain a greater amount of detrital quartz and plagioclase; as the detrital fraction increases, the argillite passes into a graywacke.

### GRAYWACKE

The graywacke of the Cannery Formation occurs in two forms: (1) as thin graded beds averaging less than 1 inch in thickness and

(2) as thick massive calcareous beds ranging in thickness from 2 to 10 feet.

Both types contain more than 15 percent matrix (fig. 7*B*), and therefore, according to Pettijohn (1957, p. 288–293), these rocks are graywacke deposited by a concentrated medium. The thin-bedded graywacke of type 1 displays graded bedding and in places small-scale crossbedding indicative of deposition by a medium fluid enough to allow mixing of grains and sorting. The massive graywacke of type 2 lacks current structures and sorting features and may have been deposited by a medium too viscous to allow free mixing of grains.

The graywacke of type 1 is most commonly dark greenish gray, but other colors such as dusky yellow green, medium dark gray, and medium bluish gray occur in places. The thin beds weather to a rough surface that contrasts sharply with the smooth-weathering surfaces of the argillite and chert. The upper and finer parts of these beds tend to develop a shaly parting.

The graywacke of the first type is composed of subangular to angular grains of plagioclase, quartz, and rock fragments embedded in a cloudy matrix consisting of an intimate mixture of chlorite, sericite, calcite, microgranular quartz, albite, and in places analcime. The matrix, which ranges from 20 to 50 percent of the rock (fig. 7*B*, white dots), contains much fine opaque dust, part of which is pyrite and limonite, but most is unresolvable. Much of the matrix was probably originally clastic, but most of the clastic constituents have been replaced by alteration products. The grains generally have indistinct frayed borders which show signs of replacement by chlorite, sericite, and calcite of the matrix.

The grain size near the base of the graywacke beds averages about 2.0 mm in diameter and grades upward to about 0.04 mm in diameter at the top. The upward decrease in grain size is accompanied by an increase in the percentage of matrix. The upper few millimeters of the graded bed is virtually indistinguishable from the overlying chert or argillite bed, but in general the average grain size of the clasts in the chert and argillite tends to be smaller ($<0.02$ mm in diameter) than that of the uppermost parts of the graded beds. The decrease in grain size is also accompanied by an increase in quartz grains and a decrease in rock fragments.

Figure 7*A* shows the relative amounts of the chief grain types; in this diagram the white dots represent specimens of graywacke of type 1 studied in thin section. The amount of feldspar (chiefly plagioclase) and unstable rock fragments (chiefly volcanic rocks, argillite, and limestone) greatly predominates over chert and quartz.

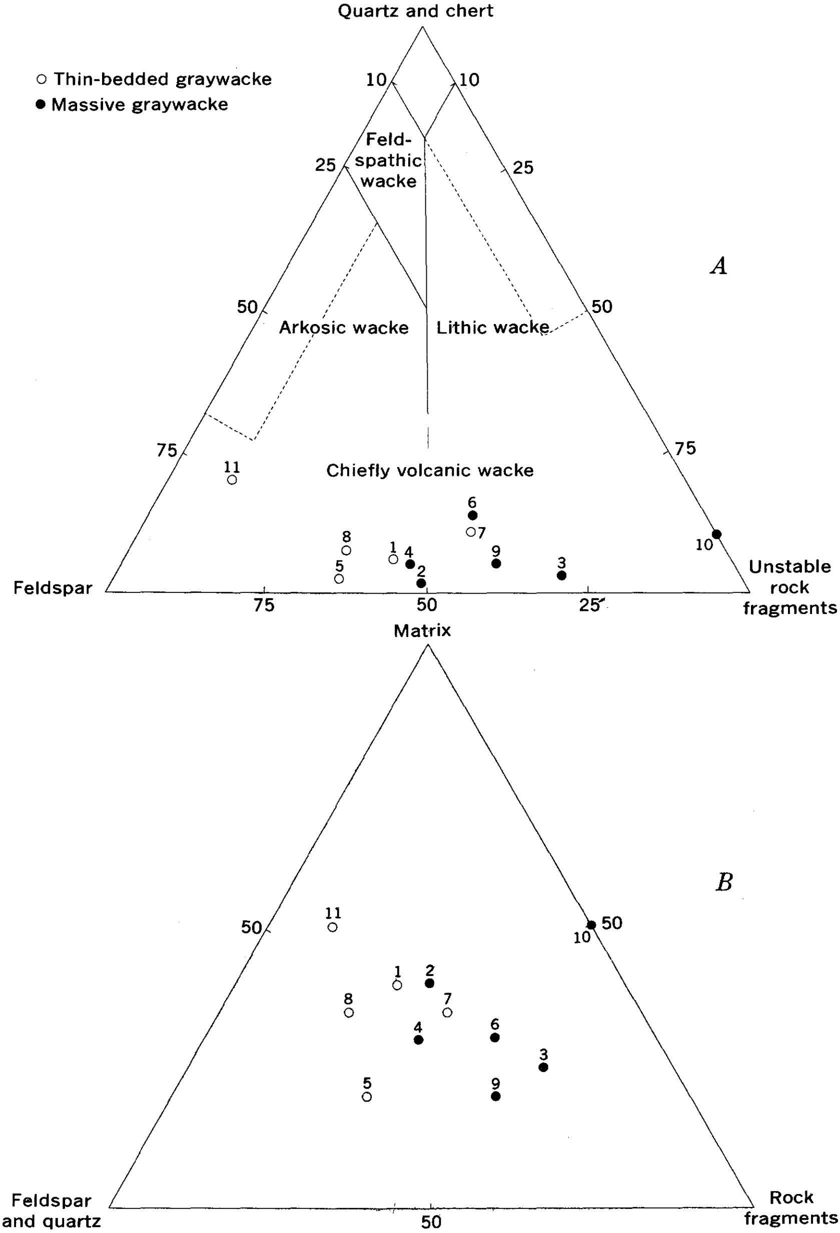



FIGURE 7.—Triangular diagrams showing composition of graywacke of Cannery Formation. *A*, Composition of clasts; *B*, composition of total rock.

Specimen 11 represents a thin section cut near the top of a graded bed; the grain size averages about 0.04 mm in diameter. The composition of the constituent grains in specimen 11 illustrates the relative increase in quartz and the relative decrease in rock fragments as grain size decreases. The overprinting in the diagram is taken from Williams and others (1954, fig. 96), and shows that this graywacke lies in the field of volcanic wacke.

The massive graywacke of type 2 is generally medium gray or medium dark green on a fresh surface, and weathers to a yellowish brown or brownish olive gray surface which is generally smooth but contains scattered pits a few millimeters in diameter. Individual grains are difficult to see on the weathered surface, and the general aspect is that of a weathered basic volcanic flow. The pits represent the casts of calcite fragments, largely fossil debris, that have been partially removed by weathering.

Although the beds of graywacke of type 2 are generally homogeneous, in a few places they contain lenses of black chert pebbles and recrystallized calcarenite.

The graywacke of type 2 differs from that of type 1 chiefly in the greater abundance of limestone rock fragments among the grains and in a greater proportion of calcite in the matrix. In other respects the compositions and textures of the two types are similar. Figure 7*A* shows the principal grain constituents of the graywacke of type 2 as black dots. This diagram shows the tendency for the graywacke of type 2 to contain a greater proportion of unstable rock fragments (white dots) than those of type 1, although the fields of the dots of the two types overlap slightly. At least half of the unstable rock fragments of type 2 are limestone. The matrix forms from 20 to 50 percent of the massive graywacke; figure 7 shows that this range is the same as that of the thin-bedded graywacke.

Plagioclase is the most common detrital mineral in either type of graywacke; it ranges from 0 (in one specimen) to 50 percent of the total rock, and averages about 35 percent. The plagioclase grains are generally partially altered to sericite; calcite, chlorite, and epidote are also common but less abundant alteration products. The degree of alteration varies considerably, even within a single thin section, from fresh, clear plagioclase grains having only a few small patches of sericite to grains completely sericitized.

The compositions of the detrital plagioclase grains fall into two groups: $An_{43}$ to $An_{53}$ and $An_1$ to $An_8$. Both groups are polysynthetically twinned and cannot always be distinguished from one another by their appearance. However, all determinations in the range $An_1$ to $An_8$ were from cloudy sericitized grains, whereas the grains having compositions from $An_{43}$ to $An_{53}$ range from clear to cloudy and sericitized. In most thin sections all plagioclase grains examined belong to one group or the other, but in a few sections both groups were represented.

In addition to detrital plagioclase, authigenic albite occurs as small crystals in the matrix, as rims on calcic plagioclase grains, and in veins. In these occurrences the albite is water clear and rarely twinned. In veins the albite is commonly associated with quartz, calcite, and, in a few thin sections, with analcime.

Quartz is a minor constituent, forming less than 8.0 percent of the detrital grains. Its proportion of the clastic grains increases in the siltstone and argillites, but because the amount of matrix also increases in these rocks, it is doubtful whether there is a real increase in the amount of quartz. Quartz also commonly occurs as microgranular aggregates in the matrix and in veins.

Analcime occurs in a few thin sections as veins and small aggregates scattered in the matrix; it occurs as euhedral inclusions in quartz and also as euhedral drusy linings of cavities the central part of which has been filled by anhedral quartz.

Calcite or limestone clasts are rare in the graywacke of type 1, but in the massive graywacke of type 2 they may form as much as 45 percent of the total rock. The grains are commonly rounded and have rather indistinct margins and irregular outlines; they are generally larger than the average grain size of the rock in which they occur, being as large as 5 mm in diameter in some samples. The grains themselves are coarse aggregates of murky, slightly twinned calcite that commonly show vague fossil structures.

Secondary calcite occurs in isolated patches and as veins in the matrix of both types of graywacke, but it is abundant only in the massive graywacke of type 2, where it may form as much as 25 percent of the total rock. In almost every occurrence calcite appears to replace the other rock constituents in contact with it.

Chlorite is an important constituent of the matrix and also of many of the detrital rock fragments. Generally it occurs in the matrix as irregular aggregates of various sizes ranging from less than 0.005 to 0.5 mm in diameter; the larger aggregates probably represent detrital grains replaced by chlorite. The chlorite aggregates themselves are equigranular and composed either of nonpleochroic or of slightly pleochroic pale yellowish-green chlorite having a first-order gray birefringence. In only one section was the chlorite intensely pleochroic, X=green to Z=yellow green.

Detrital rock fragments, other than limestone, are of three general types: volcanic rocks, argillite, and chert. The volcanic fragments consist of plagioclase microlites in a chloritic groundmass. The plagioclase in these volcanic rocks appears to have the same composition as the individual plagioclase clasts, but because of their small size, determinations were difficult to make and in general unreliable. Argillite fragments, which also include scarce, fine-grained graywacke, consist generally of a cloudy dark-brown chloritic and sericitic matrix which also contains a variable amount of microgranular quartz. Plagioclase clasts are scattered through the matrix. Chert fragments range from microgranular quartz aggregates to mixtures of chlorite and microgranular quartz, and appear to grade into argillite. The separation of chert from argillite in order to prepare the diagram of figure 7*A* was difficult and arbitrary; however, because at most, less than 5 percent of the grains are chert, it has small effect on the total composition and classification.

### ALTERED VOLCANIC ROCKS

Altered volcanic flows and breccias are minor rock types in the Cannery Formation, but locally, in the area east of Snug Cove at Gambier Bay, they form units as much as several hundred feet thick. These rocks are medium gray to greenish gray and fine grained or aphanitic; they commonly contain scattered calcite amygdales 1.0 to 5.0 mm in diameter. Slightly sheared pillow structure is common; the pillows average about 1 foot in longest dimension. In one locality the same rock type resembles a sheared breccia and contains a few scattered boulders of dark-gray, finely crystalline limestone 1.0 to 3.0 feet in diameter.

Most thin sections examined display pilotaxitic textures that consist of altered plagioclase laths averaging 0.09 mm in length in a groundmass of chlorite, calcite, pyrite, and limonite. The plagioclase laths are altered to sericite and calcite. One section contained about 10 percent colorless clinopyroxene in subhedral crystals, averaging 0.1 mm in diameter, scattered throughout the rock. Quartz, albite, and sphene are abundant in the groundmass of a few sections.

At two localities, one in the area south of Snug Cove and the other in a creek west of Gambier Bay, altered volcanic rocks contain 40 percent slightly granulated colorless clinopyroxene crystals about 0.5 mm in diameter ($2V_z = 50°–55°$), 50 percent antigorite serpentine, and 10 percent interstitial secondary quartz and albite. These rocks are olive gray and massive and usually break with a lustrous, serpentinuous surface. The high percentage of pyroxene suggests an altered ultramafic igneous rock such as pyroxenite or peridotite. Although much less deformed and containing serpentine instead of chlorite, tremolite, and epidote, this rock resembles the pyroxene-bearing phyllonites of the Gambier Bay Formation. Perhaps both rocks represent the same series of ultramafic intrusions, those in the Gambier Bay Formation (p. 16) having been subjected to greater deformation and metamorphism because of deeper burial.

## PYBUS DOLOMITE

### STRATIGRAPHY

The name Pybus Dolomite is here proposed for light brownish-gray fossiliferous cherty dolomite that crops out prominently at several places along the shores of its type locality, Pybus Bay. The best sections of this formation are on the peninsula about 1.2 miles west of Long Island on the southwest shore of Pybus Bay, at several localities along the northeast shore of the main arm of the bay, and in the vicinity of False Point Pybus.

The contact with the Cannery Formation is poorly exposed (p. 28), and its character is uncertain. Strikes of bedding in the Cannery Formation commonly diverge widely from those of the Pybus Dolomite, even within a few feet of the contact. Differences in the style of folding between thin-bedded argillite and chert of the Cannery Formation and the medium- to thick-bedded Pybus Dolomite may produce these divergences. Some of the divergences could also be caused by faulting; the contact commonly lies along fault zones, as on the peninsula between the two arms of Pybus Bay.

In contrast, the contact with the overlying Hyd Formation of Triassic age is well exposed in several localities. The Hyd Formation contains a basal breccia from 25 to 30 feet thick and composed largely of detritus from the Pybus Dolomite, and it lies upon an erosion surface cut into the Pybus Dolomite. The relief of this contact surface in any one outcrop is not more than a few feet. The beds above and below the contact are roughly parallel in most outcrops, but bedding in the basal breccia is ill defined, and accurate comparison is difficult. Near the head of the main arm of Pybus Bay, a limestone member of the Hyd Formation above the basal breccia is slightly discordant with respect to the Pybus Dolomite.

The Pybus Dolomite is about 1,000 feet thick near False Point Pybus, and this seems to be the maximum for the area. More precise measurement is not justified because of numerous strike faults that repeat small folded sections of the dolomite, commonly along with small slivers of the Hyd Formation. From False Point Pybus northward along strike the thickness gradually decreases and becomes zero immediately south of Church Point. A similar wedging out occurs north of the north arm of Pybus Bay, but poor outcrops and structural complexity prevent the accurate location of the zero isopach.

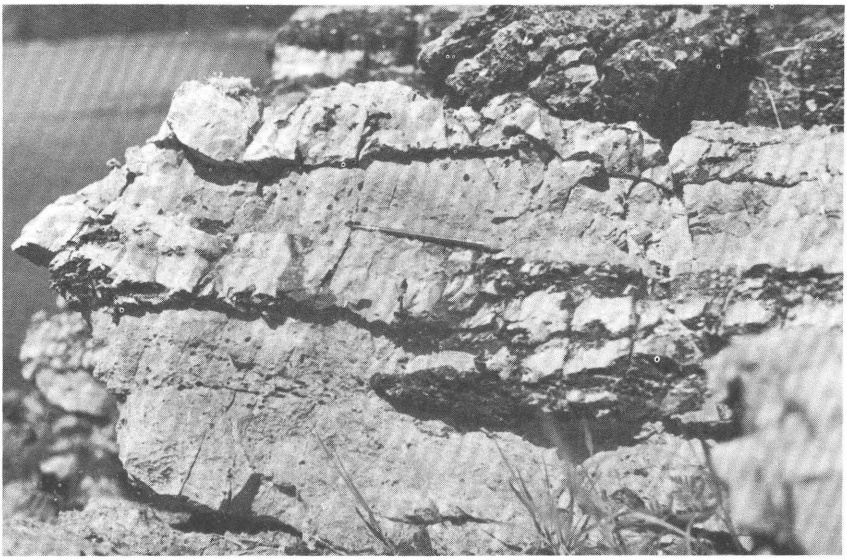
In general the zero isopach of the Pybus Dolomite probably trends irregularly southward from the vicinity of Church Point to a point somewhere west of False Point Pybus, and thence northwestward to the northwestern limit of the dolomite west of Snug Cove. North of this line the Hyd Formation lies directly upon the Cannery Formation. The Pybus dolomite has not been reported from the belt of Permian rocks that extends along the eastern side of Admiralty Island from a few miles north of Gambier Bay to the shores of Young Bay on the north coast (Lathram and others, 1960). These authors report a white bedded chert at Windfall Harbor, which lies in this belt about 40 miles northwest of Gambier Bay, but I found neither fossils nor interbeds of dolomite in this chert.

The erosion surface between the Pybus Dolomite and the Hyd Formation suggests that the disappearance of the dolomite results from truncation by erosion. However, the abrupt disappearance of dolomite fragments of the Pybus in the basal breccia of the Hyd Formation, when passing beyond the areal extent of the Pybus Dolomite, suggests that sedimentary thinning in about the same direction may also be a factor. West of Elliot Island near the south border of the area, the basal breccia of the Hyd lies in fault contact with the Cannery Formation, and the Pybus Dolomite appears to be faulted out. Here, however, the basal breccia contains only fragments of chert and argillite derived from the Cannery Formation, which fact suggests removal of the dolomite by erosion or nondeposition rather than by faulting. If this assumption is correct, the zero isopach of the Pybus Dolomite also passes through the mouth of Pybus Bay.

The Pybus Dolomite ranges from dark gray to pale yellowish brown and weathers to a finely pitted surface. The color of the weathered surface does not differ appreciably from that of the fresh rock. The texture is generally equigranular and sugary ranging from fine to medium grained. Beds average about 1 foot in thickness but range from 1 inch to 10 feet.

Mottled white and pale grayish-blue translucent chert commonly occurs as lenses and fragments in the dolomite (fig. 8*A*). In a few places, the top few feet of the formation are composed of continuous chert beds ranging in thickness from 6 to 12 inches (fig. 8*B*). Both chert lenses and chert fragments contain well-preserved silicified fossils (fig. 9). Other fossils, not preserved in the chert, have been nearly destroyed by dolomitization.

The lithology of the Pybus Dolomite is represented by the following two incomplete sections, both of which represent the upper part



*A*

*B*

FIGURE 8.—*A*, Pybus Dolomite at Pybus Bay showing transition of porous, rough-weathering chert into massive chert within a single bed. *B*, Bedded chert forming uppermost unit of Pybus Dolomite at False Point Pybus.

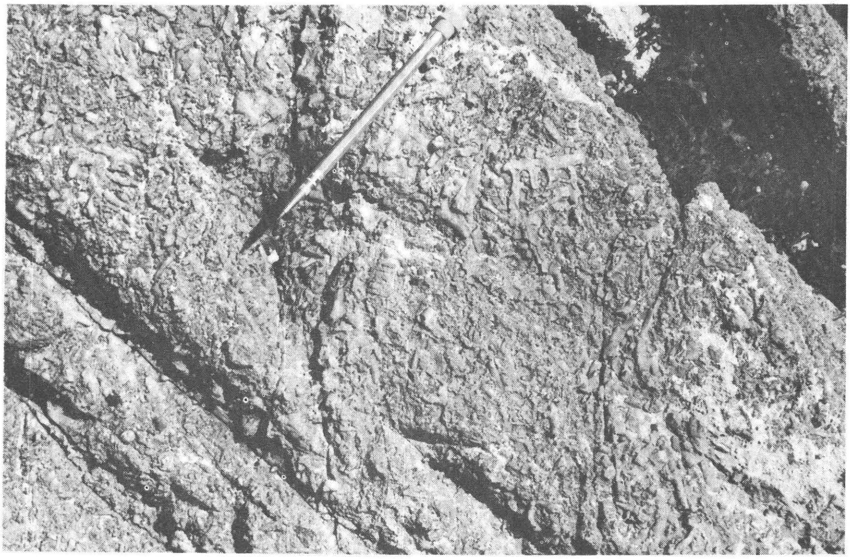


FIGURE 9.—Detail of bedding surface of porous chert in Pybus Dolomite at Pybus Bay showing silicified fossils.

of the formation. In one, the uppermost unit is bedded chert and minor dolomite, and in the other the uppermost unit is the more normal cherty dolomite. These lithologic types are the two chief variants of the uppermost unit.

I. *Section measured on small island along northeast shore of the main arm of Pybus Bay 3 miles northwest of triangulation station Dro*

| | Thickness (feet) |
|---|---|
| Hyd Formation; basal breccia. | |
| Disconformity. | |
| Pybus Dolomite: | |
| Chert and dolomite, interbedded; chert, mottled white and pale grayish-blue, in beds 6–12 in. thick; 75 percent chert | 7 |
| Dolomite, mottled dark gray and light brownish-gray, becoming pale yellowish-brown toward base; sugary; in beds 1 in. to 2 ft thick; contains pale grayish-blue chert in irregular rough-weathering lenses 1–6 in. thick that include abundant silicified brachiopods, bryozoans, and crinoid debris, and scattered smooth-weathering chert fragments; chert lenses are closely spaced in some layers and widely spaced in others; 75 percent dolomite | 340 |
| Dolomite, light brownish-gray, fine- to medium-sugary, in 1- to 4-ft beds; contains sparsely scattered white and light bluish-gray mottled chert fragments and a few chert lenses composed of silicified fossils; 90 percent dolomite | 90 |
| Covered. | |
| Total | 437 |

II. *Section measured on northeast shore of main arm of Pybus Bay 2½ miles N. 10° W. from triangulation station Dro*

| | Thickness (feet) |
|---|---|
| Hyd Formation; basal breccia. | |
| Slight angular unconformity. | |
| Pybus Dolomite: | |
| Dolomite, light brownish-gray, fine sugary; in 6-in. to 2-ft thick beds; contains light bluish-gray chert lenses weathering dark gray and yellowish-gray, consisting of silicified brachiopods, bryozoa, and crinoid debris; chert lenses irregular, rough weathering, 1 in. to 1 ft thick; 85 percent dolomite | 10 |
| Dolomite, light-gray to light brownish-gray; weathers yellowish brown; sugary in beds 5–10 ft thick; contains bluish-white smooth-weathering, sparsely fossiliferous chert lenses 1–3 in. thick | 25 |
| Covered | 50 |
| Dolomite, light grayish-brown, fine sugary; in 2- to 6-in. beds; unit includes both smooth- and rough-weathering fossiliferous chert lenses 1–2 in. thick; silicified brachiopods, bryozoa, crinoid debris | 80 |
| Dolomite, light grayish-brown, fine sugary; in beds 1 in. to 2 ft thick; contains slightly nodular pale-blue yellowish-gray weathering chert beds 1–6 in. thick; layers of close-spaced chert lenses alternate with layers of wide-spaced lenses; bedding gently undulatory; 85 percent dolomite | 50 |
| Covered. | |
| Total | 215 |

A minor rock type not represented in the above sections, but useful as a marker high in the formation along the northeast shore of Pybus Bay, is medium-gray clastic dolomite occurring in beds ranging in thickness from 1 to 3 feet. This rock consists of tightly packed layers of partially silicified brachiopods and other fossils embedded in a dolomite matrix; the brachiopods average less than 1 inch in diameter, considerably less on the average than those of the typical Pybus Dolomite. The dolomite weathers to a distinctive rough reddish-brown surface.

Two collections of fossils from the Pybus Dolomite, including several genera of brachiopods such as *Stenoscisma*, *Neospirifer*, *Spiriferella* and *Anidanthus*, have been identified as Permian by J. Thomas Dutro, Jr., (written communication, 1960; see "Fossil lists and localities, p. 95, this paper). Burchard (1920, p. 55) made a fossil collection from the Pybus Dolomite on the peninsula west of Long Island in Pybus Bay that was identified by G. H. Girty as being of Artinskian (Early Permian) age. In view of this evidence, the age of the Pybus Dolomite is considered to be Permian.

South of the Pybus-Gambier area on Admiralty Island, the Pybus Dolomite crops out in a single locality on the north shore of Herring Bay (Lathram and others, 1960), where it appears to be similar to

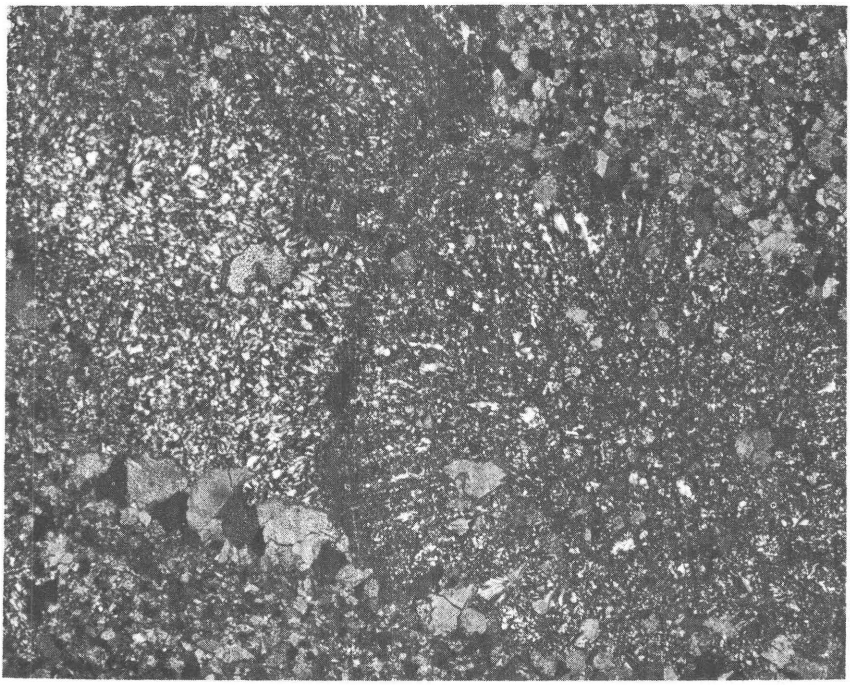


FIGURE 10.—Photomicrograph of fossil preserved or spherulitic chalcedony in granular dolomite that shows imperfect rhombic crystal outlines (crossed nicols, $\times 20$).

that at Pybus Bay. Cherty dolomites or limestones of Permian age also crop out in the vicinity of northern Kuiu Island, south of Admiralty Island. F. E. and C. W. Wright (1908, p. 54–55) report beds "of white cherty limestone 450 feet or more in thickness" at Halleck Harbor on Kuiu Island. Buddington and Chapin (1929, p. 127–129) placed these beds in their "upper division of the Permian," of which the Pybus Dolomite is also a member. Similar white cherty limestone of Permian age has been reported from the Keku Islets, Kupreanof Island near Kake, and from Suemez Island (Buddington and Chapin, 1929, p. 129–130).

## PETROGRAPHY

### DOLOMITE

Dolomite is the predominant carbonate mineral in the Pybus Dolomite. Staining by cupric nitrate ($Cu(NO_3)_2$) solution (Rodgers, 1940) showed that calcite is present only as veinlets and cavity fillings. The dolomite consists of a mosaic of subhedral dolomite crystals showing a tendency to form imperfect rhombs averaging about 0.2 mm in length (fig. 10). The crystals are cloudy because of the inclusion of very fine brown dust—probably iron-rich. Pores rang-

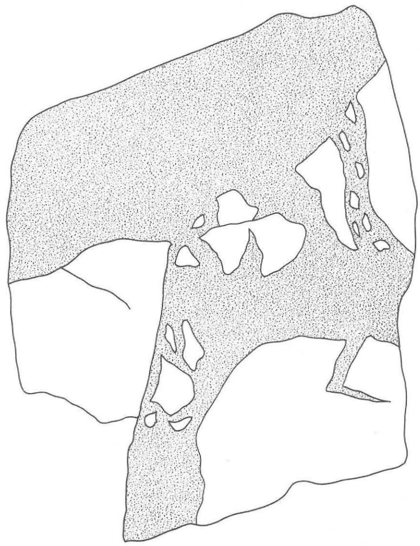


FIGURE 11.—Sketch of fractured chert (white) in dolomite (stippled) ; natural size.

ing from 0.1 mm to 0.9 mm in diameter are scattered through the dolomite mosaic; these are commonly represented by fillings of clear calcite and, in places, by quartz. Partially filled pores having drusy linings of calcite occur less commonly. The pores typically contain a thin opaque film between the filling mineral and the walls.

In general, the dolomite is equigranular, but patches of coarser and finer crystals occur that have the vague form of fossil structures. Detrital grains of rounded quartz, chert, and argillite are minor constituents of a few thin sections.

### CHERT

The chert occurs both as beds or lenses and as scattered fragments. In both forms it has two aspects which can be seen within a single lens or fragment: (1) porous, rough-weathering masses consisting of silicified fossils (largely brachiopod, bryozoan, and crinoid debris) (fig. 9); (2) solid smooth-weathering masses (fig. 8*B*). Type 1 grades into type 2 by the filling of the pore spaces between the fossils with chert (fig. 8*A*).

The chert lenses are commonly broken, but the fragments usually have not moved far. Dolomite has invaded the fractures and spaces between the fragments (fig. 11).

The chert consists of small masses (averaging about 0.004 mm in diameter) of spherulitic quartz (chalcedony). Dolomite rhombs are scattered irregularly through the chert, and small patches of quartz occur in the surrounding dolomite in the vicinity of the chert-dolomite contact. Fossil structures are outlined by streaks and patches of coarser or finer grained quartz masses (fig. 10).

One thin section examined was divided into two approximately equal parts parallel to the bedding: in one part the fossils were well preserved as chert, and in the other they were only faintly preserved as dolomite. Fossils, therefore, occur throughout the rock, but their superior state of preservation and hardness as chert makes silicified fossils much more prominent. Probably the enclosing and replacing of fossils by chert prevented them from being dolomitized and led to their better preservation.

## TRIASSIC SYSTEM

### HYD FORMATION

#### STRATIGRAPHY

The name Hyd Formation is here proposed for the dark-colored argillite, chert, graywacke, limestone, and altered volcanic rocks that crop out in a relatively thin discontinuous belt extending from the north shore of Gambier Bay to the southwest shore of Pybus Bay. The formation is named for the triangulation station Hyd on the northeast shore of Pybus Bay; the southeast shore of the peninsula at this triangulation station is the type locality of the argillite member of the formation.

The formation comprises four distinct members. These are listed below in ascending stratigraphic order except for the volcanic member, which intertongues with the other three.

1. The basal breccia, which consists mainly of chert fragments derived from the underlying Permian strata. The breccia occurs in two phases: a white chert phase and a green and red chert phase. The white phase is composed of white chert and dolomite debris derived from the Pybus Dolomite and attains a maximum thickness of 30 feet at its type locality at False Point Pybus. The contact relations with the overlying limestone member are variable. In places this contact is sharp and irregular and appears to be an erosional surface, whereas elsewhere the breccia grades upward by an increase in carbonate matrix into the overlying limestone. The distribution of the white chert phase is identical to that of the Pybus Dolomite upon which it rests. The green and red chert phase of the basal breccia is composed of bedded chert fragments derived from the Cannery Formation. This phase occurs wherever the Pybus Dolomite is absent and the Hyd Formation rests directly upon the Cannery Formation. It is typically exposed on the island north of Gain Island in Gambier Bay,

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where it attains a maximum thickness of 350 feet. In general the basal breccia in one phase or the other occurs throughout the outcrop belt of the Hyd Formation.

2. The limestone member, which is composed of two types of dark-brown medium-bedded limestone that do not crop out together. The more widely distributed of the two types weathers light gray and is very sparsely fossiliferous; it is typically exposed in the beach about 1 mile north of False Point Pybus. The other type weathers brown and is generally fossiliferous; it is known only from the sea cliffs near False Point Pybus. The limestone member attains a maximum thickness of more than 500 feet near False Point Pybus, and is absent in southern Pybus Bay, where the argillite member rests directly upon the basal breccia. In general the limestone has a variable thickness and spotty distribution throughout the outcrop belt of the Hyd Formation.
3. The argillite member, which consists of thinly interbedded dark-gray to black argillite, chert, limestone, and graywacke. This member attains a thickness of more than 280 feet in the tidal outcrops west of Elliott Island in southern Pybus Bay. These outcrops together with those on the southeastern shore of the peninsula at triangulation station Hyd in Pybus Bay are typical exposures of the member. The argillite member is very widely distributed throughout the belt of outcrops of the Hyd Formation.
4. The volcanic member, which consists chiefly of altered spilitic volcanic flows in which pillow structure is commonly well developed. This member attains a maximum thickness of 500 feet at the type locality on the peninsula northwest of Good Island in Gambier Bay. The volcanic rocks become an increasingly prominent part of the formation to the north. Their southernmost outcrops are at the head of Pybus Bay and on Gain Island in Gambier Bay; north of Gambier Bay they predominate over the associated sedimentary strata.

Volcanic rocks seem to occur at several stratigraphic levels in the Hyd Formation. At the head of Pybus Bay, altered flows directly overlie the limestone member, and the argillite member is absent. At Gain Island, volcanic flows overlie the basal breccia and also are interbedded with units of the breccia. Pillow lava near the cove east of the triangulation station Kan on the north shore of Gambier Bay contains a thin unit of the limestone member in its lower part. On the peninsula northwest of Good Island, pillow lava lies within the upper part of the argillite member. The variable stratigraphic position of the volcanic rocks, together with their thickening to the north, suggests that the rocks of the Hyd Formation were laid down during an episode of contemporaneous volcanism and sedimentation and that the volcanic member is composed of tongues of volcanic rock extending southward into the sedimentary section at different levels from a center of volcanism north of Gambier Bay. (See Lathram and others, 1960, for areal extent of probable Triassic volcanic rocks north of the Pybus-Gambier area.)

No single section of the Hyd Formation could be found in which both the upper and lower contacts are exposed, hence no accurate thickness could be measured. A composite thickness of 1,310 feet is obtained by totalling the greatest measured thickness of the various members. The general width of outcrop indicates that this total thickness is approximately correct in most places, despite variation in the thickness of the individual members.

The Hyd Formation lies unconformably upon the Pybus Dolomite in some places and upon the Cannery Formation in others. Its lower contact is a disconformity or a slight angular unconformity and represents an interval of time extending from possible Early Permian to Late Triassic.

The overlying Seymour Canal Formation seems to be structurally conformable with the Hyd Formation, but paleontological evidence indicates that a hiatus extending from Upper Triassic to Upper Jurassic separates the two formations. The contact between them must be a disconformity, but it has not been certainly identified in the field because of the similarity of the argillite member, which commonly forms the uppermost strata of the Hyd Formation, to the argillite and graywacke of the overlying Seymour Canal Formation.

Both the argillite and the limestone members of the Hyd Formation have produced fossils indicative of a Late Triassic age, and the formation is considered to be this age. Ammonites (especially *Tropites*) are prominent in the assemblage collected from the limestone and are considered to be late Karnian (medial Late Triassic) in age, whereas the collections from the argillite are dominated by *Monotis subcircularis* Gabb, indicative of a middle or late Norian (late Late Triassic) age. The identification and age correlations of fossils were made by N. J. Silberling (written communication, 1959; see "Fossil lists and localities", p. 96).

Rocks of the Late Triassic age crop out almost continuously along the east side of Admiralty Island from Gambier Bay northward to the Mansfield Peninsula (Lathram and others, 1960; see also fig. 1 of this report). According to these authors, the dominant rocks in this belt are basic volcanic flows, commonly pillow lavas, and thin-bedded grayish-black chert, calcareous argillite, and limestone. Rocks comparable to the basal breccia and the limestone member have not been reported north of the Pybus-Gambier area.

In contrast, the volcanic member has not been reported from Admiralty Island south of the Pybus-Gambier area (Martin, 1926, p. 89–92; Lathram and others, 1960), and sedimentary members of the Hyd Formation have been observed in only two isolated outcrops south of Pybus Bay. The basal breccia, the limestone member, and the argillite member crop out in the Chapin and Herring Bays area (H. C. Berg, oral communication, 1960), and the argillite member containing conglomerate beds crops out near Carroll Island (E. H. Lathram, oral communication, 1960).

Elsewhere in southeastern Alaska, rocks of Late Triassic age crop out in the Juneau area, on Kupreanof Island near Hamilton Bay, and on the Keku Islets, Kuiu Island, Screen Island, and Gravina Island (Martin, 1926, p. 65–95). In addition, marble and schist on the west coast of Chichagof Island have been tentatively assigned to the Triassic, possibly Late Triassic, by Reed and Coats (1941, p. 29–30). The details of the stratigraphy of the Hyd Formation cannot be correlated with the Upper Triassic in other parts of southeastern Alaska on the basis of the published descriptions. These descriptions do indicate, however, that dark-hued limestone, chert, calcareous argillite, and conglomerate or breccia similar to those of the Hyd Formation are widespread sedimentary rock types in the Upper Triassic of this region.

Martin (1926, p. 81, 91–94) reported volcanic rocks, including pillow lavas, associated with sedimentary rocks of Karnian age in the Juneau area and of Norian age in the Keku Strait area. If these age correlations are valid, they substantiate the evidence in the Pybus-Gambier area that volcanic rocks occur at different stratigraphic levels and represent eruptions that were contemporaneous with the Late Triassic sedimentary deposition.

## PETROGRAPHY

### BASAL BRECCIA

The breccia member, at the base of the Hyd Formation, occurs in two phases: a white chert phase and a green and red chert phase. The white chert phase consists largely of a massive breccia composed of angular to subrounded fragments of mottled white and grayish-blue chert and a lesser amount of light-brown dolomite derived from the Pybus Dolomite, embedded in a dolomite or limestone matrix that generally makes up about 10 percent of the rock (fig. 12). The fragments range in length from less than 1.0 inch to 1.0 foot and average about 2.0 inches. Locally the breccia is distinctly bedded and shows a sorting of the fragments into coarser and finer layers; where this sorting occurs, the fragments are more rounded than in the more typical massive breccia.

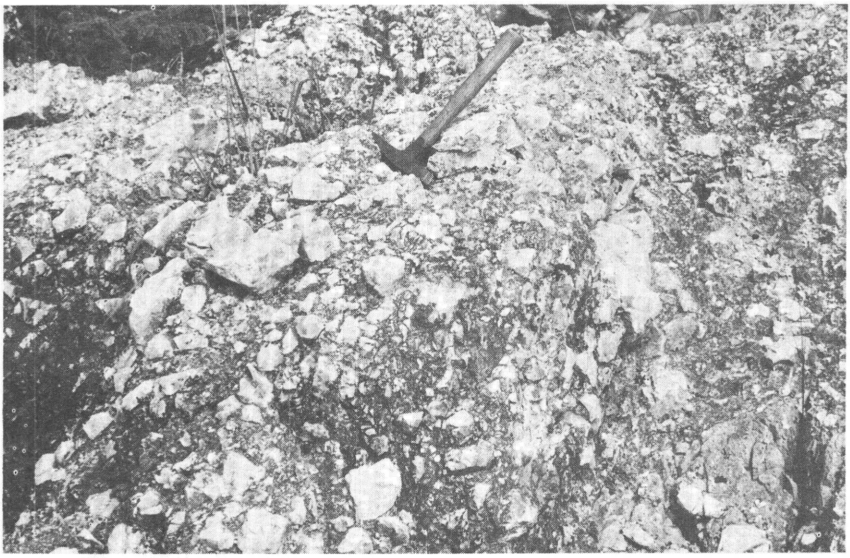


FIGURE 12.—Massive, white chert phase of the basal breccia of the Hyd Formation near the head of the main arm of Pybus Bay.

The green and red chert phase consists of a breccia composed chiefly of angular fragments of bedded chert and argillite derived from the Cannery Formation, embedded in a calcareous argillite matrix that forms generally less than 10 percent of the rock. The fragments range in size from coarse sand to small cobbles, commonly showing moderate hues of green, gray, red, and purple. In localities near the zero isopach of the Pybus Dolomite, such as Church Point, a few scattered fragments of white chert and dolomite characteristic of the Pybus Dolomite occur in the breccia. Near Church Point and Gain Island the chert and argillite fragments are recrystallized to a sugary texture and have taken on brighter hues of green and red; here the matrix is also recrystallized and consists of a yellowish-brown-weathering iron-rich dolomite. In this area the breccia is overlain and in places interbedded with volcanic flows of the Hyd Formation. Perhaps the heating of the pore fluids during the volcanic eruption caused the recrystallization and oxidation of the breccia.

Microscopically the chert and argillite fragments of the green and red chert breccia are identical to the chert and argillite of the Cannery Formation described in a previous section. The matrix consists most commonly of a cloudy mixture of microgranular quartz, plagioclase, sericite, and calcite or dolomite; silt-sized clasts of quartz and plagioclase are scattered through the matrix. Pyrite in small euhedra is a common minor constituent of these rocks. The yellowish-brown-weathering matrix found in the vicinity of Gain Island consists almost entirely of iron-rich dolomite, and the chert fragments there consist of a sutured mosaic of quartz containing abundant sericite inclusions.

### LIMESTONE MEMBER

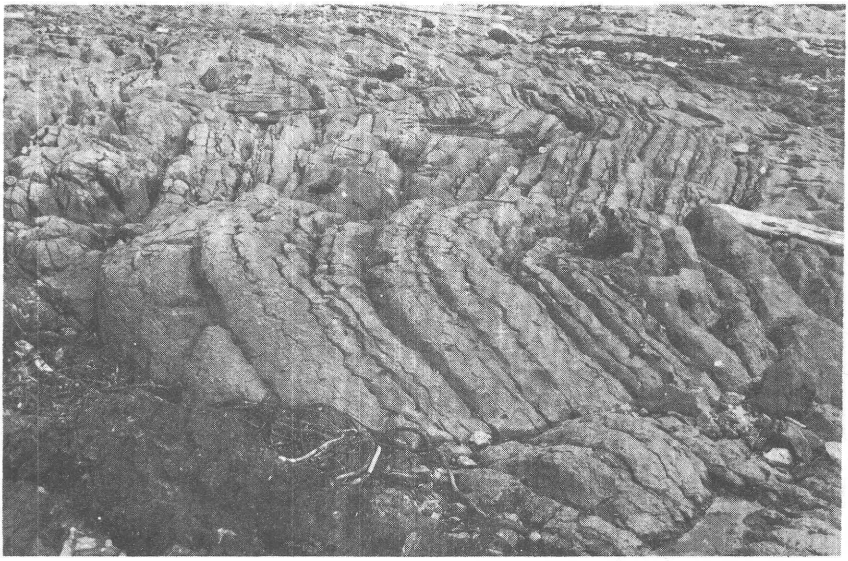
The limestone member consists of two types of limestone that do not crop out together. The more widespread light-gray-weathering limestone is medium dark brown to dark brown very sparsely fossiliferous, and very fine grained. It occurs in beds ranging in thickness from 0.5 to 10 feet and averaging about 2.0 feet, which are separated by dark-brown undulating stylolitic contacts (fig. 13*A*). The more areally restricted, fossiliferous limestone is medium dark gray, yellowish brown to reddish brown weathering, and fine grained (fig. 13*B*). In this limestone the bedding is indicated on the weathered surface by irregular resistant layers, averaging about 0.5 foot in thickness, alternating with nonresistant layers that form lenticular pits and troughs and give the outcrop a rough, pockmarked appearance.

### ARGILLITE MEMBER

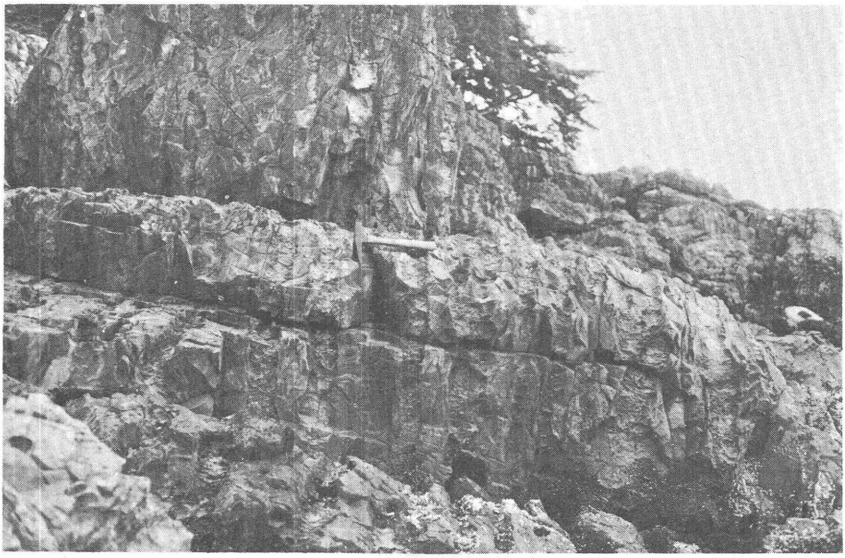
The argillite member consists of thinly interbedded, predominantly dark-gray argillite, chert, limestone, and graywacke (fig. 14*A*). The relative proportion of the four rock types is variable, but argillite is generally the most abundant and the most widespread. The beds range in thickness from 0.25 to 6.0 inches, and average about 1.0 inch. Siliceous and calcareous argillite occur in about equal amounts; both are homogeneous rocks and generally lack slaty cleavage. The siliceous argillite weathers to a minutely fractured, brownish-gray surface and grades into radiolarian chert having a conchoidal or sharply angular fracture. The calcareous argillite weathers to a slightly rough, brown surface.

The limestone is dark brown, light gray weathering, and very fine grained; it resembles closely the light gray-weathering phase of the limestone member. The graywacke is calcareous and very fine grained; it is commonly graded and crossbedded on a small scale.

In thin section the three most common rock types—argillite, chert, and graywacke—resemble one another in texture and appear to differ only in the size and relative amounts of the same components. All have a matrix consisting of a cloudy mixture of microgranular quartz, new-formed plagioclase (albite), calcite, chlorite, sericite, and pyrite; also present is a fine semiopaque dust which tends to form in tenuous layers delineating bedding surfaces. This dust is probably carbonaceous material and is responsible for the prevailing dark color of the rocks. Scattered through the matrix are angular clasts of plagio-



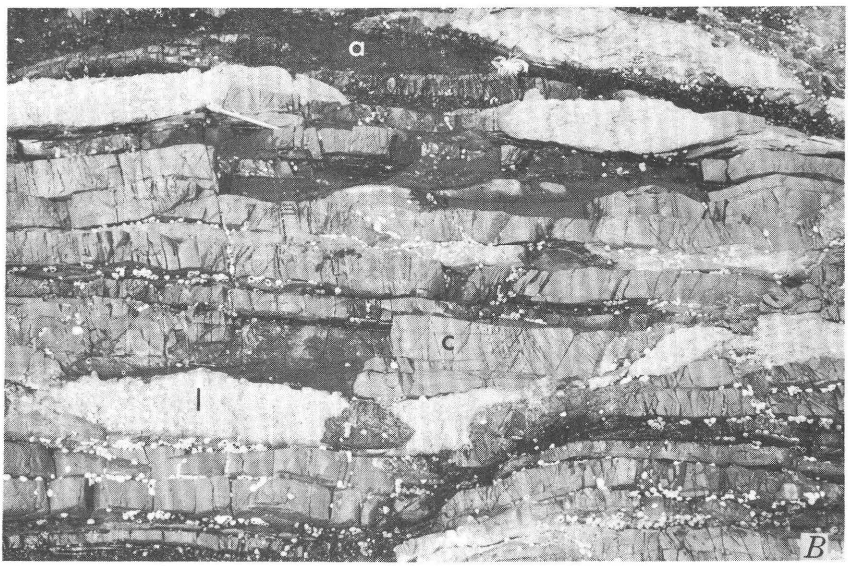
*A*



*B*

FIGURE 13.—*A*, light-gray-weathering limestone of the limestone member, Hyd Formation, near False Point Pybus. *B*, Fossiliferous, brown-weathering limestone of the limestone member, Hyd Formation, south of False Point Pybus.


*A*




*B*

FIGURE 14.—*A*, Steeply dipping strata of the argillite member of the Hyd Formation in tidal outcrop on southwest shore of Pybus Bay, west of Elliott Island; the strata lie unconformably beneath gently dipping Tertiary strata (composed of conglomerate and sandstone) at the line of trees; the gentle dip of the Tertiary strata (Admiralty Island Volcanics) is indicated by the topography and snow lines in the background. *B*, Detail of strata in figure 14*A*, chiefly argillite (a), chert (c), and limestone (l), showing boudinage structure in limestone.

clase and quartz, and more rounded clasts of calcite or limestone. The clasts are generally of coarse silt size except in the graywacke, where the bottom layer of a graded bed (commonly 1 grain thick) may attain a grain diameter of as much as 0.2 mm (fine sand).

In the calcareous rocks, abundant calcite occurs in the matrix as murky patches that have corroded plagioclase grains in contact with them. An extreme type, a calcarenite that occurs sparsely in a few localities, consists of 40 percent clasts, 35 percent of which are rounded calcite grains showing faint fossil structures, in a matrix consisting of a fine aggregate of calcite crystals. The calcite clasts average about 0.2 mm in diameter and are considerably larger than those in most graywacke.

In the chert and siliceous argillite, microgranular quartz predominates over the other constituents. In the purer chert, calcite sericite, and chlorite are minor. One such chert, which is prominent near the top of the member, consists of a very fine grained, almost submicroscopic mass of quartz through which are scattered flakes of sericite. Radiolarian tests, similar to those described from the Hood Bay and Cannery Formations, are scattered along the bedding surfaces of this rock. The tests are composed of spherulitic quartz and have circular or elliptical outlines averaging about 0.1 mm in diameter (fig. 15). The chert also contains very sparse, angular clasts of plagioclase and quartz ranging in diameter from 0.05 to 0.4 mm. The bedding planes in the chert are outlined by fine dark-brown dust that tends to form very thin laminae. The light-colored rock layers between the dark laminae pinch and swell; they range in thickness from 0.5 to 2.0 mm.

### VOLCANIC MEMBER

The volcanic member consists chiefly of greenish-gray altered spilitic volcanic flows commonly showing well-developed pillow structure (fig. 16). The flows weather to shades of yellowish green, grayish olive green, and grayish red, and are veined with white calcite. The pillows of the pillow lava range from 1 to 3 feet in diameter; they consist of a coarser crystalline core, with a border zone rich in amygdules, and an aphanitic rim. The amygdules are most commonly composed of calcite, chalcedony, and chlorite. The matrix between the pillows is a mixture of calcite and fine fragments of volcanic rock. Phenocrysts are not conspicuous in the pillow lava.

In composition the volcanic rocks fall into two groups that cannot be distinguished in the field: (1) a predominant sodium-rich type in which all plagioclase appears to be albite, (2) a much less abundant potassium-rich type in which all the feldspar appears to be potassic.

The first type agrees with published descriptions of spilites (Turner and Verhoogen, 1960, p. 258–263; de Roever, 1942, p. 223–233); rocks of

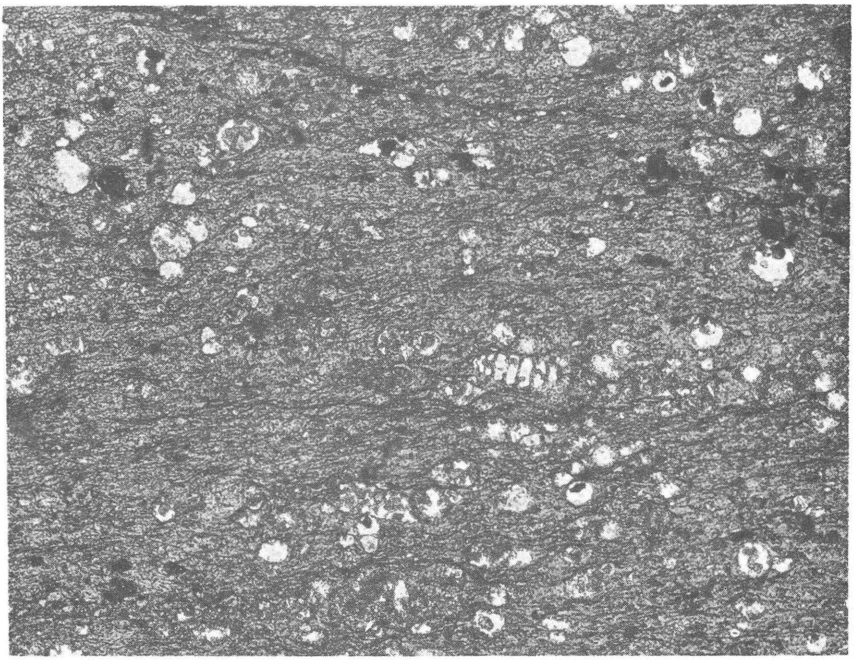


FIGURE 15.—Photomicrograph of radiolarian chert, Hyd Formation; Radiolaria tests consist of spherulitic quartz, in a matrix of argillaceous material and microcrystalline quartz (plain light, ×45).

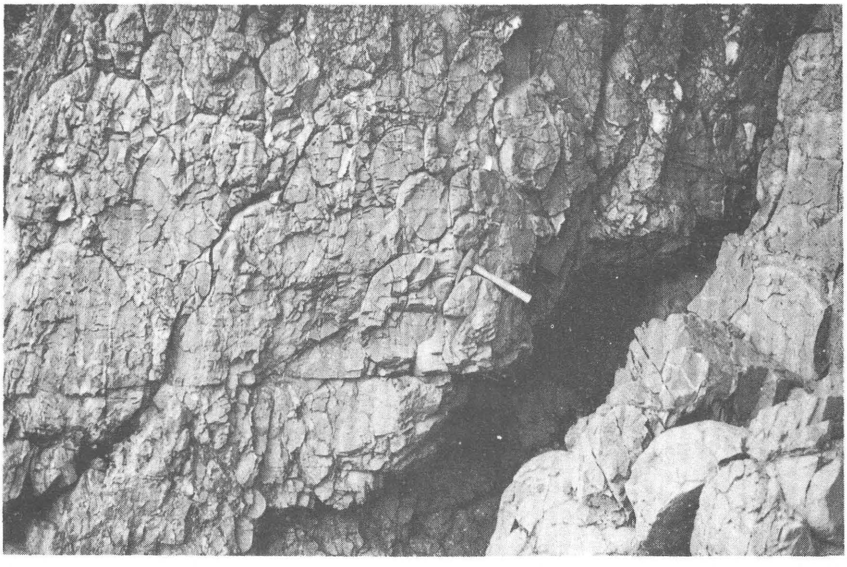


FIGURE 16.—Subvertically dipping pillow lava in Hyd Formation, near Good Island, Gambier Bay; top is to the left.

this type include both pillow and nonpillow structural types. Microscopically these rocks have an altered intergranular texture consisting of a cloudy, indistinct groundmass of albite, chlorite, epidote, calcite, and opaque minerals. The groundmass albite, which averages about 50 percent of the rock, occurs as an irregular, interconnecting mass containing abundant fine inclusions of chlorite, sericite, and calcite. Sparse small fresh, finely twinned albite laths, averaging about 0.18 mm in length, are also scattered throughout the groundmass. Chlorite, occuring as inclusions in albite, is the next most abundant constituent, and averages about 20 percent of the rock. In addition, the chlorite occurs throughout the groundmass as interstitial flakes, and also as larger aggregates whose forms suggest pyroxene and amphibole crystal outlines. Most of the chlorite is slightly pleochroic from Z=yellowish green to X and Y=pale green, and shows a low first order birefringence. However, the chlorite of one section displays more intense pleochroic colors from Z=bluish green to X and Y=green, and a first-order yellow birefringence.

Sparse plagioclase phenocrysts, averaging about 1.5 in length, are scattered throughout most specimens. The phenocrysts show polysynthetic twinning, and are strongly altered to chlorite, calcite, and sericite. Commonly only ragged remnants of the original phenocrysts remain; the alteration tends to be controlled by cleavage planes. The composition of both the small crystals of the groundmass and the phenocrysts ranges from $An_3$ to $An_7$. The absence of potassic feldspar was indicated by sodium cobaltinitrite stain test.

Volcanic rocks of the potassium-rich second type are known only from one locality: the peninsula northwest of Good Island, where about 500 feet of pillow lava crops out in the hinge of a tightly folded anticline. Microscopically the potassium-rich rock is composed of sparse subhedral potassic feldspar phenocrysts and an altered pilotaxtic groundmass consisting of thin potassic feldspar laths and interstitial chlorite, calcite, and opaque minerals (fig. 17). The groundmass feldspar averages about 0.1 mm in length and commonly displays simple twinning; the margins of the laths are indistinct and contain chlorite and calcite inclusions. Calcite also occurs as clear patches ranging from 0.04 to 5.0 mm in diameter, most of which probably represent amygdales. The opaque minerals are largely limonite and are especially abundant as fine dust in the larger chlorite patches, whose outlines suggest pyroxene and amphibole crystal forms.

The potassic feldspar phenocrysts are subhedral with a tendency toward irregular indistinct borders. Both untwinned and simply twinned types are present; in general, the birefringence is a first-order gray, noticeably lower than that for plagioclase. The pheno-

FIGURE 17.—Photomicrograph of poeneitic pillow lava, Hyd Formation; cluster of simply twinned potassic feldspar phenocrysts in groundmass of potassic feldspar microlites, chlorite, calcite, and opaque minerals; patch of calcite at right margin is an amygdule (crossed nicols, $\times 40$).

crysts contain abundant chlorite inclusions but appear to be unaltered in other respects. Sodium cobaltinitrite stain showed both phenocrysts and groundmass feldpar to be potassic. Universal stage measurements indicate that the feldspar is monoclinic with the optic plane perpendicular to (010); a few rather poor measurements indicate that $2V_x$ is about 60°. The value of the optic axial angle and the orientation of the optic plane place these feldspars in the orthoclase cryptoperthite series of Tuttle (1952, p. 557–558). Ragged feldspar crystals suggestive of altered remnants of original calcic plagioclase, such as are present in the spilitic rocks, are lacking from the potassic rock. In the latter, no textures were seen which might be interpreted as indicating replacement of an original feldspar by potassic feldspar.

A chemical analysis of the potassic rock showed it to contain 5.4 percent $K_2O$ and 1.9 percent $Na_2O$ in contrast to 0.75 percent $K_2O$ and 4.93 percent $Na_2O$ for the average spilite (Sundius, 1930, p. 9). de Roever (1942, p. 223–224) reported potassic equivalents of spilites, which he calls poeneites after Brouwer (1940, p. 263), associated with spilites and keratophyres, from the Permian of Timor. Table 2

TABLE 2.—*Chemical analyses of spilites and poeneites*

| Constituent | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 44.6 | 52.05 | 51.22 |
| $Al_2O_3$ | 17.1 | 18.35 | 13.66 |
| $Fe_2O_3$ | 1.6 | 10.07 | 2.84 |
| FeO | 8.5 | .40 | 9.20 |
| MnO | .1 | .16 | .25 |
| Mgo | 5.1 | .91 | 4.55 |
| CaO | 4.5 | 1.96 | 6.89 |
| $Na_2O$ | 1.9 | 1.39 | 4.93 |
| $K_2O$ | 5.4 | 8.97 | .75 |
| $H_2O$ | 5.3 | 2.88 | 1.88 |
| $TiO_2$ | 1.8 | 2.24 | 3.32 |
| $P_2O_5$ | .6 | .94 | .29 |
| $CO_2$ | 3.2 | None | .94 |
| Rest | ---------- | .11 | ---------- |
| Total | 100 | 100.43 | 100.72 |

1. Pillow lava, Gambier Bay, Admiralty Island, Alaska; rapid rock analysis by L. D. Elmore, H. Barlow, S. D. Botts, G. Chloe, U.S. Geol. Survey.
2. Poeneite, Noil Tobe, Timor (de Roever, 1942, p. 237–238).
3. Average spilite, average of 19 analyses (Sundius, 1930, p. 9).

shows a comparison of chemical analyses of a typical poeneite, an average spilite, and the pillow lava. De Roever found all transitions between spilites and poeneites and suggested intermediate rock names such as spilitic poeneite and poeneitic spilite. Most of the poeneites described by de Roever contain more than 8.0 percent $K_2O$, and hence the present rock might be called spilitic poeneite in his classification.

## JURASSIC AND CRETACEOUS SYSTEMS

### SEYMOUR CANAL FORMATION

#### STRATIGRAPHY

The name Seymour Canal Formation is here proposed for the thick sequence of argillite, graywacke, and conglomerate exposed at its type locality, the mouth of Seymour Canal in the northeast part of the Pybus-Gambier area (fig. 1). Typical sections are also exposed along the northern and northwestern shore of Pybus Bay and in the islands near the mouth of the bay. In general, rocks of the Seymour Canal Formation form the eastern and southeastern border of the Pybus-Gambier area. They crop out in a broad belt which bends sinuously through Pybus Bay from Elliott Island northeastward to Point Pybus, and thence beneath the water of Stephens Passage. They reappear in eastern Gambier Bay, where they form a nearly rectilinear belt of outcrops trending north-northwest and extending almost continuously along the shores of Seymour Canal for a distance of about 40 miles north of Gambier Bay (Lathram and others, 1960; see also fig. 1). The terrain underlain by the Seymour Canal Formation is low and featureless, except for a few rounded hills underlain by conglomerate. Fossil evidence indicates that the stratigraphic interval from Upper Triassic to Upper Jurassic is missing between the Sey-

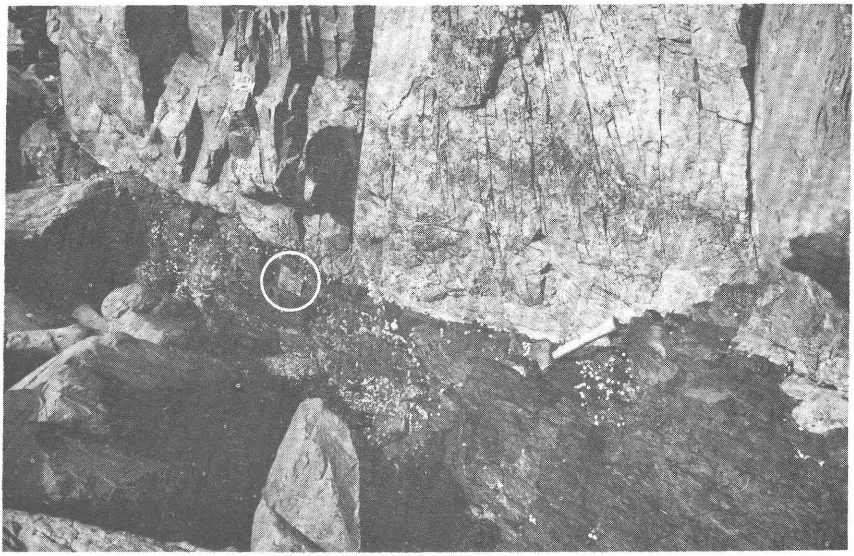


FIGURE 18.—Contact between slaty argillite of Seymour Canal Formation (below) and flows of the Brothers Volcanics, West Brother island; note angular fragment of volcanic rock (circle) embedded in argillite; bedding in argillite is about parallel to contact, whereas fracture cleavage dips steeply to right.

mour Canal Formation and the underlying Hyd Formation. Inasmuch as no structural discordance could be detected between them, the contact is considered to be a disconformity.

Overlying the Seymour Canal Formation is the Brothers Volcanics. The contact between the two, as seen on the western shore of West Brother island, is conformable. Angular fragments of the overlying volcanic rocks occur in the argillite for as much as 2 feet below the contact, and suggest that the underlying mud was soft at the time of volcanic extrusion and that sedimentation was probably taking place when volcanism began (fig. 18). The exact stratigraphic position of the Brothers Volcanics with respect to the entire Seymour Canal Formation is unknown because the upper contact of the volcanics is not exposed. The Brothers Volcanics crops out within the general outcrop area of the Seymour Canal Formation, as indicated by outcrops on scattered islands in Stephens Passage, and they may actually be interbedded in the upper part of the formation.

The Seymour Canal Formation consists largely of dark-gray slaty argillite and thin-bedded volcanic graywacke, but locally contains thick lenticular bodies of conglomerate and massive graywacke. The thin-bedded graywacke occurs in variable abundance from place to place throughout the argillite section, whereas the conglomerate and massive graywacke units are more local and appear to be confined to the upper part of the formation throughout the area. A minimum thickness of 4,000 feet was estimated for the lower part of the formation as exposed on the northeastern shore of the main arm of Pybus Bay. This section, however, does not include the conglomerate facies, which appears from its position in the outcrop belt to be in the upper half of the formation. The actual thickness of the formation is probably as much as 8,000 feet. These figures can be regarded as no more than estimates because intense folding and the lack of marker beds in the Seymour Canal Formation preclude reliable measurement of stratigraphic thickness.

Fossil collections from the argillite of the Seymour Canal Formation indicate that the age of the formation ranges from Late Jurassic to Early Cretaceous. The two most diagnostic forms collected are *Buchia rugosa* (Fischer) and *B.* cf. *B. volgensis* (Lahusen). Collections containing *B. rugosa* (Fischer) are considered by R. W. Imlay (written communication, 1959) to be middle Kimmeridgian to early Portlandian (Late Jurassic) in age; other collections containing *B.* cf. *B. volgensis* (Lahusen) are considered by Imlay to be probably Berriasian (Early Cretaceous) in age. Because of the intense folding and the lack of marker beds, the relative stratigraphic position of beds containing the two fossils cannot be determined, but in general beds containing *B. rugosa* (Fischer) tend to crop out nearer to the lower contact of the formation than do those containing *B.* cf. *B. volgensis* (Lahusen).

The Seymour Canal Formation crops out on the small islands and reefs in southern Pybus Bay and then disappears beneath the water of Frederick Sound and the Tertiary rocks. It reappears farther south on Admiralty Island in a single locality between Herring and Chapin Bays, where fossils of Early Cretaceous age have been collected (E. H. Lathram, oral communication, 1960; see also Lathram and others, 1960).

North of Gambier Bay, rocks probably correlative with the Seymour Canal Formation crop out for the entire length of Seymour Canal and northwestward as far as the eastern shore of Mansfield Peninsula (Lathram and others, 1960). According to these authors, no fossils have been found in the formation on Admiralty Island north of the Pybus-Gambier area. These rocks on Mansfield Peninsula and on the neighboring islands to the east have been grouped by Barker (1957) into two formations: (1) a lower unit, Symonds Formation, consisting of slate and graywacke, and (2) an upper unit, Shelter Formation, consisting of conglomerate, slate, and greenstone. Barker considered both formations to be of possible Early Cretaceous age because they appear to be the northern extension of the rocks containing *Aucella* [*Buchia*] at Pybus Bay. The Symonds Formation by definition includes only the slate and graywacke below the conglomeratic Shelter Formation, and hence may be equivalent only to the lower part of the Seymour Canal Formation. The conglomeratic units in the Seymour Canal Formation may correlate with the Shelter Formation but, in view of the lenticular form of these units and of the distance (65 miles) separating the Pybus-Gambier area from the type section of the Shelter Formation, the use of the name Shelter is not justified in the Pybus-Gambier area.

On the mainland northwest of Juneau, Knopf (1911, p. 14–17; 1912, p. 15–18) gave the name Berners Formation (later abandoned by Martin, 1926, p. 260) to the slate, graywacke, and greenstone at Berners Bay, and on the basis of plant fossils he considered them to be Upper Jurassic or Lower Cretaceous. The rocks of the Berners Formation extend southeastward to the vicinity of Auke Lake, north of Juneau, where they were called the Treadwell Formation, of Jurassic(?) to Early Cretaceous(?) age, by Barker (1957). Knopf correlated the Berners Formation with the slate and graywacke at Point Young on northern Admiralty Island and with rocks of the same lithology containing *Aucella* [*Buchia*] at Pybus Bay; that is, the Seymour Canal Formation of this report.

In general, slate or argillite, graywacke, and conglomerate containing *Buchia* occur in two broad belts in southeastern Alaska: (1) an eastern belt along the west flank of the Coast Range batholith, extending from the vicinity of Ketchikan on the south to the vicinity of Skagway on the north and westward as far as the Pybus-Gambier area; (2) a western belt extending along the west coasts of Baranof and Chichagof Islands and northwestward along the west flank of the Fairweather Range (Dutro and Payne, 1957; Reed and Coats, 1941). Other than those discussed in the previous paragraphs, detailed correlations between the Seymour Canal Formation and other strata of Jurassic and Cretaceous age in these two belts are not justified by present knowledge.

## PETROGRAPHY

### ARGILLITE AND THIN-BEDDED GRAYWACKE

The argillite and thin-bedded graywacke, which characterize the Seymour Canal Formation throughout its visible extent, have the general characteristics of flysch deposits in many parts of the world (fig. 19). The argillite itself is rather massive, dark gray, and noncalcareous, but it contains scattered concretions of yellowish-weathering limestone and few exotic inclusions of older limestone, (fig. 20). The intercalated thin-bedded graywacke layers are dark gray indurated rocks that weather to light gray. Individual graywacke beds range from 1/4 inch to 2 feet in thickness, but most are about

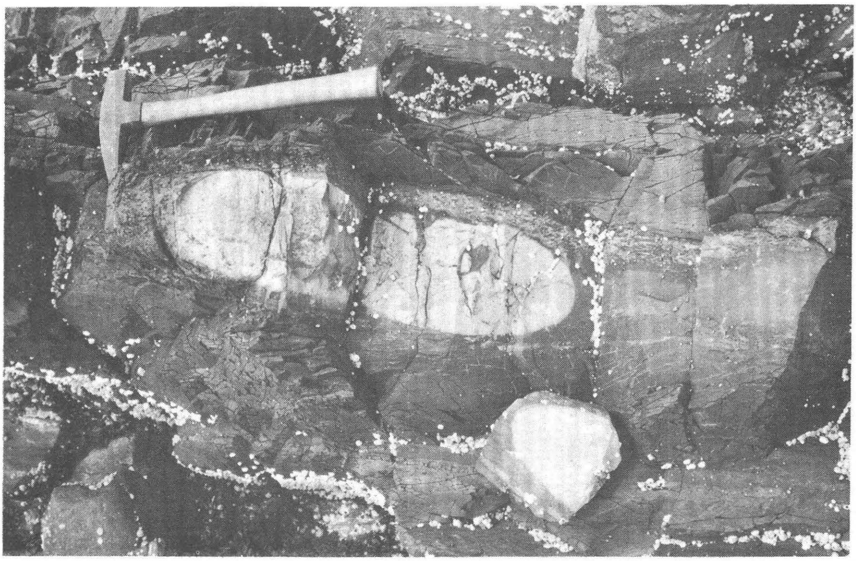
FIGURE 19.—Thin-bedded graywacke and argillite, Seymour Canal Formation, north of Point Pybus; top is to the right.

1 inch thick. They are commonly continuous within any outcrop, but may vary noticeably in thickness. Graded bedding, small-scale cross-bedding, convolute laminations, and various sole markings, which are characteristic of turbidite deposits as described by Kuenen (1957), are typical of the Seymour Canal graywacke. In a few layers, which are as much as 20 feet thick, the thin graywacke beds have been broken and the fragments more or less scattered through the argillite in a manner suggesting submarine slumping.

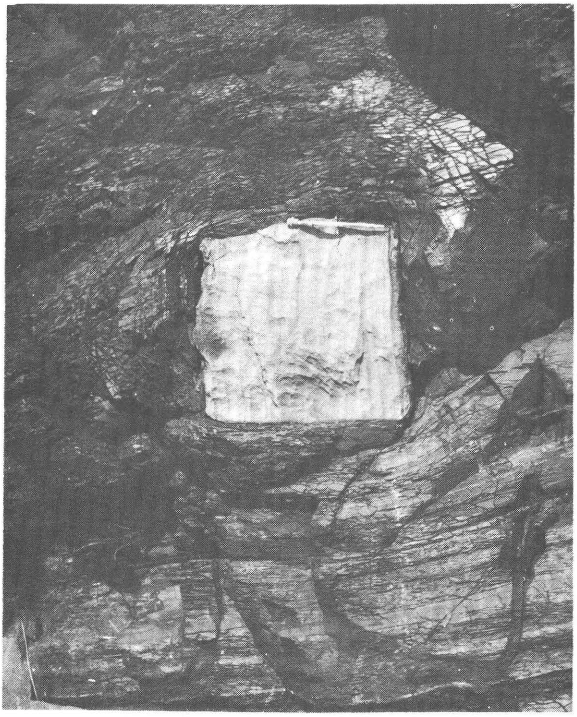
The fracture cleavage that is characteristic of the argillite in the Seymour Canal Formation throughout most of its area of outcrop is much more pronounced in the salt-water shoreline exposures than in exposures away from shore. Probably wedging by the crystallization of salt in the largely closed cleavage fractures is necessary for them to appear as open fractures.

Microscopically the typical noncalcareous argillite consists of an almost unresolvable brown matrix composed of chlorite, sericite, clay mineral, pyrite, and very fine semiopaque dust, through which are scattered angular grains of plagioclase and quartz averaging less than 0.02 mm in diameter. The matrix commonly forms about 90 percent of the rock.

The concretions of the argillite are composed of dark-brown fine-grained limestone that weathers a light yellowish gray and shows faint bedding parallel to that of the argillite. Although the bedding in the argillite bows out slightly above and below the concretions, it



*A*



*B*

FIGURE 20.—*A*, Limestone concretion in argillite of Seymour Canal Formation, Pybus Bay. *B*, Exotic inclusion of older limestone in argillite and thin-bedded graywacke of Seymour Canal Formation, Gambier Bay.

seems to do so no more than would be expected from the differential compaction of a soft matrix around a body that became gradually more competent than the matrix as compaction proceeded. The concretions average about 2.0 feet in length and about 6 inches in thickness; a few occur as thin beds 2 to 3 inches thick and from 6.0 to 10 feet long. As indicated by figure 20*A*, a sharp contact typically exists between the light-weathering concretion and the dark-colored argillite. Commonly, however, the argillite in the vicinity of the concretion has been penetrated by calcite to a thickness of 1 to 2 inches normal to the bedding and of 1 to 2 feet parallel to the bedding. This calcareous zone weathers to a rough brown surface from which project angular remnants of noncalcareous argillite. Similar brown-weathering calcareous patches and layers are often seen without an obvious core of limestone; in some places these calcareous zones contain small limestone and fossil fragments.

The concretions, both as lenses and as beds, may be true concretions in the sense used by Pettijohn (1957, p. 203) in that calcite has accumulated in the pore spaces of the rock around nuclei, such as calcareous fossil and other limestone fragments. The strong deformation to which the rocks of the Seymour Canal Formation have been subjected probably accounts for the pull-apart and typical boudinage structures seen in concretions at some localities.

The exotic inclusions also found in the argillite consist of fragments of limestone of any shape, commonly angular, ranging from a few inches to a few feet in longest dimension, in which the bedding may have any orientation relative to that of the surrounding argillite (fig. 20*B*). Unlike the concretions, the exotic inclusions do not have diffuse calcareous aureoles in the enclosing argillite. Furthermore, these inclusions strongly bend down the underlying beds but were not themselves deformed. This indicates that they were introduced as consolidated limestone fragments into soft mud.

A common type of inclusion consists largely of a dark-gray or brown fine-grained limestone which weathers light gray; a less common type consists of medium-gray fine-grained marble; both varieties are probably fragments of older rock. They commonly occur in argillite sections containing no calcareous beds of any type from which they might have been derived by submarine erosion and redeposition or by tectonic disruption. The inclusions commonly occur in thinly bedded fine-grained rocks characteristic of a quiet environment relatively distant from shore (Pettijohn, 1957, p. 293–294), and not in the chaotic landslide deposits seen elsewhere in the formation. Rafting and dumping by some agent such as icebergs, tree roots, or other floating objects seems to be the most logical origin.

The thin-bedded graywacke is medium to dark gray and is a highly indurated rock that weathers light gray in calcareous varieties and olive gray in chloritic varieties. The graywacke beds show little tendency to break or weather out along bedding surfaces, and sole markings, such as flute casts, drag marks, and load casts, are generally seen only in sections. In detail, the graywacke beds grade upward from medium or fine sandstone at the base to coarse siltstone at the top. The lower contact with the argillite is commonly sharp and irregular and contains channels, depressions, and irregular upward projections of the argillite; thin slabs of argillite are commonly scattered along the bottom layers of the graywacke bed (fig. 21). The upper contact is more indistinct; it commonly shows smooth, undulating ripple mark cross sections. A bed may simply grade upward from base to top in a single cycle, but thicker beds tend to be composed of several cycles of grading, commonly associated with sets of small-scale crossbedding, superposed one upon the other. However, such beds ordinarily tend to become finer from base to top in spite of repeated cycles of grading and repeated sets of crossbedding (fig. 21). Convolute bedding (Kuenen, 1953, p. 1056; Crowell, 1955, p. 1364) is a less common feature than those described above (fig. 19); the irregularly distorted laminae constituting convolute bedding occur generally in the finer parts of the beds. The distortion of the laminae may die out either upward or downward or in both directions in the manner described by Webby (1959, p. 469).

Microscopically the thin-bedded graywacke consists largely of subrounded to angular grains of feldspar, argillite, and volcanic rock fragments set in a murky brown chloritic or calcitic matrix. Minor

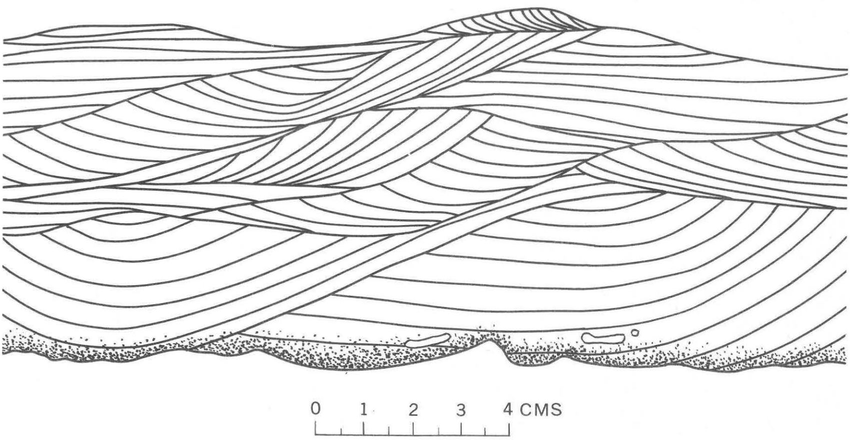



FIGURE 21.—Sketch of graywacke bed, showing small-scale crossbedding, Seymour Canal Formation; argillite above and below.

grain types include biotite, quartz, chert, and limestone. The matrix ranges from 10 to 60 percent of the rock and averages about 35 percent (fig. 22*B*); these rocks, therefore, are graywacke under most recent classifications (Gilbert, *in* Williams and others, 1954, p. 292–294; Pettijohn, 1957, p. 290–293).

Figure 22*A* shows the relative amounts of the chief groups of grain types estimated in representative thin sections of thin-bedded graywacke (clear circles). The relatively unstable feldspar and rock-fragment grains greatly predominate over the stable quartz and chert grains. The quartz and chert grains are commonly present in trace amounts only. The relative amounts of feldspar and rock fragments are about equal overall, but the finer grained rocks tend to contain a greater percentage of feldspar, and the coarser grained rocks tend to contain a greater percentage of rock fragments. The grains average about 0.2 mm in diameter and commonly grade from 0.5 to 0.02 mm in diameter from base to top of a 1- to 2-inch bed; the decrease in grain size upward is accompanied by an increase in the amount of matrix.

Plagioclase is abundant and forms most of the feldspar grains, whereas potassic feldspar is rare in most specimens, attaining a maximum of 10 percent of the grains in one specimen. The plagioclase occurs as slightly or moderately sericitized grains showing polysynthetic twinning and, in a few thin sections, faint zoning; the composition of the plagioclase ranges from $An_{12}$ to $An_{48}$, most grains falling in the range $An_{42}$ to $An_{45}$. The potassic feldspar occurs as highly sericitized untwinned grains and was determined with the aid of sodium cobaltinitrite stain. The volcanic rock fragments, which are the most abundant of the unstable rock fragments, commonly show a trachytic or pilotaxitic texture consisting of partly sericitized plagioclase microlites averaging about 0.01 mm in length set in a chloritic groundmass; sparse plagioclase phenocrysts are seen in a few grains. The argillite fragments consist of a cloudy, very fine grained, largely unresolvable chloritic matrix through which are scattered silt-sized angular grains of plagioclase and quartz.

Biotite is a ubiquitous minor constituent, generally forming less than 5 percent of the rock. Its characteristic pleochroism is: Z and Y=reddish brown and X=pale yellowish orange; commonly the flakes are partially altered to chlorite and are distorted between more competent grains.

The matrix of the graywacke is a murky brownish mixture of chlorite, calcite, pyrite, epidote, limonite, and much nonbirefringent cloudy material; leucoxene and sericite are common in a few specimens. The chief variation in composition among the typical graywacke is in the proportion of chlorite and calcite. All gradations

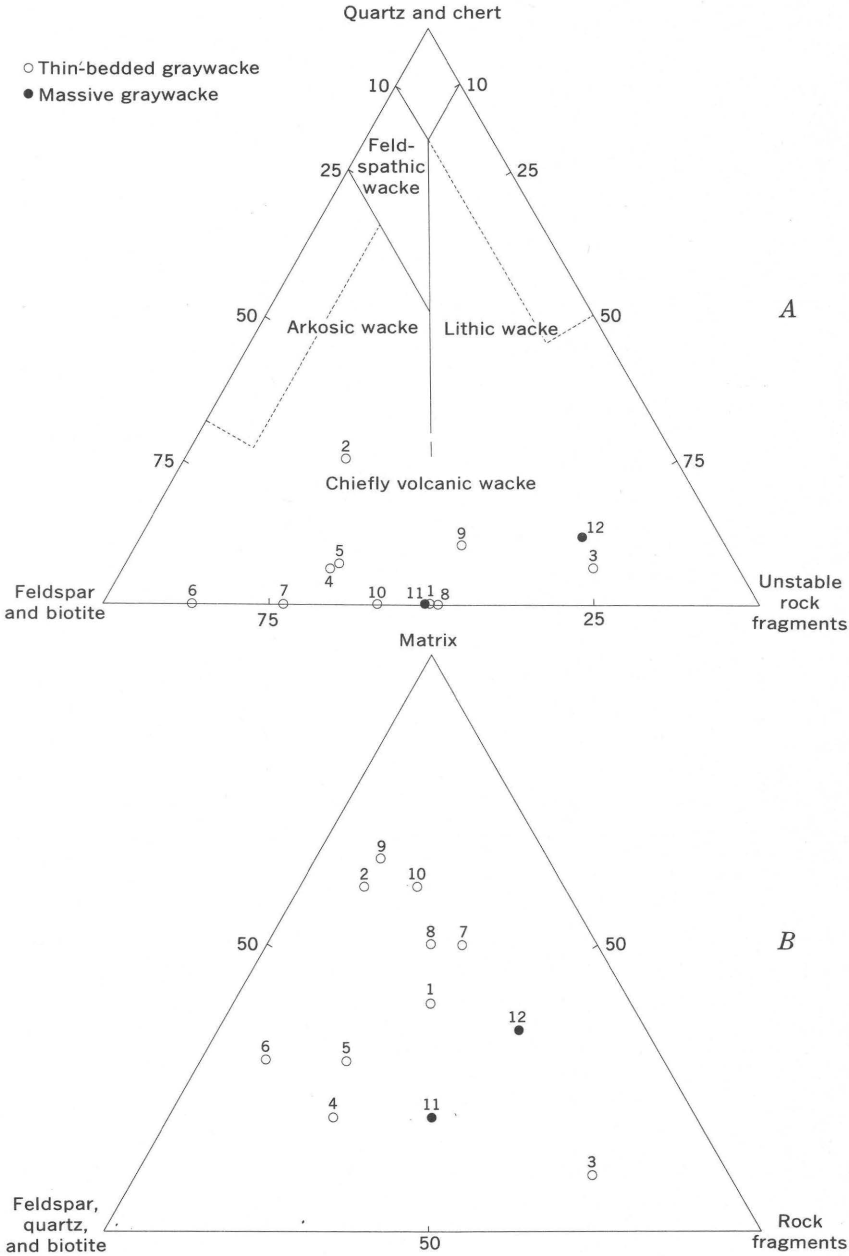



FIGURE 22.—Triangular diagrams showing composition of graywacke in Seymour Canal Formation.

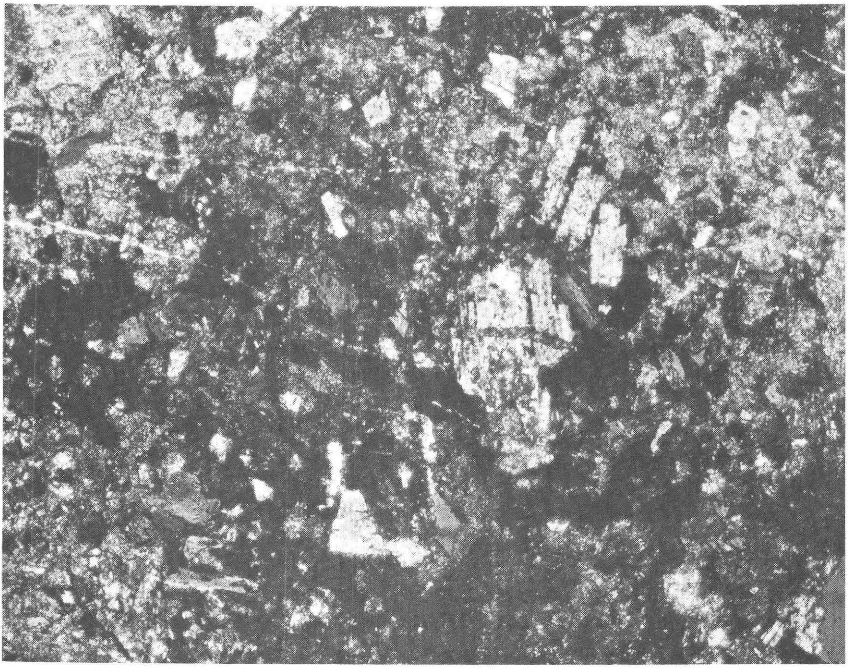


FIGURE 23.—Photomicrograph of graywacke, Seymour Canal Formation, in which a granular mosaic of prehnite (stippled gray) has partially replaced matrix and plagioclase grains (crossed nicols, ×71).

exist between graywacke in which calcite forms nearly 100 percent of the matrix and those in which chlorite is predominant and calcite occurs only in trace amounts. The matrix in all specimens has corroded and replaced the margins of the grains. Replacement of grains is especially pronounced in rocks having a calcareous matrix; in these, calcite has strongly replaced the grains, especially the plagioclase grains, commonly leaving only isolated ragged remnants of larger grains in patches of calcite. This process greatly reduces the size and total volume of clastic grains in calcareous graywacke.

Prehnite is the dominant mineral of the matrix in two of the specimens examined in which it forms about 50 percent of the rock. In these specimens the matrix consists of a mosaic of equant anhedral prehnite crystals ranging from 0.3 to 0.5 mm across which poikiloblastically enclose the clastic grains and minor patches of chlorite, calcite, and epidote. The prehnite has replaced the plagioclase clasts ($An_{31}$) almost completely (fig. 23) and, to a lesser degree, the other clasts (volcanic rock and argillite fragments). The prehnite is nearly colorless or very pale green and has a maximum birefringence of second-order blue.

### CONGLOMERATE AND MASSIVE GRAYWACKE

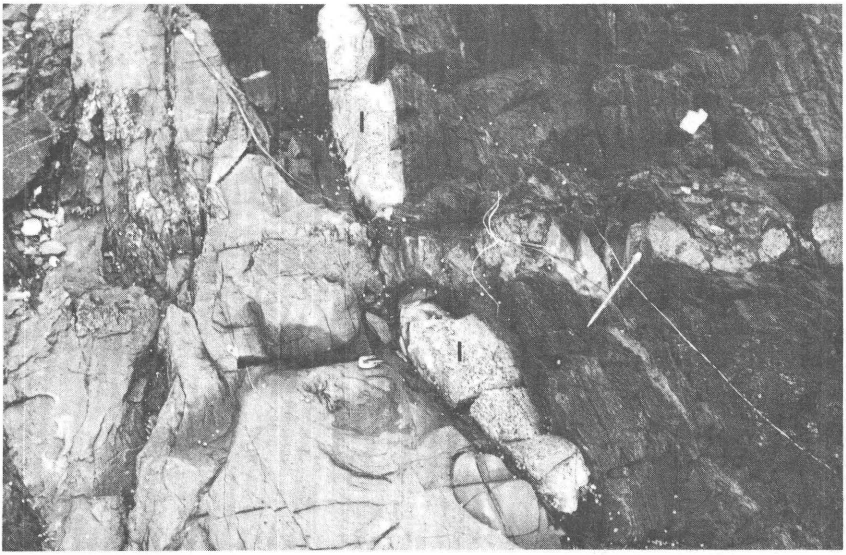
Conglomerate and massive graywacke occur together as thick lenticular masses in the upper part of the Seymour Canal Formation; the larger masses are shown on the geologic map (pl. 1). In these masses, the largest of which is 2,000 feet thick on Elliott Island, conglomerate beds commonly thin along the strike and intertongue with massive graywacke, which in turn intertongues with argillite and thin-bedded graywacke. Such orderly facies change, although it seems broadly characteristic, is disturbed in detail by intrusions of conglomerate and massive graywacke into the argillite and thin-bedded graywacke (fig. 24). Furthermore, large angular blocks of thin-bedded graywacke and argillite as much as 30 feet across occur here and there within the conglomerate. Both conglomerate and massive graywacke layers lack internal bedding structure and appear unsorted (fig. 25). They are thought to be the products of submarine slide downslope into a basin floor where the argillite and thin-bedded graywacke were accumulated in more regular fashion.

The amount of matrix in the conglomerate is variable and ranges from less than 10 percent (fig. 25*A*) to more than 90 percent (fig. 25*B*). The most common matrix is a brownish-gray medium- to coarse-grained graywacke identical in lithology to the massive graywacke. By a decrease in pebbles, conglomerate containing this matrix commonly grades into massive graywacke. A less abundant but widespread matrix consists of dark-gray argillaceous graywacke or sandy argillite, which grades into massive argillite by a decrease in pebbles and sand (fig. 25*B*).

The massive graywacke and the similar matrix of the conglomerate closely resemble the thin-bedded graywacke in composition of matrix and in grain constituents (see black dots in fig. 22*A*, *B*). In general, the massive graywacke tends to contain a greater percentage of rock fragments than does the thin-bedded variety. Remarks given above concerning variations in composition and petrographic details of the matrix of the thin-bedded graywacke are also appropriate for the massive graywacke.

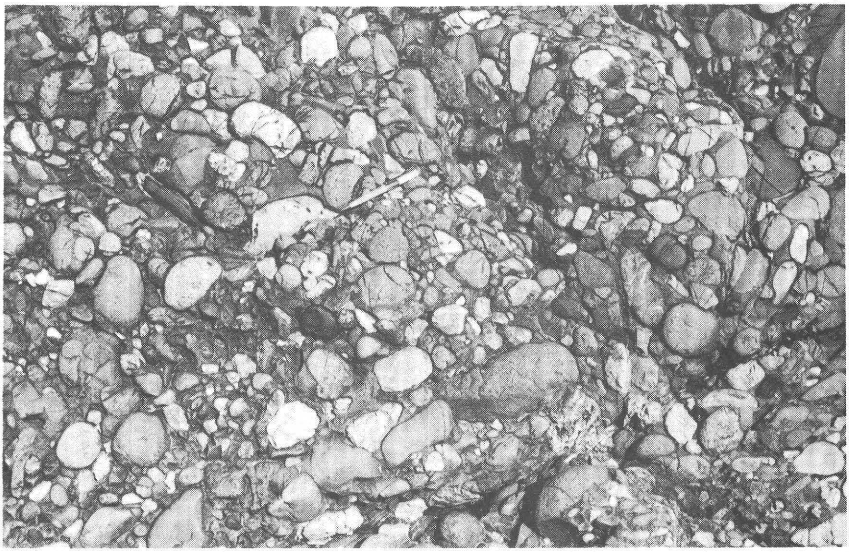
The less abundant, dark gray argillaceous matrix consists largely of clastic grains of plagioclase, argillite, and volcanic rock fragments set in a murky brown, almost unresolvable mixture that consists of chlorite, calcite, semiopaque dust, and in places small crystals of clinozoisite. The proportion of chlorite and calcite varies from one specimen to another, but in general chlorite predominates and the matrix is at most only slightly calcareous. The argillaceous matrix grades from medium dark-gray graywacke containing 60 percent

*A*



*B*

FIGURE 24.—*A*, Intrusion of conglomerate into argillite and thin-bedded graywacke, Seymour Canal Formation, Gambier Island (horizontal surface). *B*, Intrusion of graywacke dike from massive graywacke bed on left into slaty argillite and thin-bedded graywacke; note disrupted limestone concretion (1); Seymour Canal Formation (horizontal surface).



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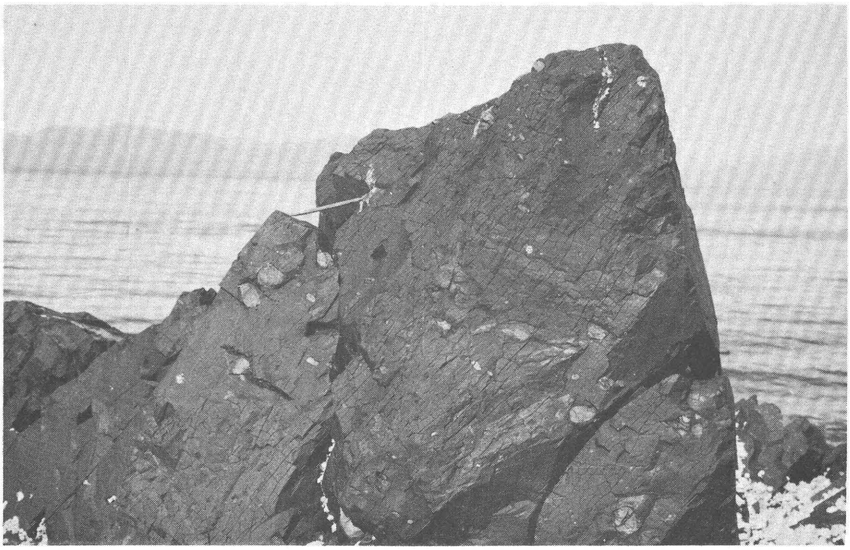


*B*

FIGURE 25.—*A*, Cobble conglomerate, Seymour Canal Formation, Elliott Island, Pybus Bay; less than 10 percent graywacke matrix. *B*, Conglomeratic argillite, Seymour Canal Formation, Romp Island, Gambier Bay; more than 90 percent slaty argillite matrix.

sand grains to dark-gray argillite containing 20 percent or less sand and coarse silt grains.

The fragments composing the conglomerate, exclusive of the matrix, consist largely of subrounded to rounded pebbles and cobbles of rock fragments. Boulders as much as 3 feet in diameter are scattered through the cobble conglomerate. These larger clasts are not seen in pebble conglomerate. Two counts of 150 clasts each, made at two widely separated localities, illustrate the common types of clasts:

| | *North end Long Island (percent)* | *South end Gambier Island (percent)* |
|---|---|---|
| Limestone, fine-grained, dark-brown | 9 | 11 |
| Graywacke, medium- to fine-grained, dark-gray | 21 | 11 |
| Slate, dark-gray, noncalcareous | 4 | 7 |
| Argillite, dark-brown, calcareous | 10 | 5 |
| Chert, black | 3 | 3 |
| Chert, light-gray or brown | 8 | 9 |
| Volcanic rock, porphyritic (feldspar), grayish-green | 2 | 19 |
| Volcanic rock, porphyritic (feldspar), dark-gray | 3 | 5 |
| Felsite, quartz phenocrysts, light-gray | 16 | 8 |
| Granodiorite | 12 | 4 |
| Diorite, fine crystalline | 10 | 12 |
| Diorite, mafic phenocrysts | 2 | 4 |
| Quartz, white | --------- | 2 |

## BROTHERS VOLCANICS

### STRATIGRAPHY

The name Brothers Volcanics is here proposed for the sequence of andesitic volcanic flows, breccias, and associated volcanic sedimentary rocks at least 2,000 feet thick on The Brothers islands in the southeastern part of the Pybus-Gambier area. These islands were previously mapped as diorite by Buddington and Chapin (1929, pl. 1) and as Jurassic and Cretaceous intrusive igneous rocks by Dutro and Payne (1957).

The Brothers Volcanics seems to lie conformably on the Seymour Canal Formation, as shown by the contact exposed on West Brother island (fig. 18) and by the general structural conformity of the two formations. The Brothers Volcanics may lie either partly or wholly within the uppermost part of the Seymour Canal Formation, as suggested by the location of their outcrops within the eastern and possibly younger part of the outcrop belt of the Seymour Canal Formation, or they may lie wholly above the Seymour Canal.

The Brothers Volcanics is composed of about equal amounts of massive andesitic flows (fig. 18) and flow breccias and minor intercalated volcanic graywacke. The flows are chiefly dark gray, purplish gray, dark greenish gray, and rarely medium gray, and weather

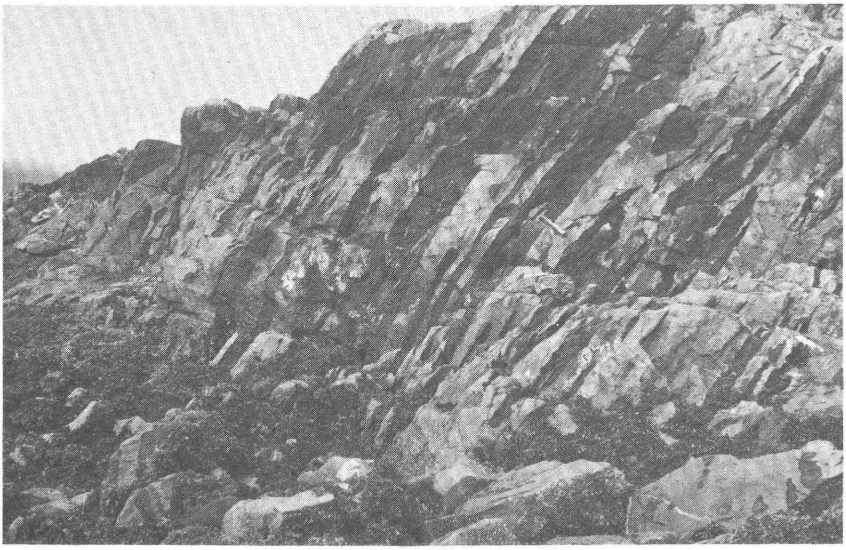


FIGURE 26.—Steeply dipping volcanic graywacke, Brothers Volcanics, south shore of East Brother island; shows rough-weathering calcareous lenses in smooth-weathering noncalcareous rock.

light green, dark green, and yellowish olive. They range from fine grained to aphanitic in texture and in places contain euhedral phenocrysts, averaging about 2.0 mm in length, of plagioclase, pyroxene, and less commonly hornblende. The flows grade into flow breccias containing angular fragments of the above rock types ranging in length from 0.5 inch to 3.0 feet, embedded in a matrix of the same composition. The rocks commonly contain scattered calcite amygdales averaging about 3.0 mm in diameter.

The volcanic graywacke occurs in units, as much as a few hundred feet thick, intercalated in the flows and breccias. Some of these rocks may be tuff, but most are certainly poorly sorted, waterlaid sedimentary rocks and are classed as volcanic graywacke (Gilbert, in Williams and others, 1954, p. 304). The graywacke is medium dark gray and coarse grained, and is composed almost entirely of rock fragments that appear to be derived from the flows and breccias. Both calcareous and noncalcareous types occur interbedded. The calcareous graywacke generally forms slightly irregular lenticular masses 0.5 inch to 3.0 feet in the noncalcareous graywacke. The calcareous masses weather to a rough, olive-gray surface that contrasts sharply with the smooth-weathering surface of the noncalcareous graywacke (fig. 26).

Although no fossils were found in the Brothers Volcanics, they are considered here to be of Late Jurassic and Early Cretaceous age, as is the Seymour Canal Formation. This correlation is based on the general structural conformity of the two formations, and the previously described features of their contact (p. 56). C. W. Wright (1906, pl. 33) mapped the volcanic rocks of The Brothers as "surface lavas and tuffs" and correlated them with the Tertiary volcanic rocks of southern Admiralty Island (Admiralty Island Volcanics of this paper). The steep attitudes of the Brothers Volcanics (pl. 1), however, are in general conformable with those of the Seymour Canal Formation, whereas the attitudes of the known Tertiary rocks in the region are mostly very gentle.

Volcanic rocks possibly correlative with the Brothers Volcanics form most of the Glass Peninsula on northeastern Admiralty Island (Lathram and others, 1960). This belt, which consist of altered augite-bearing volcanic breccia and tuff and minor slate, lies in contact on the west with the argillite and graywacke that crop out along the shores of Seymour Canal and that are considered here to be an extension of the Seymour Canal Formation. The volcanic rocks of the Glass Peninsula were considered by Buddington and Chapin (1929, p. 158–159) to be Jurassic or Cretaceous in age. Northwestward along the trend of the Glass Peninsula, similar volcanic rocks crop out on Douglas Island in the vicinity of Juneau. Martin (1926, p. 255–256) called these rocks the Douglas Island Volcanic Group, and considered them to be of probable Late Jurassic age. In general, then, the belt of volcanic rocks extending from Douglas Island southeastward to the tip of the Glass Peninsula may be represented in the Pybus-Gambier area by the Brothers Volcanics.

Rocks correlative with the Brothers Volcanics do not crop out on Admiralty Island south of the Pybus-Gambier area (Lathram and others, 1960). Buddington and Chapin (1929, p. 165–167) stated that southeast of Admiralty Island greenstone volcanic rocks occur throughout the belt of Jurassic and Cretaceous rocks which lies along the western flank of the Coast Range batholith. Reed and Coats (1941, p. 34–35), on the west coast of Chichagof Island in the western belt of Jurassic and Cretaceous rocks, reported "greenstone schist" intercalated in their graywacke formation, which they considered to be Late Jurassic and Early Cretaceous in age.

## PETROGRAPHY

### FLOWS AND BRECCIAS

The typical flow rock contains phenocrysts of sericitized plagioclase (30 percent), pyroxene (15 percent), and hornblende (trace) set in a very fine grained pilotaxitic groundmass composed of plagioclase microlites, chlorite, calcite, and opaque minerals. Plagioclase phenocrysts range in length from 0.2 to 1.0 mm and commonly show polysynthetic twinning and normal zoning. Sericitization of the plagioclase prevents accurate determination of composition, but compositions from

$An_{25}$ to $An_{48}$ are indicated. Clinopyroxene phenocrysts are euhedral and colorless, and show rare simple twinning; the angle $Z \wedge c$ lies in the range 39° to 45°, and $2V_z$ in the range 50° to 54°. Hornblende is generally euhedral and commonly shows simple twinning; its pleochroism is from Z and Y = greenish brown to X = pale yellowish brown. Both pyroxene and hornblende commonly have rims of chlorite and opaque grains.

The plagioclase microlites are indistinct needles less than 0.02 mm in length whose composition could not be determined. Chlorite occurs largely as interstitial aggregates; it shows a pleochroism from X and Y = green to Z = pale yellowish green and an anomalous bluish-gray birefringence. Calcite occurs as patches scattered throughout the specimens examined; some of the patches represent amygdales. Fine opaque dust, consisting in part of pyrite, is disseminated throughout the groundmass. Pyrite also occurs as larger euhedral crystals as much as 0.2 mm in length.

#### GRAYWACKE

The noncalcareous graywacke contains a cloudy brown chloritic matrix, whereas the calcareous graywacke contains an almost clear calcite cement that has partially replaced the grains embedded in it. In both varieties the grains form about 60 percent of the rock and range in size from medium sand to coarse pebbles; the average grain size is very coarse sand. Bedding is commonly shown by slight variations in the grain size of adjacent layers. An important difference between the graywacke and the flow rocks examined is that the graywacke contains large (as much as 2.0 mm in length) cloudy, somewhat mottled untwinned and simply twinned feldspar grains that have been shown by sodium cobaltinitrite stain to be potassic feldspar. Perhaps this difference indicates an introduction of potassium during or following sedimentation, but sampling was not extensive enough to be conclusive.

## TERTIARY SYSTEM

### UNNAMED CONGLOMERATE AND SANDSTONE

#### STRATIGRAPHY

A gently dipping sequence of interbedded conglomerate, lithic sandstone, and minor amounts of shale, probably of nonmarine origin, crops out on the west shore of Pybus Bay west of Elliott Island and in eastern Little Pybus Bay. Previous workers (Wright, 1906; Buddington and Chapin, 1929; and Dutro and Payne, 1957) mapped this unit with the marine argillite, graywacke, and conglomerate that is herein called the Seymour Canal Formation and considered to be Jurassic and Cretaceous in age.

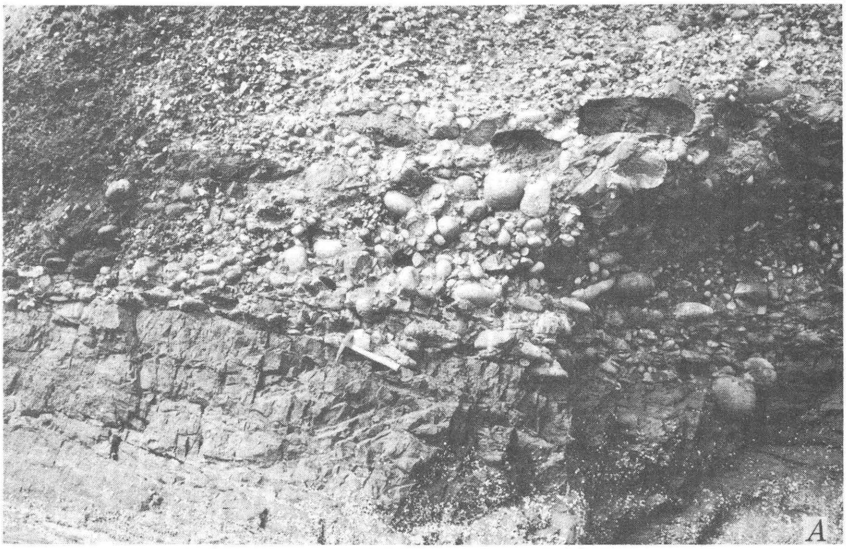
This gently dipping sequence overlies the strongly deformed strata of the Cannery, Hyd, and Seymour Canal Formations with pronounced angular discordance. The contact is visible on the west shore of Pybus Bay near the south border of the area (pl. 1; fig. 27*A*). The conglomerate and sandstone unit is conformably overlain by the Admiralty Island Volcanics, as seen on the islands and reefs in Little Pybus Bay (fig. 27*B*). The dominance of cobbles of rock types similar to those of the Admiralty Island Volcanics in the top few feet of the conglomerate indicates that volcanism began before the end of conglomerate deposition.

The outcrop of the conglomerate and sandstone unit in the Pybus-Gambier area is confined to a triangular area bounded on the west by the Admiralty Island Volcanics, on the south by the boundary of the area, and on the east by older rocks cropping out along the west coast of Pybus Bay. The unit is about 2,000 feet thick near the south border of the area but thins northward and pinches out immediately south of Cannery Cove.

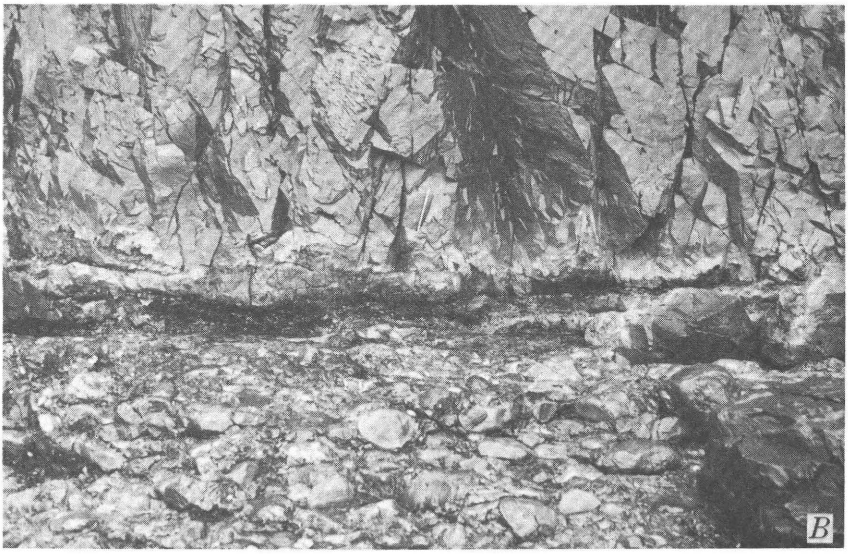
The conglomerate and sandstone occur in highly lenticular beds that in part represent stream channels and in part alluvial fans. Conglomerate which predominates over sandstone by a ratio of about 3 : 1, consists chiefly of rounded cobbles of a wide variety of rock types. Silicic plutonic rocks and argillite dominate in the unit as a whole, but volcanic rocks dominate in the top few feet. The clasts are embedded in a medium- to light-gray coarse-grained lithic sandstone matrix that is similar to the sandstone of the sandstone beds. The sandstone is characterized by an abundance of lustrous dark-gray phyllite fragments and generally less than 15 percent quartz; it contains both calcareous and argillaceous matrix, generally in excess of 10 percent, and may be classified as lithic wacke (Gilbert, in Williams and others, 1954, p. 297).

Fossil leaves indicative of a late Eocene age (J. A. Wolfe, written communication, 1961) occur in shale about 200 feet stratigraphically below the top of the unit at the head of Little Pybus Bay. (See "Fossil lists and localities.") According to Wolfe: "The flora from Little Pybus Bay represents the same assemblage that Hollick (in Buddington and Chapin, 1929, p. 267–268) described from Hamilton Bay on Kupreanof Island. All of the Little Pybus species are also found in the Kupreanof flora, and a correlation is certain. The flora from Kupreanof, and hence the Little Pybus flora, is of late Eocene age, although older than any flora known from Kootznahoo Inlet."

The rocks of the conglomerate and sandstone unit closely resemble the gently dipping conglomerate, sandstone, and shale of the Kootznahoo Inlet area on western Admiralty Island (Wright, 1906, p. 144–




*A*




*B*

FIGURE 27.—*A*, Unconformable contact between unnamed conglomerate (Eocene) and argillite of Seymour Canal Formation (below); note slabs of argillite in conglomerate; southern Pybus Bay. *B*, Conformable contact between Admiralty Island Volcanics above and unnamed conglomerate (Eocene) below; conglomerate composed largely of volcanic fragments in top few feet; Little Pybus Bay.

147; Lathram and others, 1960). Although the Kootznahoo section is in general finer grained and contains much more coal than the section at Little Pybus Bay, the sandstones of the two areas are quite similar and contain an abundance of dark-gray lustrous phyllite grains. The strata of the two areas probably were laid down in similar continental environments and shared some common source areas.

According to Buddington and Chapin (1929, p. 260–267), more than 1,350 feet of sandstone and intercalated conglomerate containing plant fossils of Eocene age underlie rhyolitic and basaltic volcanic rocks at Port Camden, Kuiu Island, and at Hamilton Bay, Kupreanof Island. These rocks were considered by these authors to be part of a once continuous belt of Tertiary continental deposits extending northward and including the similar deposits on Admiralty Island. Thus these deposits were laid down in an early Tertiary basin, in which the Admiralty Island Volcanics were also deposited, that has been called the Admiralty trough by Payne (1955; see also Miller and others, 1959, p. 22).

*Section of lower part of the conglomerate and sandstone unit measured on the shores of the peninsula between Little Pybus and Pybus Bays*

| | *Thickness (feet)* |
|---|---|
| Covered. | |
| Conglomerate and sandstone unit: | |
| Conglomerate, pebble and cobble; rounded clasts of granite, gneiss, black slate, phyllite, white chert in a light-gray coarse-grained slightly calcareous lithic sandstone matrix; matrix less than 10 percent | 25 |
| Sandstone, light-gray, medium- to coarse-grained, slightly calcareous, slabby, crossbedded; contains scattered dark-gray lustrous phyllite grains; very sparse rounded pebbles scattered throughout; crossbedding sets from 0.5 to 2.0 ft thick | 15 |
| Conglomerate, as above; contains boulders 1.0 to 4.0 ft in length | 4 |
| Sandstone, as above | 12 |
| Covered | 15 |
| Conglomerate, boulder and cobble; similar to conglomerate above; contains abundant fragments of medium-gray fine-grained volcanic breccia and porphyritic diorite | 110 |
| Sandstone, as above | 3 |
| Covered | 45 |
| Conglomerate, pebble and cobble, rounded clasts of types given above in medium dark-gray coarse-grained lithic sandstone matrix; matrix about 40 percent; contains abundant grains of dark-gray lustrous phyllite; lenses of medium dark-gray slightly bluish coarse-grained lithic sandstone; sandstone lenses crossbedded in sets 0.5 to 2.0 ft thick; unit contains slightly rounded slabs of slaty argillite near base | 145 |
| Angular unconformity. | |
| Seymour Canal Formation. | |
| Total | 374 |

736–005 O—64——6

*Section of upper part of the conglomerate and sandstone unit in northern Little Pybus Bay*

| | Thickness (feet) |
|---|---|
| Admiralty Island Volcanics. | |
| Conformable contact. | |
| Conglomerate and sandstone unit: | |
| Conglomerate, cobble, medium dark-gray; subrounded cobbles averaging 3 in. in length; 20 percent coarse sandstone matrix; cobbles chiefly dark-gray, finely crystalline vesicular volcanic rocks; a few black chert and white quartz pebbles | 10 |
| Conglomerate, pebble-to-cobble, medium light-gray, massive; rounded clasts of granite, gneiss, quartz, felsite, black slate in medium-gray coarse-grained lithic sandstone matrix; matrix about 40 percent; clasts average about 3 in. in length; unit includes a few 1- to 3-ft-thick lenses of medium light-gray medium- to coarse-grained sparsely pebbly lithic sandstone | 65 |
| Sandstone, medium light-gray (weathers reddish yellow), fine-grained, micaceous (muscovite), slabby, crossbedded; crossbedding sets average 1.0 in. in thickness; symmetrical ripple marks; scattered brown iron-rich concretions from 1 to 2 in. in diameter | 10 |
| Shale, medium-gray, fissile | 20 |
| Sandstone, medium dark-gray with slight bluish cast; coarse grained, lithic, crossbedded, slightly calcareous, massive; contains abundant slablike grains of dark-gray lustrous phyllite; crossbedding sets average about 1.0 ft in thickness | 10 |
| Covered. | |
| Total | 115 |

## PETROGRAPHY

### CONGLOMERATE

The conglomerate consists of rounded clasts of various colors embedded in medium- to light-gray coarse-grained lithic sandstone matrix. The amount of matrix ranges from less than 10 to 40 percent of the rock, and the average is near the lower end of the range. The sandstone of the matrix resembles closely the sandstone of the lenses but lacks the current structures of the latter. The conglomerate is commonly massive, but in places crude bedding is indicated by layers of clasts of contrasting size; individual units or beds range in thickness from a few to tens of feet (fig. 27*A*).

The clasts range from pebbles 0.25 inch in diameter to boulders 5.0 feet in longest dimension, and the average lies in the small cobble range (2.5 to 5.0 inches in diameter). As mentioned above, the uppermost few feet of the formation consists almost entirely of clasts of volcanic rocks similar in type to those of the overlying Admiralty Island Volcanics (fig. 27*B*). These types decrease downward with a corresponding increase in types characteristic of the unit as a whole. Below the top few feet, volcanic rock fragments are rare, but where locally abundant they are composed of rock types unlike those of the Admiralty Island Volcanics. Characteristic clast constitutents are illustrated by the following count taken near the base of the formation (200 clasts counted):

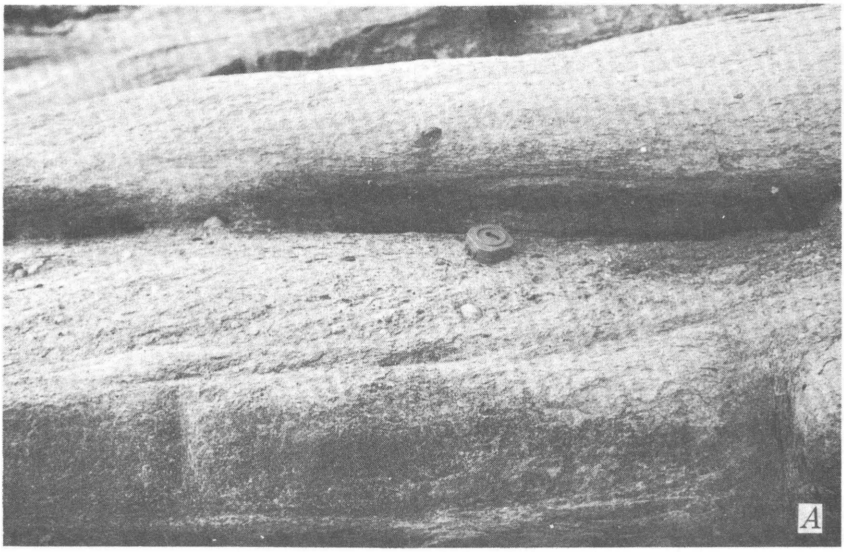
| | *Percent* |
|---|---|
| Diorite (plagioclase phenocrysts) | 9 |
| Granite | 27 |
| Gneiss | 9 |
| Quartz, white, milky | 5 |
| Quartzite | 7 |
| Chert, black | 6 |
| Argillite, dark-gray | 18 |
| Graywacke | 6 |
| Greenschist | 3 |
| Gabbro | 5 |
| Sandstone, pale-red | 1 |
| Felsite, light-gray (quartz phenocrysts) | 1 |
| Tuff, green | 3 |

The porphyritic diorite clasts appear to be identical to the diorite cropping out in the northwest part of the Pybus-Gambier Bay area (see p. 89), and indicate that this plutonic body was undergoing erosion before the deposition of the conglomerate or at the same time. The abundant argillite clasts could have been derived from any of the several pre-Tertiary formations previously described. The conglomerate of the Seymour Canal Formation may have been a source of coarse detritus within the local area.

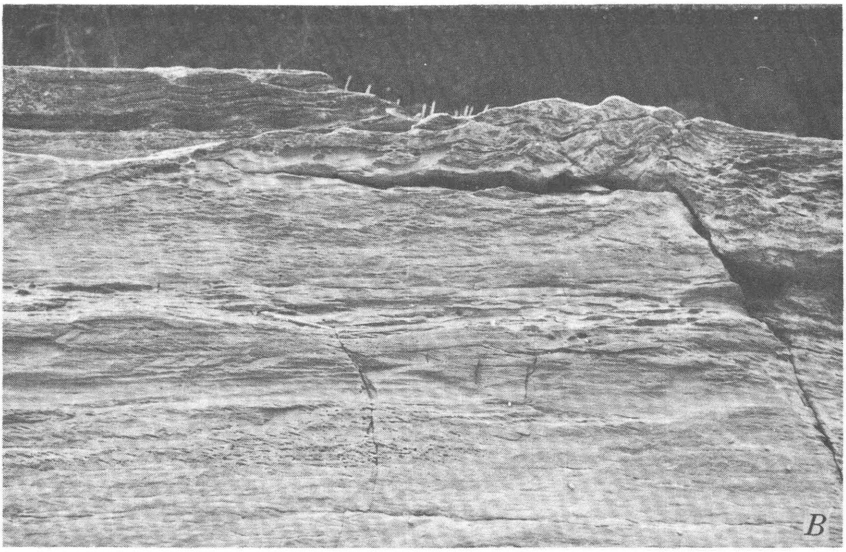
### SANDSTONE

A well-indurated lithic coarse-grained sandstone is the most abundant rock type in this category; it occurs both in beds and as matrix in the conglomerate. Two general varieties are recognized, between which all gradations occur: (1) light yellowish-gray sandstone containing an abundant calcareous matrix and sparse dark-gray phyllite fragments and (2) medium dark-gray sandstone containing a sparse micaceous matrix and abundant dark-gray phyllite fragments. The phyllite fragments are lustrous slabs that lie subparallel to the bedding and give the rocks in which they are abundant a slight bluish cast. The sandstone of the beds commonly contains scattered pebbles and cobbles and, unlike that of the conglomerate matrix, often displays crossbedding in sets ranging in thickness from 0.5 to 2.0 feet (fig. 28*A*).

In a few places, light- to medium-gray fissile siltstone and silty shale is intercalated with the sandstone. These rocks commonly show symmetrical ripple marks and small-scale crossbedding (fig. 28*B*). Muscovite is an abundant detrital constituent and imparts a lustrous sheen to the bedding surfaces. In a few places, the silty shale contains




*A*




*B*

FIGURE 28.—*A*, Coarse sandstone of conglomerate and sandstone unit at Little Pybus Bay; note scattered pebbles and large-scale crossbedding in layer below Brunton compass. *B*, Fine-grained sandstone of the conglomerate and sandstone unit at Little Pybus Bay; note symmetrical ripple bedding at top and small-scale (0.5–1.0 in.) crossbedding sets near middle of bed.

layers of carbonized plant fragments and coaly material a few millimeters thick.

The calcareous sandstone consists of rounded to subangular grains of the following kinds embedded in a calcareous matrix: quartz (10–15 percent), quartzite (5–10 percent), partially sericitized, multiply twinned plagioclase (10–20 percent), phyllite (10 percent), biotite (2–5 percent), muscovite (1–5 percent), quartzofeldspathic aggregates (2–5 percent), graywacke (0–1 percent), and chert (trace). The calcareous matrix, which averages about 40 percent of the rock, consists of a cloudy mosaic of anhedral calcite crystals containing a few frayed patches of fine detrital grains and authigenic sericite. These patches seem to be remnants of an original micaceous-detrital matrix (similar to that of the micaceous sandstone) that has been almost completely replaced by calcite. The calcite hase also partially replaced the larger detrital grains, and the result is a greater percentage of matrix in the calcareous sandstone than in the noncalcareous sandstone (average 10 percent); plagioclase grains have been the most completely replaced.

Because of the abundant rock fragments and the calcite cement or matrix, the calcareous sandstone would ordinarily be classified as lithic arenite in Gilbert's classification (in Williams and others, 1954, p. 297). However, the evidence above suggests that the original matrix consisted of a micaceous detrital mixture, and hence these rocks were probably originally lithic wacke.

The micaceous sandstone contains grain types similar to those of the calcareous types but contains a much greater amount of phyllite (30 percent or more). The phyllite is a fine-grained rock that contains abundant sericite showing a strong preferred orientation parallel to a prominent foliation surface; microfolds in this foliation surface are common. The matrix, which averages about 10 percent of the rock, consists of a sericite and chlorite mixture containing a few calcite patches and scattered fine detritus. The grains are either in contact with one another or separated by a thin layer of micaceous matrix. Dark reddish-brown biotite, partly altered to chlorite, occurs sparsely as thin flakes bent around competent grains. These rocks are also lithic wacke, although some contain slightly less than the requisite 10 percent matrix.

## ADMIRALTY ISLAND VOLCANICS

### STRATIGRAPHY

The name Admiralty Island Volcanics is here proposed for the thick sequence of gently dipping andesitic and basaltic flows and minor rhyolitic breccia and tuff that crops out in the southwestern part of the Pybus-Gambier area. It is typically exposed west and north of

FIGURE 29.—Terrain west of Canary Cove, showing gently dipping flows of the Admiralty Island Volcanics.

Little Pybus Bay and extends beyond the area, and covers about 300 square miles in southern Admiralty Island (Lathram and others, 1960). The volcanic rocks rest conformably upon the unnamed conglomerate and sandstone unit in the Little Pybus Bay area (p. 73; fig. 27*B*), but from Cannery Cove northwestward they overlie strongly deformed rocks of pre-Tertiary age with a marked angular unconformity. The Admiralty Island Volcanics is overlain by scattered unconsolidated deposits of Quaternary age.

The formation attains a thickness of at least 9,500 feet west of Cannery Cove but thins southward to less than 5,000 feet near Little Pybus Bay. Individual flows range in thickness from 10 to 50 feet and form a regularly layered sequence in which some flows seem to persist for miles. The rugged topography underlain by the volcanics consists of alternating cliffs and gentle dip-slopes that reflect the thick layering and gentle dips of the flows (fig. 29). Fresh unaltered flow rock is dark gray to grayish black and weathers yellowish brown, reddish brown, greenish gray, and black. The most common type contains plagioclase phenocrysts set in a fine-grained or aphanitic groundmass. In their upper parts the flows commonly contain amygdales composed of chalcedony, calcite, or chlorite. The flows are generally massive and irregularly fractured (fig. 27*B*), but in a few places they display crude columnar jointing.

The Admiralty Island Volcanics is cut by numerous dikes, ranging in thickness from 0.25 inch to 20 feet, that have compositions similar to those of the flows. The dikes are also abundant in the older rocks in a zone about 1 mile wide that borders the outcrop of the volcanics, but beyond this zone dikes are scarce. This fact suggests that the Tertiary volcanism did not extend far beyond the present areal extent of the Admiralty Island Volcanics. Figure 30 shows the orientation of dikes in the prevolcanic rocks in the zone just described. The average dike orientation, striking N. 32° E. and dipping 75° to the south, is about normal to the axial planes of the second folds in the pre-Tertiary rocks (p. 9).

Alteration is widespread in both flows and dikes of the Admiralty Island Volcanics. The presence of chlorite and epidote imparts a greenish-gray color to the altered rocks. The relation of the altered rocks to the unaltered rocks is unclear because of the difficulty of tracing out individual flows or dikes in the rugged terrain. However, all gradations from unaltered to completely altered rocks occur in different localities, and suggest that zones of altered rock grade into unaltered rock. Altered and unaltered dikes have the same general orientation (fig. 30) and thus probably belong to the same episode of intrusion.

The Admiralty Island Volcanics ranges in age from late Eocene to Oligocene. The basal part at Little Pybus Bay is considered here to be late Eocene because of its conformity with the underlying conglomerate and sandstone unit and because of the concentration of volcanic fragments in the uppermost layers of the underlying conglomerate, which indicates that volcanism began before the end of conglomerate deposition (p. 73; fig. 27*B*). Fossil leaves of Oligocene age (J. A. Wolfe, written communication, 1961) occur in sandy shale interbedded with volcanic sandstone and conglomerate at Murder Cove, near the southern tip of Admiralty Island; these sedimentary strata are intercalated with the flows and breccias of the Admiralty Island Volcanics. The stratigraphic position of these strata is uncertain, but they appear to lie in the middle part of the volcanics and have a considerable thickness of flows above them.

Buddington and Chapin (1929, p. 266–267) described basaltic and andesitic lava flows underlain by sandstone and conglomerate of Eocene age south of Admiralty Island on Kupreanof, Kuiu, and Zarembo Islands. In addition, they found small outcrops of similar volcanic rocks on the Castle Islands in Duncan Canal and on small islands near Onslow Island in the Ketchikan district. Northwest of Admiralty Island volcanic flows and tuffs of possible Tertiary age occur on Pleasant Island and on the Sisters, in Icy Strait (Lathram and others, 1959).

Miller and others (1959, p. 22) considered the nonmarine sedimentary rocks of Tertiary age and overlying volcanic rocks cropping out

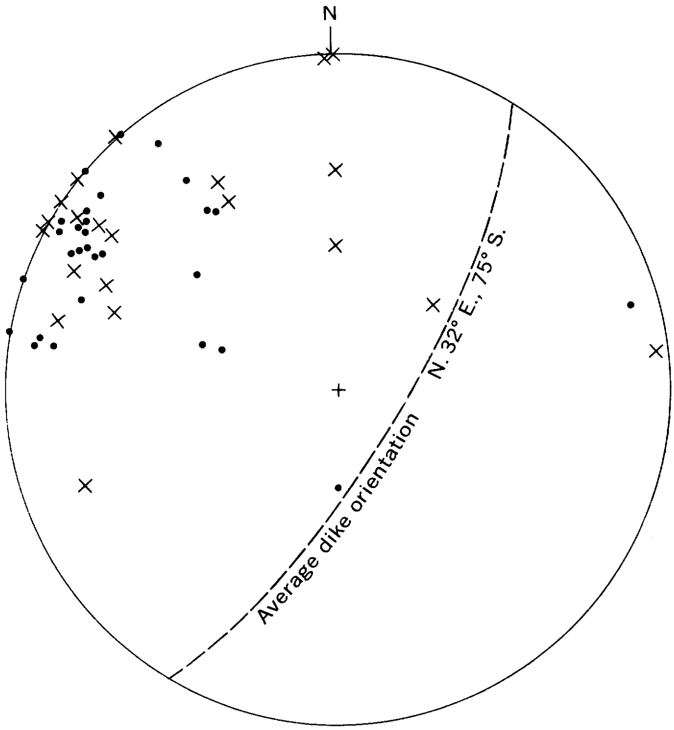



FIGURE 30.—Equal area, lower hemisphere plot of poles to 50 dikes associated with the Admiralty Island Volcanics; ·, unaltered dike; ×, altered dike.

on Admiralty, Kupreanof, and Kuiu Islands to be remnants of deposits in their Tertiary Admiralty trough.

## PETROGRAPHY

### UNALTERED ROCKS

Rocks here termed "unaltered" are either completely unaltered or are only slightly altered. They are composed largely of plagioclase, pyroxene, magnetite and (or) ilmenite, and less commonly of glass. The most common texture consists of plagioclase and lesser amounts of clinopyroxene phenocrysts embedded in a trachytic or pilotaxitic groundmass composed of abundant plagioclase microlites, interstitial pyroxene, and magnetite and (or) ilmenite. Two of the 19 thin sections studied contained a hyalopilitic groundmass in which the interstices between the plagioclase microlites are occupied by dark-brown, slightly devitrified glass. Intergranular and subophitic textures involving the above minerals (except glass) are not common and occur chiefly in dike rocks.

The Chayes system of modal analysis is not satisfactory for fine-grained rocks such as the present volcanic rocks (Chayes, 1956, p. 95); however, a few such analyses were made in order to check visual estimates. Modal analysis of a typical holocrystalline unaltered rock gave the following mineral composition (by volume): plagioclase, 60 percent; pyroxene, 20 percent; magnetite and (or) ilmenite, 5 percent; unresolvable material, 15 percent. Similar analysis of an unaltered glassy rock gave the following mineral composition: plagioclase, 42 percent; pyroxene, 8.0 percent; glass, 50 percent.

Plagioclase phenocrysts are distributed widely in the rocks studied, but their abundance varies greatly. The phenocrysts may be uniformly scattered through the rock or may occur in clots which commonly consist of larger phenocrysts partially enclosing smaller ones. The phenocrysts occur in two size groups: (1) larger phenocrysts ranging from 1.0 to 4.0 mm in length; and (2) smaller phenocrysts ranging from 0.25 to 0.75 mm in length. Both groups of phenocrysts are generally fractured, rounded, and corroded, but the smaller ones tend to be less rounded and less corroded. Phenocrysts of both groups are complexly and polysynthetically twinned and show a distinct oscillatory zoning. The larger phenocrysts range in composition from $An_{55}$ to $An_{88}$, but most fall in the range $An_{70}$ to $An_{84}$. The smaller phenocrysts appear to be more sodic in general, and the majority fall in the range $An_{54}$ to $An_{68}$.

The composition of the groundmass plagioclase could not be determined with accuracy because of the small size of the plagioclase crystals (average about 0.25 mm in length). Extinction angle determinations, in addition to a few universal stage measurements, indicate that the composition of the microlites lies in the range $An_{56}$ to $An_{66}$.

Clinopyroxene phenocrysts ranging in length from 0.3 to 1.0 mm are common but are far less abundant than plagioclase phenocrysts. The pyroxene of the phenocrysts is generally colorless, subhedral, and rounded and commonly shows simple twinning on (100); the clinopyroxene phenocrysts tend to form clots, and in some places penetrate plagioclase phenocrysts. A few universal stage measurements indicate that $2V_z$ lies in the range 52° to 70°, and the angle $Z \wedge c$ lies in the range 44° to 55°

The pyroxene grains of the groundmass are equant, and are generally smaller than the plagioclase microlites with which they are asociated. In a few seceions, however, the pyroxene grains of the groundmass are larger and tend to enclose the plagioclase ophitically. Both colorless and pleochroic types are common; in the latter, which may be titanaugite (Winchell and Winchell, 1951, p. 417), the pleochroism is Z=violet and X=pale yellowish brown.

The chief opaque minerals are metallic gray in reflected light, and commonly show octahedral sections characteristic of magnetite and angular skeletal form common in ilmenite. Both minerals are probably present. The opaque minerals occur largely as finely disseminated grains in the groundmass, and less commonly as larger crystals comparable in size to the pyroxene crystals.

### ALTERED ROCKS

The alteration of the rocks of the Admiralty Island Volcanics resembles propylitization as Wilshire (1957, p. 244–245) used the term. Wilshire defines propylitization as the process of alteration of calc-alkaline or calcic volcanic rocks, unattended by deformation, which produces in andesites some combination of the following secondary minerals: epidote, albite, chlorite, and calcite. The chief alteration products found in the rocks of the Admiralty Island Volcanics are chlorite, calcite, sericite, and epidote; albite, magnetite and (or) ilmenite, and quartz are less important alteration products.

The groundmass appears to be the most susceptible to alteration and is commonly altered where the phenocrysts are only slightly altered. In the last stage of alteration, both the phenocrysts and the groundmass are composed of the alteration products listed above.

Plagioclase is most commonly altered to sericite, epidote, and calcite (fig. 31) ; in a few places it is also partially replaced by irregular masses of clear albite. These minerals may be present in any combination in a given specimen. The alteration products occur commonly along the cleavage and other fractures in the incipient stages; the cores of the plagioclase crystals seem to be the first to be attacked. A common type of alteration is one in which partially sericitized plagioclase is partially replaced by a mosaic of epidote and a cloudy aggregate of calcite. In a few rocks the plagioclase is entirely altered to a fine aggregate of sericite and an irregular mass of clear albite.

Both phenocrystic and groundmass pyroxene crystals are commonly completely altered where plagioclase is only slightly altered. The chief alteration products are chlorite, epidote, calcite, magnetite and (or) ilmenite, and less commonly tremolite (?). The magnetite, altered in places to limonite, occurs chiefly as small grains in chlorite in and around the margins of altered pyrozene crystals. A colorless amphibole, possibly tremolite, occurs in one specimen as saw-toothed growths on the pyroxene crystals (fig. 32).

Chlorite most commonly shows a pleochroism from Z=pale yellowish green to X and Y=pale green and an anomalous low-order blue birefringence. The chlorite occurs ordinarily as a fine flaky aggregate without a noticeable preferred orientation; in a few places it assumes a spherulitic habit.

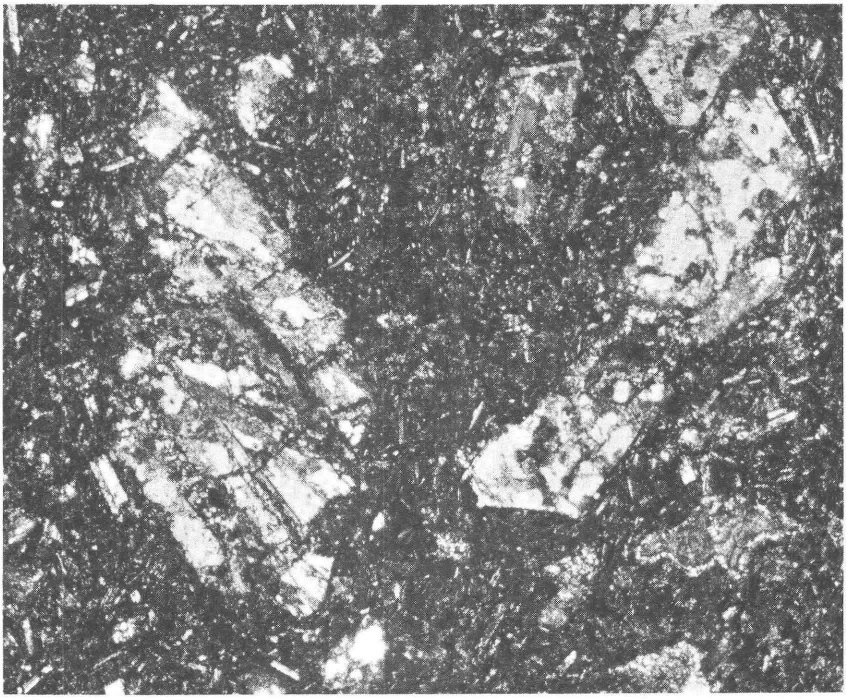


FIGURE 31.—Photomicrograph of partially altered andesitic flow, Admiralty Island Volcanics, showing plagioclase phenocrysts (white), partially replaced by a fine-grained mixture (cloudy gray) composed chiefly of calcite and lesser amounts of sericite and chlorite; groundmass is composed largely of microlites of plagioclase, chlorite, calcite, and magnetite and (or) ilmenite (crossed nicols, ×40).

Calcite occurs either as cloudy fine aggregates or as large clear crystals. Epidote occurs both as mosaics and as small isolated equant subhedral crystals; its pleochroism is Z=greenish yellow and X=pale greenish yellow.

Quartz is a minor alteration product in a few rocks in which it occurs in small irregular individual crystals in and around plagioclase phenocrysts that have been almost completely altered to epidote, sericite, and calcite. In these rocks it is also present as very fine mosaics sparsely scattered through the groundmass.

#### TUFFS, BRECCIAS, AND OTHER MINOR ROCK TYPES

The minor pyroclastic rocks are generally of a lighter color than the flow rocks. The few examined are highly altered rocks composed of angular to subangular fragments of sericitized plagioclase and chloritic volcanic rock fragments, some of which contain abundant quartz mosaics, set in a matrix composed of a mass of shardlike forms now composed of microcrystalline quartz, clay minerals, and possible

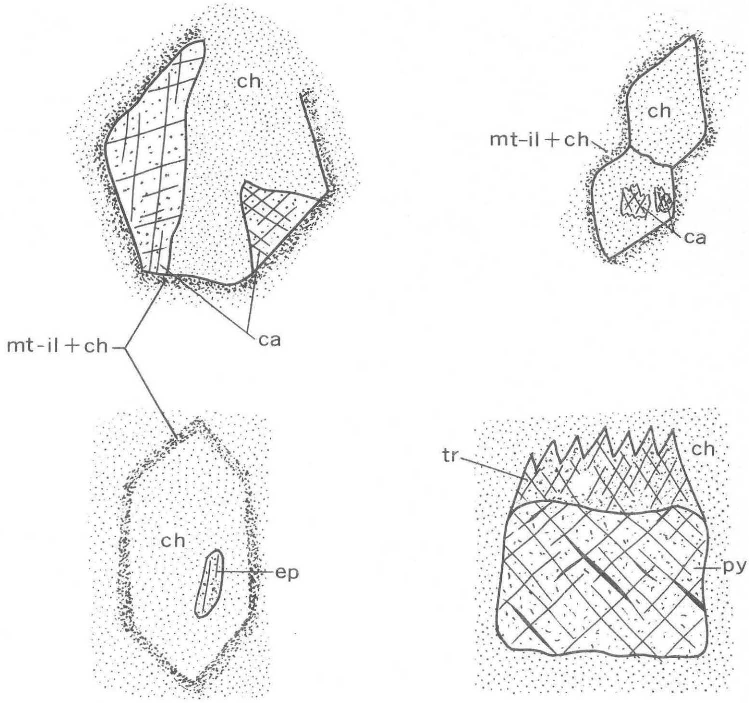



FIGURE 32.—Sketches from thin section of altered pyroxene crystals ; ch, chlorite ; ep, epidote ; py, pyroxene ; mt-il and ch, magnetite and (or) ilmenite and chlorite ; ca, calcite, tr, tremolite.

zeolites. Small crystals of zircon and apatite are minor constituents in these rocks. No glass was observed.

A medium light-gray, aphanitic flow occurring in one locality contains abundant pores or vesicles, some of which are filled with epidote. The rock consists of scattered remnants of plagioclase phenocrysts averaging about 1.0 mm in length in a pilotaxitic groundmass composed largely of plagioclase microlites, equant epidote crystals, and interstitial chlorite. The plagioclase phenocrysts are partially replaced by pale-yellow mosaics and abundant fine inclusions of epidote; sericite is present in minor amounts. The plagioclase phenocrysts have a composition in the range $An_{13}$ to $An_{16}$.

### CHEMICAL COMPOSITION

Because of the variability of the plagioclase composition, the classification of the rocks of the Admiralty Island Volcanics is based on their chemical composition. Four rapid-rock analyses were made of unaltered or slightly altered rocks; the slightly altered rocks contain small amounts of chlorite, sericite, and calcite (table 3, nos. 1–4).

TABLE 3.—*Analyses of rocks from the Admiralty Island Volcanics*

[Rapid-rock analyses by Paul L. D. Elmore, Ivan H. Barlow, Samuel D. Botts, and Gillison Chloe, U.S. Geol. Survey]

| Constituent | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 47.4 | 53.9 | 55.9 | 57.9 | 44.1 | 55.2 | 58.9 |
| $Al_2O_3$ | 18.0 | 16.6 | 18.3 | 17.8 | 15.4 | 15.8 | 15.1 |
| $Fe_2O_3$ | 2.2 | 1.6 | 1.1 | 1.1 | 1.6 | 3.2 | .85 |
| FeO | 7.9 | 5.6 | 5.0 | 4.9 | 7.8 | 6.6 | 4.0 |
| MgO | 5.5 | 4.4 | 2.7 | 3.8 | 5.2 | 3.3 | 2.4 |
| CaO | 10.5 | 7.7 | 7.7 | 7.3 | 9.0 | 6.0 | 4.4 |
| $Na_2O$ | 2.5 | 3.5 | 3.6 | 3.6 | 2.9 | 4.6 | 3.9 |
| $K_2O$ | .20 | .48 | .98 | 1.4 | 2.0 | 1.2 | 1.8 |
| $H_2O$ | 2.6 | 1.7 | 2.5 | .92 | 4.3 | 1.8 | 2.7 |
| $TiO_2$ | 1.6 | 1.1 | 1.1 | .91 | 2.0 | 1.8 | .82 |
| $P_2O_5$ | .20 | .22 | .24 | .18 | .68 | .40 | .18 |
| MnO | .14 | .14 | .10 | .10 | .15 | .14 | .08 |
| $CO_2$ | 1.4 | 2.6 | .26 | .05 | 4.5 | .05 | 4.8 |
| Total | 100 | 100 | 99 | 100 | 100 | 100 | 100 |
| Powder sp gr | 2.80 | 2.77 | 2.70 | 2.82 | 2.80 | 2.85 | 2.74 |

1. Unaltered porphyritic basalt from near base of section on west shore of Little Pybus Bay.
2. Slightly chloritized, nonporphyritic andesitic basalt from north side of ridge top 1.3 miles east of head of South Arm of Hood Bay.
3. Unaltered glassy porphyritic basaltic andesite from ridge top near altitude 2,627 ft, 1.6 mile N. 30° W. from head of Eliza Harbor.
4. Slightly chloritized, porphyritic andesite from east shore at head of Eliza Harbor.
5. Altered lava from top of peak 3,626 ft altitude, 2.7 miles east of head of Eliza Harbor.
6. Altered lava from north side of ridge top 0.8 mile south of South Arm of Hood Bay.
7. Altered dike from shore north of Cannery Cove, 0.5 mile west of triangulation station Dave.

In addition, three analyses of almost completely altered rocks were made (table 3, nos. 5–7). The analyses of the unaltered rocks show a range in $SiO_2$ composition from 47.4 to 57.9 percent, most containing 53.9 to 55.9 percent $SiO_2$. Williams (1950, p. 234–235) calls those rocks containing less than 54 percent $SiO_2$ basalts, and those containing more than 54 percent $SiO_2$ andesites. On this basis, specimen 1, with 47.4 percent $SiO_2$, is a basalt, and specimen 4 is an andesite; the rest range from andesitic basalts to basaltic andesites. Number 1, most basic of the seven specimens, was collected from a flow near the base of the formation, whereas the rest were collected at higher stratigraphic levels.

According to Wilshire (1957, p. 257), the propylitized andesites at Ebbetts Pass, Calif., show a decrease in $Al_2O_3$, $K_2O$, and $Na_2O$ in comparison to unaltered andesites. He attributed the loss of $Al_2O_3$ and $Na_2O$ in large part to the replacement of plagioclase by calcite. These changes in composition cannot be followed closely in the present analyses because analyses could not be made of unaltered and altered parts of the same rock body as in Wilshire's work. In the analyses of table 3, $K_2O$ and $Na_2O$ show no constant sense of change between altered and unaltered rocks; however, $Al_2O_3$ is distinctly lower in the altered rocks. The intermediate $Al_2O_3$ percentages of specimens 2 and 4 may reflect the degree of alteration in these rocks.

## QUATERNARY SYSTEM

### UNCONSOLIDATED DEPOSITS

Unconsolidated deposits of glacial clay and gravel and recent alluvial gravel, all of which are too small to show on the geologic map, are scattered along the floors of most stream valleys. Fossils of marine invertebrates were found in glacial clay at two localities. One locality, containing mollusk shells, is at an altitude of 150 feet in the channel of a stream flowing northeastward into southeastern Gambier Bay (fig. 33, loc. 37). The other locality, containing Foraminifera tests, occurs at an altitude of 475 feet in the channel of a stream lying west of False Point Pybus that flows east and south into Stephens Passage (fig. 33, loc. 38). Thus sea level in glacial times was at least 475 feet higher than at present.

## NORTHWESTERN PYBUS-GAMBIER AREA

The northwestern part of the Pybus-Gambier area lying west of Gambier Bay and northwest of the Gambier fault is poorly known and has been mapped on a reconnaissance scale only (pl. 1) in order to complete the geologic mapping of the Sitka B–1 quadrangle. In general, it is a poorly exposed area of plutonism and contact metamorphism. Because of the metamorphism and the lack of exposures in this area, the rock units mapped elsewhere in the Pybus-Gambier area could not be recognized with certainty. The structure is, therefore, poorly known; the rocks are in general layered, but in most places bedding and foliation could not be distinguished from one another. For this reason a special map symbol that does not distinguish between bedding and secondary foliation is used in plate 1 for the attitudes of the dominant planar structure present.

The southeastern boundary is taken at the Gambier fault; although this fault appears to bring metamorphic rocks on the north against nonmetamorphic rocks on the south, the country along the fault is poorly exposed and the relations are by no means clear. To the east, the metamorphic rocks of the Gambier Bay Formation appear to grade westward into coarser grained but similar varieties in the contact zones of the plutons. Four generalized units are mapped as follows:

*Hornfels.*—Mostly thinly layered dark green amphibole-bearing hornfels containing scattered minor units of dark-gray thin-bedded, fine sugary quartzite that is probably a metachert. The rocks in general are not obviously foliated, but in a few places they are schistose and indistinguishable from the greenschist unit. Tight small-scale folds are common. The unit may include metamorphic equivalents of the Hood Bay, Cannery, and Hyd Formations.

*Greenschist.*—Complexly folded greenschist and subordinate amounts of fine-grained mica schist. These rock types are in general similar to the greenschist of the Gambier Bay Formation but are more coarsely crystalline; the coarser grain size is at least in part due to contact metamorphism. The unit may be roughly equivalent to the noncalcareous parts of the Gambier Bay Formation.

*Marble.*—Light-gray to white thick-bedded medium- to coarse-grained marble containing minor units of medium-gray, thinly platy fine- to medium-grained marble and greenschist. The marble locally contains abundant needles which in some places are wollastonite and in others are tremolite. A coarse foliation is commonly present, but its relation to bedding is not known. The dip slope of the thick-bedded marble weathers to a rough karst topography. The marble occupies topographically high positions and may overlie part of the greenschist; it may be equivalent to the marble member of the Gambier Bay Formation.

*Diorite.*—Only the border zones of the two plutonic bodies have been sampled. The most common rock type seen is a porphyritic hornblende-andesine diorite containing abundant phenocrysts of andesine ranging from 5 to 10 mm in length. Samples from the contact zone of the northernmost pluton are rich in magnetite and pyroxene. The plutons in places intrude rocks of all three of the above metamorphic units; generally the grain size of the metamorphic rocks increases toward the contact. The country rocks of the contact zones are commonly cut by a complex of veins of the diorite. Such effects appear to be limited to zones ranging in width from 50 to 100 feet, beyond which the only contact effects seen are those of crystallization.

## GEOLOGIC HISTORY

### DEVONIAN AND DEVONIAN(?) DEPOSITION

The known history of the Pybus-Gambier area began with the deposition of the Gambier Bay and Hood Bay Formations. These two formations may have been deposited contemporaneously with an interfingering of their deposits. A subsiding marine trough occupied the region and received, in the Gambier Bay area, alternate layers of mafic volcanic rocks and fine-grained muddy sediments; siliceous types were common among the latter. Shallow mafic and ultramafic dikes and sills intruded the layered rocks. Probably in Middle Devonian time, possibly toward the end of the sedimentation, the deposition of calcareous mud prevailed, and other types of deposits were temporarily diminished. After several hundred feet of calcareous mud was deposited, normal, more argillaceous sedimentation resumed.

Fine-grained muddy sediments similar to those of the Gambier Bay

Formation, but not accompanied by mafic volcanic rocks, characterized the deposition of the Hood Bay Formation in the western Pybus-Gambier area. Thousands of feet of thin-bedded, siliceous and non-siliceous mud, rich in organic material, accumulated in an anaerobic environment below the wave base. Occasionally turbidity currents brought in muddy sand layers; locally, thick lenses of impure calcareous mud rich in organic material accumulated.

Both the Gambier Bay Formation and the Hood Bay Formation are composed in their sedimentary phases of fine-grained clastic sediments; lack of a nearby source of coarse clastic material is thus indicated. Therefore, the volcanism of the Gambier Bay Formation was submarine, and the volcanic rocks were not undergoing subaerial erosion locally.

### POST-GAMBIER BAY-HOOD BAY AND PRE-CANNERY DEFORMATION

Sometime after the deposition of the Gambier Bay Formation in Middle(?) Devonian time and before the deposition of the Cannery Formation in Permian time, the area was folded into broad, open warps and was elevated into the zone of erosion.

### PERMIAN DEPOSITION

A subsiding marine trough again occupied the area in Permian time, and several thousand feet of the thinly bedded siliceous and non-siliceous fine-grained sediments of the Cannery Formation was deposited. Occasional turbidity currents deposited muddy volcanic sand in thin layers; a few more viscous currents deposited massive chaotic coarser deposits of sand which contain scattered limestone fragments. Submarine volcanism, possibly emanating from the northeast, extruded a few layers of pillow lava in the Gambier Bay area. The fine-grained volcanic detritus must have been derived from a more distant source; perhaps the local volcanism was entirely submarine. The silica of the abundant Radiolarian-bearing siliceous sediments may have been derived from submarine volcanic eruptions and hot springs.

An episode of comparative stability followed the deposition of the Cannery Formation during which clear-water conditions prevailed and very little detrital material reached the area. During this time about a thousand feet of calcareous mud and limestone debris accumulated; brachiopods and bryozoans flourished. Before consolidation, the silica in this deposit was concentrated into layers and nodules; numerous calcite shells were silicified during or following this process. After the concentration of the silica, but before lithification, the calcite of the deposit was replaced by dolomite. Calcareous fossils were largely destroyed by the dolomitization, but those that had been previously replaced by silica were preserved. This deposit, the Pybus Dolomite, may not have extended north to the Gambier Bay area and may have pinched out again to the south near Little Pybus Bay.

### POST-PYBUS AND PRE-HYD UPLIFT

The deposition of Pybus Dolomite was followed by emergence and erosion; a slight warping appears to have accompanied the uplift. The Pybus Dolomite, now lithified, was stripped from part of the area by erosion, which also bevelled the slightly tilted beds of the Cannery Formation.

### TRIASSIC DEPOSITION

Deposition of the Hyd Formation began with the accumulation of coarse detritus upon the slightly irregular erosion surface; chert and dolomite debris collected upon the Pybus Dolomite, and debris composed of bedded chert and argillite collected upon the Cannery Formation. This close correlation between deposit and underlying terrane suggests land-laid deposition in an arid region having inadequate water available to remove the erosional debris. Before the close of the coarse clastic deposition, volcanism, centered north of the area, laid down thick flows of mafic volcanic rock. The last part of the breccia deposition may have been marine, inasmuch, as the Late Triassic seas transgressed the area. Carbonate deposition followed that of the coarse clastic sediments, which apparently ceased when the area and the surrounding country were completely inundated. After a few hundred feet of dark calcareous mud was deposited, an interbedded sequence of fine-grained muddy sediments began accumulating, and a few hundred feet of thinly bedded dark-colored siliceous, calcareous, and argillaceous mud was deposited. Occasional turbidity currents deposited thin beds of fine-grained muddy sand in the quiet, slightly reducing environment. Submarine volcanism continued throughout the interval of sedimentation, sending out flows of pillow lava from centers to the north of the area. The detritus is largely composed of andesitic volcanic debris, but its general fine-grained character suggests that it was derived from a distant volcanic source and that the local centers of volcanism were largely submarine.

### POST-HYD AND PRE-SEYMOUR CANAL UPLIFT

After the deposition of the Hyd Formation, the area was brought into the zone of erosion by uplift. Any warping accompanying this

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uplift must have been very mild, as it has not been detected in the field.

### JURASSIC AND CRETACEOUS DEPOSITION

The sea again transgressed the area in Late Jurassic time, initiating the deposition of the Seymour Canal Formation in a rapidly subsiding marine trough. Chiefly fine-grained muds accumulated in the Pybus-Gambier area, which must have been located some distance offshore from a dominantly andesitic volcanic source area. Often, however, turbidity currents swept down the sides of the trough and deposited thin layers of muddy sand. Less often, possibly only in the later part of the deposition, submarine landslides came down the sides of the trough and deposited large masses of chaotic coarse detritus at the break in slope. Parts of these landslides may have continued slightly farther into the trough as extremely viscous currents and deposited thick chaotic beds of coarse muddy sand. The landslide deposits disrupted and intruded the fine-grained sediments already deposited.

At or near the close of the deposition, volcanism in the eastern part of the area extruded the andesitic flows and breccias of the Brothers Volcanics. The detritus of the Seymour Canal Formation is in general volcanic, and it is possible that part of it was derived from contemporaneous volcanism to the east, of which the Brothers Volcanics may be a product. The deposition ended in Early Cretaceous time after possibly 10,000 feet of sediment had been deposited.

### POST-SEYMOUR CANAL AND PRE-EOCENE DEFORMATION

The deposition of the Seymour Canal Formation was followed, or perhaps was brought to a close, by strong deformation in Cretaceous time. The conglomerates of the Seymour Canal Formation may have resulted from early stages of this deformation.

During the first post-Seymour Canal deformation, the rocks of the Pybus-Gambier area were compressed into gently plunging, nearly isoclinal folds having subvertical north-northwest-striking axial planes. Axial-plane foliation developed in the rocks of the Gambier Bay and Seymour Canal Formations.

During the second deformation, renewed compression, oriented about northeast-southwest as during the first, broke the area into elongate blocks by northwest-striking thrust faults. West of the False Point Pybus fault zone, second folds formed with northwest-striking axial planes and axial plunges ranging from moderate to subvertical formed in the limbs and axial planes of the first folds.

The third deformation, involving renewed compression oriented about as before, resulted in the formation of kink folds in the Gambier Bay Formation and possibly the formation of fractures and faults in the nonmetamorphic pre-Tertiary rocks.

### PLUTONISM

The deformation just described may have been closely followed by plutonic intrusion and contact metamorphism in the northwestern part of the Pybus-Gambier area.

### TERTIARY DEPOSITION

The post-Seymour Canal deformation left the area emergent and undergoing erosion. In late Eocene time a subaerial basin formed, perhaps by faulting, in the southwestern part of the area. The rugged mountains cut in the folded Mesozoic and Paleozoic rocks adjacent to this basin poured down coarse detritus into it, probably forming steep alluvial fans through which cut steep-gradient streams. The climate was probably humid, and lakes and swamps, in which plant life flourished, formed in the central parts of the basin. After about 2,000 feet of coarse gravel had accumulated, volcanic fissure eruptions began to flood the southwestern country with flows of basalt and andesite. The flows may not have extended to the northeastern shore of Pybus Bay. At least 9,500 feet of flows accumulated, forming the Admiralty Island Volcanics.

### POST-ADMIRALTY ISLAND UPLIFT

The Pybus-Gambier area was subjected to high-angle faulting and mild warping after or in the final stages of the volcanic eruption. Perhaps subsidence in the region of greatest thickness, near the southwest corner of the area, is in part responsible for the deformation of the Admiralty Island Volcanics themselves. The area remained largely dry land throughout the remainder of Tertiary time.

### QUATERNARY DEPOSITION

A rise in sea level in glacial times resulted in the deposition of fossil-bearing marine glacial clay in stream valleys at various levels as much as 475 feet above the present sea level.

## FOSSIL LISTS AND LOCALITIES

The following is a complete list of fossil collections made during the present investigation. The numbers before the description of each fossil locality are as follows: First number refers to fossil locality shown in figure 33, second number is field station number, and third is U.S. Geological Survey locality number.

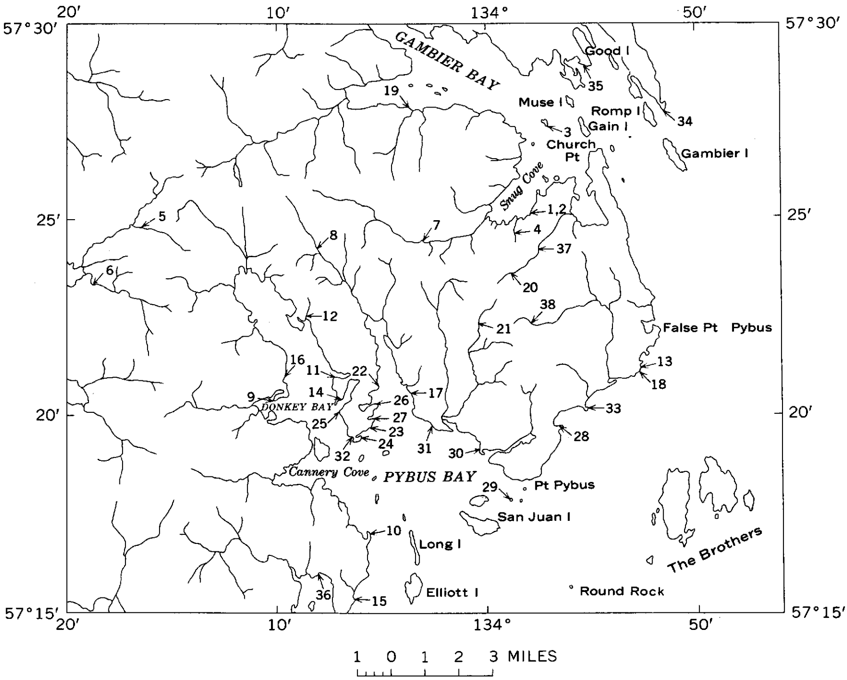


**Figure 33.—Index map showing fossil localities. See text, page 93, for explanation of numbers.**

## GAMBIER BAY FORMATION

1. 58ALy448; dark-gray marble on point of land 0.9 mile south-southwest of Gem Point on south shore of Snug Cove, Gambier Bay.
   Digonophylinid coral, indet.
   *Thamnopora*? sp.
   *Amphipora*? sp.
2. 58ALy448a; same lithology as 448; on northwest side of same point of land.
   Colonial coral,
   hydrozoan, or bryozoan, unidentifiable
3. 58ALy456; dark-gray marble on south point of Muse Island, Gambier Bay.
   *Thamnopora*? sp.
   *Amphipora*? sp.
4. 59ALy54; dark-gray marble in creek bed 1.7 miles south-southwest of Gem Point, Snug Cove, Gambier Bay.
   Dendroid tabulates (*Thamnopora-Cladopora* type) and other corals, poorly preserved

## HOOD BAY FORMATION

5. 59ALy240; dark-gray clastic limestone 2.5 airline miles upstream from mouth of stream flowing southwest into North Arm of Hood Bay.
   Branching favositid corals, indet.
   Stromatoporoids, indet.

6. 59ALy276; dark-gray, calcareous argillite interbedded with grayish-black chert 0.5 mile upstream from mouth of stream flowing northwest into North Arm of Hood Bay.
   *Atrypa*? sp.

## CANNERY FORMATION

7. 59ALy38 (USGS 18491–PC); massive, calcareous, coarse-grained graywacke in stream bed 2.0 airline miles from mouth of stream flowing east into the west end of Snug Cove, Gambier Bay.
   ?*Allotropiophyllum* sp.
   Bryozoan fragments, indet.
   Echinoderm debris, indet.
8. 59ALy278; massive calcareous coarse-grained graywacke in thin-bedded chert and argillite section in bed of creek flowing southeast into head of north arm of Pybus Bay, 2½ miles from mouth.
   Bifoliate fistuliporoid bryozoan debris
   Ramose bryozoan debris
   Fenestrate bryozoan debris (includes *Protoretepora* or *Synocladia*)
9. 58ALy128; massive calcareous coarse-grained graywacke in thin-bedded section of chert and argillite on tip of west-trending peninsula, north shore of Donkey Bay, Pybus Bay.
   Fistuliporoid, trepostomatous, stenoporoid, and fenestrate cryptostomatous bryozoan debris
   Foraminiferal debris
   Algal debris
   Echinoderm debris

## PYBUS DOLOMITE

[Fossils marked by asterisk are extremely abundant in that collection]

10. 57ADu69 (USGS 18345–PC); light brownish-gray, yellowish-gray-weathering sugary dolomite and bluish-white chert nodules in beach outcrops on north end of peninsula on the southwest shore of Pybus Bay 1.2 miles west of the north end of Long Island; exact stratigraphic position unknown; basal 25 feet of exposed section.
    Echinoderm debris, indet.
    Bryozoan fragments, indet.
    *Linoproductus*? sp.
    *Waagenoconcha*? sp.
    **Stenoscisma* cf. *S. plicata* (Kutorga)
    *Neospirifer* sp.
    *Licharewia*? sp.
    *Squamularia*? sp.
    **Spiriferella keilhavii* (von Buch)
    *Spiriferella* sp.
    "*Dielasma*" cf. "*D.*" *plica* (Kutorga)
11. 58ALy195a (USGS 20591–PC); medium-gray, reddish brown-weathering clastic dolomite in beach outcrop on north shore of peninsula on northeast shore of main arm of Pybus Bay 1.9 miles N. 10° E. of triangulation station Hyd; probably near the top of the section.
    Echinoderm debris, indet.
    Bryozoan fragments, indet.
    *Derbyia* sp.

*Strophomenoid brachiopod, n. gen.
*Chonetina*? sp.
**Anidanthus* aff. *A. alatus* Cooper
*Waagenoconcha* sp.
*Spiriferella* sp. (small)
*Squamularia* sp.
*Crurithyris*? sp.
*Rhynchopora* sp.
Bellerophontacean gastropod, indet.

## HYD FORMATION

### LIMESTONE MEMBER

12. 58ALy290; in creek bed, altitude 90 feet, near northeast shore of main arm of Pybus Bay, 2.4 miles north of triangulation station Dro.
*Montlivaltia?*—(or at least a scleractinian solitary coral)

13. 58ALy330; small island close to shore 1.15 miles southwest of triangulation station Pybus near False Point Pybus; from yellowish-brown weathering limestone (fig. 13*B*).
*Tropites* (*Tropites*) sp.
Clionitid ammonites (two species)
*Cosmonautilus* sp.
*Pleuronautilus* sp.
Belemnoid, undet.
*Gervilleia* sp.
Trigoniid pelecypod ("*Myophoria*" sp.)

### ARGILLITE MEMBER

14. 58ALy204 (includes 57ADu74 and 75); northeast shore main arm of Pybus Bay 0.4 mile northeast of triangulation station Hyd.
*Monotis subcircularis* Gabb
*Heterastridium* sp.

15. 58ALy36; west side of West Channel, Pybus Bay, 1.2 miles southwest of light on Grave Island.
*Monotis subcircularis* Gabb

16. 57ADu77; southwest shore of main arm of Pybus Bay about 0.5 mile northwest of triangulation station Dro.
*Halobia* sp. A.

17. 58ALy221 (includes 57ALy101); east shore north arm of Pybus Bay near line between secs. 20 and 29, T. 52 S., R. 71 E.
*Monotis subcircularis* Gabb
*Heterastridium* sp.

18. 58ALy328; shore 1.4 miles southwest of triangulation station Pybus near False Point Pybus.
*Halobia*? sp.
*Attractites*-like belemnoids
Crushed or fragmentary ammonoids, indet.

19. 58ALy465; south shore of western Gambier Bay, 1.3 miles west-southwest of triangulation station Tie.
Impression of a ribbed ammonite, indet.

20. 58ALy494; in creek bed, altitude 300 feet, 2.3 miles south-southeast of Gem Point, Gambier Bay.
Scleractinian solitary coral, indet.

21. 58ALy496a; in creek bed, altitude 460 feet, 3.6 miles north of triangulation station Deer on north shore of Pybus Bay.
    Shell fragments with finely spaced ribbing, probably *Halobia*

## SEYMOUR CANAL FORMATION

22. 57ADu71 (Mes. loc. 27334); reefs near point of peninsula on western shore of the north arm of Pybus Bay 0.6 mile north of triangulation station Bob; in argillite.
    *Buchia rugosa* (Fischer)
23. 57ADu72 (Mes. loc. 27336); shore west of mouth of north arm of Pybus Bay 0.7 mile south-southwest of triangulation station Bob; in argillite.
    *Phylloceras* sp.
24. 57ADu73 (Mes. loc. 27335); reefs off tip of northeast-projecting peninsula near tip of major peninsula separating the arms of Pybus Bay 2,000 feet east of cabin; in argillite.
    *Buchia rugosa* (Fischer)
25. 58ALy87 (Mes. loc. 27066); on beach at entrance to narrow bay, northeast shore of the main arm of Pybus Bay 1,000 feet southeast of triangulation station Hyd; in argillite.
    *Buchia* sp.
    *Spiticeras*? sp.
26. 58ALy230d (Mes. loc. 27067); on beach near mouth of north arm of Pybus Bay 500 feet north of triangulation station Bob; in argillite.
    *Camptonectes* sp.
27. 58ALy231a (Mes. loc. 27068); on beach at entrance to small bay west of the entrance to the north arm of Pybus Bay 2,000 feet south of triangulation station Bob; in argillite.
    *Buchia* cf. *B. rugosa* (Fischer)
28. 58ALy260 (Mes. loc. 27069; also 57AL114a, b, c, Mes. loc. 27332, 27333, 27334); on beach on south shore of bay 1.5 miles northeast of Point Pybus; in argillite.
    *Buchia* cf. *B. volgensis* (Lahusen)
    *Spiticeras*? sp.
29. 58ALy266 (Mes. loc. 27070, 27071); on small island 1.0 mile southwest of Point Pybus; in argillite.
    *Buchia rugosa* (Fischer)
30. 58ALy270b (Mes. loc. 27072); on the north shore of Pybus Bay 1,000 feet north of triangulation station Deer; in argillite.
    *Buchia rugosa* (Fischer)
31. 58ALy275 (Mes. loc. 27073); on north shore of Pybus Bay 1.6 miles northwest of triangulation station Deer; in argillite.
    *Buchia rugosa* (Fischer)
32. 58ALy278 (Mes. loc. 27074); on beach east of mouth of the main arm of Pybus Bay 250 feet east of cabin; in argillite.
    *Pleuromya* sp.
    *Lima* sp.
33. 58ALy324a (Mes. loc. 27075); low reef near shore 2.2 miles northeast of Point Pybus; in argillite.
    *Buchia* sp.
34. 58ALy338 (Mes. loc. 27076, 27077); south tip of peninsula in eastern Gambier Bay 3,400 feet northeast of triangulation station Romp; in argillite.
    *Buchia* cf. *B. volgensis* (Lahusen)
    *Buchia* sp.

35. 58ALy409a (Mes. loc. 27078); south shore of peninsula in eastern Gambier Bay 0.8 mile northeast of triangulation station Nose; in argillite.
*Buchia?* sp.

## UNNAMED CONGLOMERATE AND SANDSTONE

36. (Mes. loc. WP–6115); light medium-gray micaceous fissile shale; in beach exposure exposure at head of Little Pybus Bay, about 1,000 feet N. 40° E. from north end of small wooded island near center of sec. 21, T. 53S., R. 71 E.
Conifers:
*Glyptostrobus* sp.
*Metasequoia glyptostroboides* Hu and Cheng
Cycads:
*Dioon praespinulosum* Hollick
Dicots:
*Laurus hamiltonensis* Hollick
*Malpoenna magnifica* Hollick
*Sassafras alaskanum* Hollick
*Dillenites microdentatus* Hollick

## QUATERNARY DEPOSITS

37. 58ALy512b; bluish-gray pebbly clay; in channel of stream flowing northeastward into southeastern Gambier Bay, altitude 150 feet.
Foraminifera, undet.
Pelecypods, undet.

38. 58ALy487; bluish-gray sandy clay; in channel of stream lying west of False Point Pybus, flowing east and south into Stephens Passage, altitude 475 feet.
Foraminifera, undet.

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