Gastineau Channel Formation, a Composite Glaciomarine Deposit Near Juneau, Alaska

GEOLOGICAL SURVEY BULLETIN 1394-C

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By ROBERT D. MILLER

CONTRIBUTIONS TO STRATIGRAPHY

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A description of the depositional environment and lithology of diamictons of late Pleistocene and early Holocene age.

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GASTINEAU CHANNEL FORMATION, A COMPOSITE GLACIOMARINE DEPOSIT NEAR JUNEAU, ALASKA

By ROBERT D. MILLER

ABSTRACT

The Gastineau Channel Formation is a heterogeneous sequence of glaciomarine materials exposed in the Juneau area, Alaska, that consist of pebbles and larger clasts dispersed through a fine-grained matrix of silt and sand. The age of the formation is late Pleistocene and early Holocene. The formation is named after Gastineau Channel, a fiord that separates the Juneau mainland from Douglas Island and along which exposures of the formation are especially common; the type area for the formation is the low-lying land along Gastineau Channel on the Juneau mainland and Douglas Island.

Three facies constitute the formation; the first facies, considered to be generally the oldest, is a stone-rich diamicton that is a till-like mixture of clasts within a matrix that is predominantly silt and sand; the second is a gravel-rich diamicton that is very hard and dense; the third facies is a sand-rich diamicton, the finest grained and least dense deposit of the three facies. Marine mollusks, barnacles, and Foraminifera are found in all facies of the formation.

Coarse fragments in the finer grained matrix in all three facies apparently were transported outward from shores by seasonal accumulations of sea ice and by berg ice broken from glaciers outside the immediate Juneau area. There is no evidence that large glaciers reached tidewater along Gastineau Channel or the other fiords for some considerable distance to the north of Juneau within at least the last 10,000 years.

On the basis of numerous radiocarbon determinations on shells of marine fauna in the three facies of the formation, the Gastineau Channel Formation is considered to be late Pleistocene and early Holocene in age.

INTRODUCTION

This report results from a geologic study of surficial deposits, in and near the Juneau urban area, as part of an earthquake hazards study of Alaskan coastal communities. Diamictons previously grouped as till or marine till were found to consist of mappable glaciomarine deposits traceable as a continuous unit over a considerable area.

DEFINITION

The Gastineau Channel Formation is here defined as that sequence of heterogeneous glaciomarine deposits of late Pleistocene and early Holocene age, consisting of pebbles and larger clasts dispersed through a fine-grained matrix of predominantly silt and sand, that is exposed in the Juneau area. Formal stratigraphic names have not previously been applied to unconsolidated deposits in the Juneau area of Alaska. Surficial deposits of various origins lie along the lower slopes of the mountains bounding the fiords and bays, and these deposits were studied in the Juneau area during the summers of 1965, 1966, 1968, and 1971.

The Gastineau Channel Formation is named after Gastineau Channel, a fiord that separates the Juneau mainland from Douglas Island and along which exposures of the formation are especially common. The formation is also well exposed along Montana Creek, a tributary of the Mendenhall River northwest of Juneau. The known extent of the Gastineau Channel Formation is shown in figure 1; the regional extent of the formation is not known, but apparently similar deposits are widespread in southeastern Alaska and southward into northwestern Washington (Armstrong and Brown, 1954; Easterbrook, 1963).

Three facies constitute the Gastineau Channel Formation. These facies are envisioned as having accumulated for the most part sequentially from the oldest to the youngest facies, but also as having accumulated in part simultaneously. The first facies, considered to be generally the oldest, is a gray to dark-bluish-gray stone-rich diamicton that is a till-like mixture of clasts within a generally compact and massive fine-grained matrix. The matrix consists of a heterogeneous accumulation of sand, silt, gravel, and clay-sized particles, in order of predominance. Cobbles and boulders, some as large as 10 feet across, are scattered through the deposit. Weakly developed lenticular and tabular layers or partings occur locally; shells of marine mollusks, barnacles, and Foraminifera are common. The second facies is a gray to dark-bluish-gray gravel-rich diamicton that consists mostly of closely packed angular to subangular pebble-sized fragments in a predominantly sandy matrix. This facies is low in silt and clay-sized particles, but is very hard and dense. Boulders as large as 15 inches in diameter are scattered throughout the facies; tests of Foraminifera and broken shells of mollusks and barnacles are present in the deposit, but are less common than in the other two facies. The third facies is a gray to dark-bluish-gray sand-rich diamicton. It is a mixture in which the sand matrix is dominant; however, pebbles, cobbles, and boulders, some as large as 5 feet or more across, are scattered throughout the deposit. Shells of mollusks, many of which are articulated, and barnacles, as well as tests of Foraminifera, are common. This facies differs from the other two facies in several ways; well-developed thin laminations or layers in the matrix are widespread. Plant remains in the form of individual roots and stems, some of which are carbonized, are common in exposures. In addition, this deposit is less dense than the other facies.

All three facies of the Gastineau Channel Formation are typically overlain by a thin but widespread blanket of reddish organic-rich beach gravels. The presence of and thickness of the beach gravel depend on the local depositional environment and subsequent exposure to erosion.

TYPICAL EXPOSURES

The type area for the Gastineau Channel Formation is designated as the low-lying land on the Juneau mainland and Douglas Island, especially in the bluffs along Gastineau Channel, and the exposures along the lower part of Montana Creek valley. The entire formation is not exposed at any one locality; typical exposures of each facies are, however, listed in table 1 and given in figure 1. The detailed locations of all the exposures in the table are designed for use with U.S. Geological Survey topographic quadrangle maps, Juneau B–2, 1962 edition, and Juneau B–3, 1962 edition. Each locality in the table, and in the text, is described by a prefix g, for Gastineau Channel Formation, a number for the facies, g1, g2, and g3, and a number for the locality, g1–1, g2–1, and so forth, or by an R, for radiocarbon date localities in deposits other than the Gastineau Channel Formation, and a number for the locality, R–1, R–2, and so forth.

The first facies underlies the downtown area of Juneau in addition to the selected exposures listed in table 1. Several test holes were cored in this facies in the downtown area, and the deepest hole bottomed at 91 feet below the surface. The hole penetrated about 38 feet of sand and gravel in an emerged delta and terminated in the till-like diamicton. Foraminifera were found throughout the sampled cores, and there was no distinctive break in texture or density of the material to suggest more than one age of deposition. This hole penetrated the thickest known section of the first facies—more than 53 feet; elsewhere, the facies is generally less than 25 feet thick where it overlies exposed bedrock.

TABLE 1.—*Typical exposures of Gastineau Channel Formation and results of laboratory tests of selected samples*

[Bulk density determined by Proctor compaction test. U, undated; N.d., not determined]

Locality no.	Location: Section	Location: T. (S.)	Location: R. (E.)	Lithologic character	Type of dated material	Age (years B.P.)	Bulk density	Altitude above mean sea level (feet)	Remarks
g1-1	S½NW¼NW¼ 10	41	67	Stony diamicton.	Mollusks	[1]11,920±1,110 (W-2396).	N.d.	±400	In landslide scarp; highest dated sample in Gastineau Channel Formation. Where trail to Salmon Creek Reservoir crosses scarp.
2	SE¼SE¼ 23	40	65	do	do	[2]10,640±300 (W-1827).	N.d.	±100	Overlies glacially striated bedrock; shells in 6-ft-thick zone. Opposite parking lot at Auke Lake.
3	SW¼SW¼NE¼ 2	40	65	do	Peat	[3]>39,000 (W-2721).	N.d.	±375	Dated peat; predates deposition of Gastineau Channel Formation.
4	NW¼SE¼SE¼ 16	41	67	do	Mollusks	[1]10,760±500 (W-2394).	N.d.	80	In floor of gravel pit; beneath delta at mouth of Eagle Creek, Douglas Island.
					do	[4]9,150±800 (W-2395).	N.d.	106	From diamicton above deltaic deposit.

g2–1	SW¼SW¼ 20	41	65	Gravelly diamicton.	U	U	141	±100	Closely packed rock fragments, in roadcut through ridge north of Peterson Creek, Douglas Island.
2	Near center 5	41	66	do	U	U	N.d.	±100	In roadcut through small ridge, locally known as Vanderbilt Hill.
3	NW¼ 29	40	65	do	U	U	N.d.	±50	In roadcut through Point Louisa.
4	NE¼ 29	40	65	do	U	U	142	±50	In roadcut through ridge near Indian Cove.
5	NW¼NW¼ 24	40	65	do	Mollusks	[2]10,240±300 (W–1826).	N.d.	138	Roadcut in interfluve between Auke Lake and Montana Creek valley.
6	SE. cor. SE¼ 9	41	66	do	do	[1]9,800±300 (W–2392).	N.d.	±45	West of Cove Creek, Douglas Island.
g3–1	SW¼NE¼SW¼ 23	40	65	Sandy diamicton.	do	[4]10,630±500 (W–2263).	118	98	In drainage ditch embankment of parking lot, Community College, Auke Lake.
2	NW¼SE¼ 22	41	67	do	do	[1]9,700±800 (W–2393).	N.d.	55	Beneath deltaic sand and gravel, mouth Kowee Creek, Douglas Island.

TABLE 1.—*Typical exposures of Gastineau Channel Formation and results of laboratory tests of selected samples*—Continued

Locality no.	Location: Section	Location: T. (S.)	Location: R. (E.)	Lithologic character	Type of dated material	Age (years B.P.)	Bulk density	Altitude above mean sea level (feet)	Remarks
g3-3	SW¼NW¼NW¼ 26	41	67	do	do	U	N.d.	80	Excavation for apartment house, west side Douglas Road, Douglas Island; unbroken, articulated mollusks.
4	NE. cor. NW¼SW¼ 26	40	65	do	do	U	N.d.	60	Along Fritz Cove Road, Mendenhall Peninsula.
R-1	SE¼ 21	40	65	Diamicton layer within deltaic deposits.	Barnacles, in life position.	[2]12,730±500 (W-1830).	N.d.	102	Diamicton layers alternate with sand and gravel. W-1831 determined from diamicton layer within higher deltaic deposit overlying eroded surface on lower deltaic beds.
				Diamicton layer.	Mollusks	[2]12,880±500 (W-1831).	N.d.	60	
				Sand in delta.	do	[2]12,300±350 (W-1839).	N.d.	52	
2	SE¼NW¼ 23	41	67	do	do	[2]10,880±340 (W-1829).	N.d.	190	Foreset beds in delta, mouth of Gold Creek, Juneau.

3	Not recorded in Broecker and Kulp (1957)	Peat	[5]10,300±400 (L–297D).	N.d.	±750	Upper reaches Montana Creek valley.
4	do	do	[5]10,300±600 (L–297A).	N.d.	±750	Lemon Creek valley, 1,000 ft downvalley from 18th-century ice position.

[1] Meyer Rubin, U.S. Geol. Survey (written commun., 1970).
[2] Marsters, Spiker, and Rubin (1969).
[3] Meyer Rubin, U.S. Geol. Survey (written commun., 1972).
[4] Meyer Rubin, U.S. Geol. Survey (written commun., 1969).
[5] Broecker and Kulp (1957).

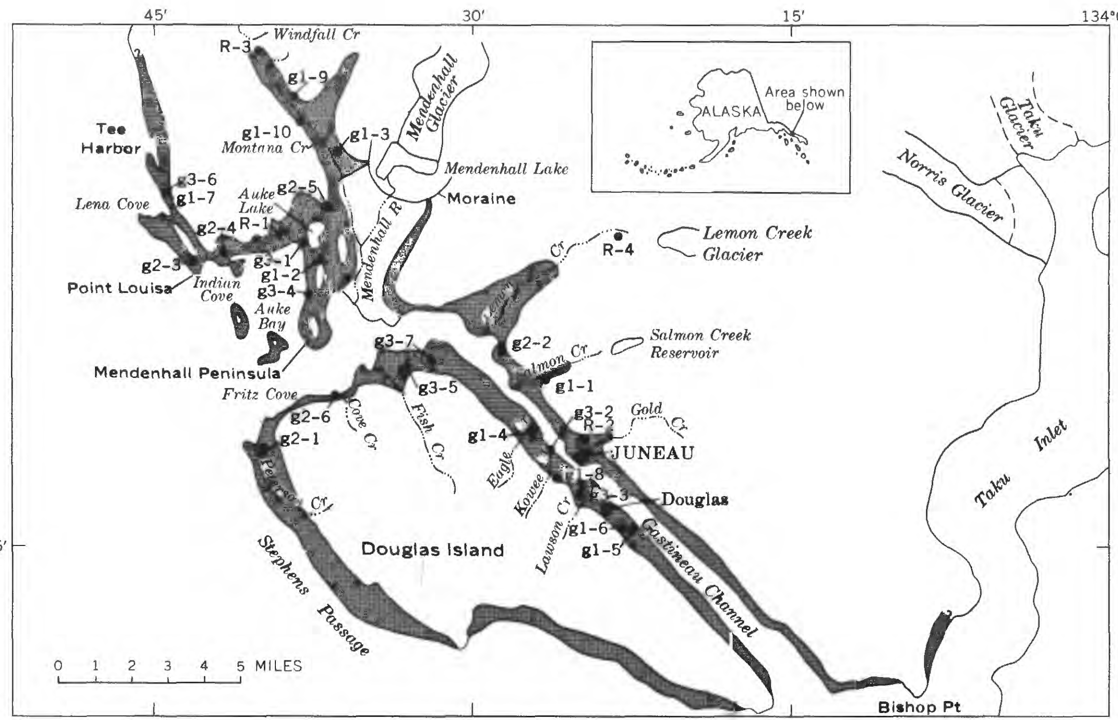


FIGURE 1.—Map showing the known distribution of the Gastineau Channel Formation (patterned). Localities considered typical or referred to in the text as fossil lc calities are prefixed with g for Gastineau Channel Formation and a number indicating the facies (g1, g2, and g3) and a second number for the locality (g1–1, g2–3, and so forth), or by an R, for radiocarbon date localities in deposits other than the Gastineau Channel Formation and a number for the locality (R–1, R–2, and so forth).

The second facies is less widespread than the other two facies along Gastineau Channel; it occurs in isolated mounds and ridges at altitudes of less than 250 feet above mean sea level. Exposure g2–1 (table 1), in a roadcut through a small ridge north of Peterson Creek on Douglas Island best typifies the texture and density common to this facies. This particular deposit is so closely packed with rock fragments that a railroad pick bounced from the surface of the material with but slight penetration. The thickness of the facies seems to be variable, depending on local depositional environments; most exposures reveal less than 20 feet of material, but the base of the material has not been exposed.

The third facies crops out intermittently along both sides of Gastineau Channel, along Fritz Cove, Auke Bay, Lena Cove, Tee Harbor, and the lower reaches of Montana Creek valley near the confluence with the Mendenhall River. These deposits generally veneer preexisting surfaces that slope upward at about 10°–15° from the modern beaches or sea bluffs to the mountainsides. Scarps that are generally no more than 10 feet high commonly separate the sand-rich diamicton of the third facies from the somewhat older, higher, and more extensive stone-rich till-like diamicton of the first facies. The third facies is known to reach an altitude of at least 200 feet above mean sea level, but may extend considerably higher on the mountain slopes. One locality, g3–2 (fig. 1), is overlain by an emerged delta; elsewhere, most of the other localities lie nearer the surface beneath muskeg and thin beach deposits. The third facies is the thinnest of the three facies in the formation, and generally ranges in thickness from 4 to 12 feet.

FOSSILS

Marine fossils occur in all three facies of the formation. Barnacle shells, Foraminifera tests, and unbroken and broken shells of pelecypods, gastropods, and scattered brachiopods have been recovered from all facies, although fragments are dominant in the dense deposits of the gravel-rich diamicton of the second facies of the Gastineau Channel Formation. Molluscan faunas collected from selected localities in the Juneau area are listed in table 2, and Foraminifera from selected sites are listed in table 3. Interpretation of the life environment of the mollusks suggests relatively shallow water, ranging in depth from 60 to 150 feet (W. O. Addicott and J. W. Miller, written commun., 1972). Samples of Foraminifera collected in 1958 by the late Don J. Miller were examined and the fossils identified by Ruth Todd (table 3). Interpretations of fossils collected during the study in and around Juneau seemed to indicate a maximum water depth of about 300 feet (Ruth Todd and Doris Low, written commun., 1967). A more restrictive interpretation of the water depth is provided by Roberta K. Smith (1971, p. 692), who, as a result of her regional study of Foraminifera in southeastern Alaska and British Columbia, Canada, concludes that the water was "probably less than 30 meters [about 98 feet] deep." On the basis of these paleontological evaluations, I believe that all three of the facies of the Gastineau Channel Formation probably accumulated in water that was less than 150 feet deep and perhaps less than 100 feet deep.

TABLE 2.—*Fossils collected from selected outcrops of the three facies of the Gastineau Channel Formation, Juneau area, Alaska*

[Locality numbers prefixed with g are shown in figure 1 and the locations are described in table 1; numbers prefixed with M are U.S. Geological Survey Cenozoic locality numbers assigned to faunas collected from the g-numbered localities and on file with the U.S. Geological Survey. Identification from USGS Cenozoic loc. M2651 by W. O. Addicott (written commun., 1966), and J. W. Miller (written commun., 1972). Other identifications by W. O. Addicott]

	Localities						
	M5012 g1–1	M5006 g1–2	M2651 g2–5	M5008 g2–6	M5011 g3–1	M5015 g3–3	M5014 g3–4
Pelecypods:							
Astarte alaskensis Dall	----	----	----	----	×	×	----
Chlamys rubida hindsi (Carpenter)	----	?	----	×	×	×	×
cf. *C. rubida* (Hinds) MacNeil (1967)	----	----	----	×	----	----	----
Clinocardium ciliatum (Fabricus)	×	----	----	×	×	×	----
Cyclocardia ventricosa (Gould)	----	----	----	×	×	×	×
Hiatella arctica (Linné)	×	×	×	×	×	----	×
calcarea Gmelin	----	----	----	----	×	×	----
Macoma brota Dall	?	----	----	----	----	----	×
calcarea Gmelin	×	×	----	×	×	----	×
obliqua (Sowerby) [*M. incongrua* of earlier reports]	×	----	----	----	×	×	×
Mya truncata Linné	----	×	×	×	×	×	×
Mytilus edulis Linné	×	----	----	----	----	----	----
Nuculana fossa (Baird)	----	[1]×	----	----	----	×	×
Panomya ampla Dall	----	----	----	----	----	×	×
Protothaca staminea (Conrad)	----	----	×	----	----	----	----
Serripes groenlandicus (Bruguiere)	×	×	----	----	×	×	×
Gastropods:							
Acmaea sp	----	----	----	----	----	----	×
Buccinum sp	----	----	----	×	----	----	----
Colus halli Dall	----	----	----	×	----	----	----
Cryptonatica clausa (Broderip and Sowerby)	----	×	----	----	----	----	----

TABLE 2.—*Fossils collected from selected outcrops of the three facies of the Gastineau Channel Formation, Juneau area, Alaska*—Continued

	Localities						
	M5012 g1–1	M5006 g1–2	M2651 g2–5	M5008 g2–6	M5011 g3–1	M5015 g3–3	M5014 g3–4
Gastropods—Continued:							
Lepeta concentrica (Middendorff)	----	----	----	×	----	----	----
Neptunea lirata Gmelin	----	?	----	×	×	×	×
Polinices pallidus (Broderip and Sowerby)	----	×	----	----	----	----	----
Puncturella major Dall	----	----	----	----	----	----	×
Propebela sp	----	----	----	×	----	----	----
Trochotropis cancellata Hinds	----	----	----	×	----	----	----
Brachiopods:							
Hemithyris sp	----	----	----	----	----	×	----
Barnacles:							
Balanus cf. *B. nubilus* Darwin	×	----	----	×	----	----	----
Balanus sp	×	×	----	×	×	×	×

[1] Fragments.

ENVIRONMENT

Deposits included within the Gastineau Channel Formation have been called by others shell-bearing boulder-clay, till, marine till, or terrace deposits (Twenhofel, 1952, p. 528; C. L. Sainsbury, written commun., 1953; Don J. Miller, written commun., 1958; and field notes). These earlier descriptions have related most of the glaciomarine deposits in the Juneau area to a glacial environment where glacial ice either filled the fiords or pieces of ice discharged from glaciers into Gastineau Channel in the immediate vicinity of Juneau; some of these deposits were considered to be marine terraces of postglacial age. The results of my field studies in and around Juneau led me to believe that all three facies composing the deposits in the Gastineau Channel Formation accumulated when the Gastineau Channel area and adjacent low-lying regions were free of fiord-filling glaciers (Miller, 1972).

That such an environment existed is based in part on the radiocarbon dates obtained for shells in emerged deltas lying along the mountain slopes bounding Gastineau Channel, in part on the radiocarbon dates obtained for shells in the glaciomarine materials in the Gastineau Channel Formation, in part on the radiocarbon dates obtained by others from samples of basal peat in nonmarine muskegs in mountain valleys, and in part on the interrelationship between the Gastineau Channel Formation and the emerged delta deposits in the Juneau area.

TABLE 3.—*Foraminifera collected from outcrops in the Juneau area, Alaska, by Don J. Miller, in 1958, and assigned to facies of the Gastineau Channel Formation by Robert D. Miller*

[Fossil identifications by Ruth Todd, written commun., 1959]

	Localities [1]									
	g1-5	g1-6	g2-6	g3-5	g1-7	g1-8	g1-9	g1-10	g3-6	g3-7
	f25968	f25969	f25970	f25971	f25972	f25975	f25987	f25986	f25973	f25988
Benthonic										
Astrorhizidae:										
Genus?	---	---	---	---	---	---	---	---	---	×
Miliolidae:										
Quinqueloculina agglutinata Cushman	---	---	---	---	---	---	---	---	×	---
akneriana d'Orbigny	---	×	×	---	×	---	---	---	×	---
frigida Parker	---	×	×	---	---	---	---	---	---	---
stalkeri Loeblich and Tappan	---	×	×	×	×	---	---	×	---	×
Triloculina tricarinata d'Orbigny	---	---	---	---	×	---	---	---	---	---
Pyrgo lucernula (Schwager)	---	---	×	---	×	---	---	---	---	×
Lagenidae:										
Lagena gracillima (Sequenza)	---	---	---	---	---	---	×	---	---	---
Buliminidae:										
Buliminella elegantissima (d'Orbigny)	---	---	---	---	---	---	---	---	---	×
Globobulimina auriculata (Bailey)	---	---	---	---	---	---	---	---	---	×
Virgulina fusiformis (Williamson)	---	×	×	×	---	---	×	×	×	×
Bolivina decussata Brady	---	---	---	---	---	---	---	---	---	×
pacifica Cushman and McCulloch	---	---	---	×	---	---	---	---	×	×
Fissurina sp. (globular, slit aperture)	×	---	---	---	---	---	---	---	---	---
Rotaliidae:										
Buccella frigida (Cushman)	×	×	×	×	×	---	×	×	×	×
Elphidiidae:										
Elphidium bartletti Cushman	---	---	×	---	×	---	×	×	---	×
clavatum Cushman	×	×	×	×	×	×	×	×	×	×
frigidum Cashman	×	×	×	×	×	---	---	---	×	---
Elphidiella nitida Cushman	---	---	---	---	---	---	---	---	---	×
Anomalinidae:										
Cibicides lobatulus (Walker and Jacob)	---	---	---	---	×	---	---	---	---	×
Dyocibicides biserialis Cushman and Valentine	---	---	---	---	---	---	---	---	×	×
Nonionidae:										
Nonion labradoricum (Dawson)	---	×	×	×	---	---	×	×	×	×
Nonionella turgida Williamson, var. *digitata* Nørvang	---	---	---	---	---	---	---	×	---	---

TABLE 3.—*Foraminifera collected from outcrops in the Juneau area, Alaska, by Don J. Miller, in 1958, and assigned to facies of the Gastineau Channel Formation by Robert D. Miller*—Continued

	Localities [1]									
	f25968 g1-5	f25969 g1-6	f25970 g2-6	f25971 g3-5	f25972 g1-7	f25975 g1-8	f25987 g1-9	f25986 g1-10	f25973 g3-6	f25988 g3-7
Benthonic—Continued										
Nonionidae—Continued:										
Pseudononion auricula (Heron-Allen and Earland	×	---	×	×	---	---	---	---	×	×
Astrononion gallowayi Loeblich and Tappan	---	---	---	---	---	---	---	---	×	---
stelligerum (d'Orbigny)	---	---	---	×	---	---	---	---	---	---
Cassidulinidae:										
Cassidulina islandica Nørvang	---	×	×	×	×	---	×	×	---	---
teretis Tappan	×	×	×	×	---	---	×	×	×	×
Epistominella exigua (Brady)	---	---	---	---	---	---	---	---	×	---
Planktonic										
Globigerinidae:										
Globigerina bulloides d'Orbigny	---	---	×	---	---	---	---	×	---	---

[1] Locality numbers prefixed with g are shown in figure 1; those prefixed with f are USGS numbers given to collections of Don J. Miller, to which the g-numbered localities were matched on the basis of descriptions of fossil locations in Miller's field notebooks. Locations of the sample sites are as follows:

g1-5 SE¼NW¼SE¼ sec. 36, T. 41 S., R. 67 E.
g1-6 SW¼SW¼SE¼ sec 36, T. 41 S., R. 67 E.
g2-6 SE. cor. SE¼ sec. 9, T. 41 S., R. 66 E.
g3-5 SE¼SW¼SW¼ sec. 2, T. 41 S., R. 66 E.
g1-7 SW¼SW¼NW¼ sec. 18, T. 40 S., R 65 E.
g1-8 NE. cor. SW¼NW¼ sec. 27, T. 41 S., R. 67 E.
g1-9 SW¼SE¼NE¼ sec. 34, T. 39 S., R. 65 E.
g1-10 NE. cor. SE¼SE¼ sec. 34, T. 39 S., R. 65 E.
g3-6 SW¼SW¼NW¼ sec. 18, T. 40 S., R. 65 E.
g3-7 SE. cor. SW¼ sec. 2, T. 41 S., R. 66 E.

AGE

Shells in the formation were collected for radiocarbon determination from the highest exposed shell-bearing deposits of diamicton, but shells were not available in amounts sufficient for radiocarbon determination in outcrops at altitudes believed to be near the upper limits of the Gastineau Channel Formation. Consequently, it can be inferred that the formation is somewhat older than the oldest dates obtained from the diamictons in the formation.

Such an inference has some support from the dates obtained for shells within deltaic deposits. Beds within the emerged deltas consist of sand and gravel, for the most part, but interlayered with these beds are layers of shell-bearing diamicton. Several radiocarbon dates for shells in these beds are slightly older than the oldest date obtained from diamicton in the Gastineau Channel Formation, although other dates fall within the age range determined for shells in the diamicton of the formation. Dates of 12,730±500, 12,880±500, and 12,300±350 years B.P. obtained from mollusks and barnacles in an emerged delta near Auke Bay, locality R–1 (fig. 1) (W–1830, W–1831, W–1839, respectively; Marsters and others, 1969, p. 222–223), suggest that the oldest part of the diamicton in the formation has not yet been sampled for radiocarbon determination. An example of a somewhat younger age determination, 10,880±340 years B.P. (W–1829; Marsters and others, 1969, p. 222), was obtained at locality R–2 (fig. 1) for barnacle fragments in the foreset beds, nearly 190 feet above mean sea level, within the emerged delta near the mouth of Gold Creek in Juneau.

Dates of shells in the diamictons in the Gastineau Channel Formation, listed in table 1, partly overlap the ages of shells in the deltas. Dates that range from 11,920±1,000 years B.P. (W–2396) to 9,700±800 years B.P. (W–2393; Meyer Rubin, written commun., 1970), lend support to the concept that the now-emerged deltas and the deposits of the Gastineau Channel Formation accumulated during the same interval.

Ages of basal nonmarine peats now about 750 feet above mean sea level in mountain valleys adjacent to Gastineau Channel also lie within the 12,000- to 9,700-years-B.P. range. Peat from the base of a muskeg lying in the upper part of Montana Creek valley, locality R–3 (fig. 1), was dated at 10,300±400 years B.P. (L–297D; Broecker and Kulp, 1957; Heusser, 1960, p. 97), and a similar peat, also at the base of a muskeg, in the valley of Lemon Creek, locality R–4 (fig. 1), was dated at 10,300±600 years B.P. (L–297A; Broecker and Kulp, 1957; Heusser, 1960, p. 96–97). Interpretation of the pollen in the muskeg above the dated layers indicates that the climate during the pollen accumulation was more moderate than would be expected during glacial time and that ice was absent from the dated sites after the peats began to accumulate (Heusser, 1960, table 5, fig. 24) and did not readvance over that site at a later time.

That the ages of the dated basal peats in Montana Creek and Lemon Creek valleys lie within the age span obtained for the deltas and deposits of the Gastineau Channel Formation suggests that the lower parts of the mountain valleys were ice-free, and that it is likely that all the glaciers were withdrawn from the immediate Juneau area during the deposition of the glaciomarine deposits that constitute the Gastineau Channel Formation. Nevertheless, an effective process by which sand, pebbles, cobbles, and large boulders can be transported and deposited in marine waters to be incorporated into a fine- to medium-grained matrix material and which results in a regionally distributed deposit must be available throughout the Juneau region. Though seemingly in conflict with an open-water marine environment, ice seems to be the most likely means of transport to accomplish this feat.

DEPOSITIONAL HISTORY

Origin of glaciomarine diamictons in British Columbia and northwestern Washington has been discussed in the literature. Diamictons similar to those around Juneau are widespread at altitudes of less than 700 feet above sea level along the coasts of southeastern Alaska, British Columbia, and Washington. Armstrong and Brown (1954) and Easterbrook (1963), among others, have discussed the possible origins for these deposits. Several of their possible hypotheses include those of plowing of the sea floor by glacial ice, deposition of debris from floating ice, such as shelf ice, berg ice, and sea ice, and submarine landslides, slopewash, and turbidity currents. Shelf ice, berg ice, and sea ice were decided upon by Armstrong and Brown (1954, p. 358–359) as acceptable methods of transport and deposition, and Easterbrook (1963, p. 1474) believes that shelf ice and berg ice were the means applicable to the northern Puget Sound lowland in Washington. After evaluation of these theories, I believe that sea ice, supplemented by berg ice, provides the means of accumulating, transporting, and mixing the coarse debris with the fines to produce diamicton such as that found in the Gastineau Channel Formation (Miller, 1972, p. 83–

85). Sea ice is ice that builds outward from the shores each winter season; such ice could provide transport of the coarse material deposited by streams on the sea ice during the early spring runoff. Transport is provided as the ice floats away during spring breakup, and deposition occurs as the debris is dropped from the melting ice into the continually accumulating soft and saturated finer grained deposits on the bottom of the fiord.

In addition, contributions from berg ice from outside the immediate Juneau area might have supplemented the sea ice and helped provide the extremely coarse particles found scattered throughout much of the glaciomarine deposits. The presence of berg ice, however, requires the termination of valley glaciers in the region into the open waters of the fiords. The large glaciated valleys that reach present water level north of Juneau do not contain any geomorphic evidence on the slopes higher than 500–600 feet above sea level that these valleys contained glaciers that could have been sources for berg ice 10,000 to 12,000 years ago. The presently active Taku and Norris Glaciers, to name but two, reach, or reached, the tidewaters in Taku Inlet, southeast of Juneau, in historical time. These and other valley glaciers outside the Juneau area may have been actively providing berg ice during accumulation of the Gastineau Channel Formation.

The hypothesis of transport of coarse debris by either sea ice or berg ice, or both, is not free of problems. The principal problem with each type of ice for transport and deposition is the seasonal and therefore cyclic nature of the deposition of the coarse fragments. Sea ice would probably drop its load during late spring and summer; subsequent deposition would tend to be relatively free of coarse fragments. Berg ice would probably drop its load as localized piles of coarse material, especially where the bergs capsized. Neither depositional situation is reflected in either the texture or distribution of the coarse material within the diamicton in the Juneau area. At the present time, however, there seems to be no better explanation for the presence of the coarse fragments than transport and deposition by sea and berg ice.

Judging from available field and laboratory data, I currently visualize the Gastineau Channel Formation as being composed of different facies that accumulated during depositional cycles; the facies accumulated in part simultaneously, but for the most part occurred sequentially from the oldest to the youngest (fig. 2). The oldest, or first, facies apparently began to accumulate during the maximum late Pleistocene depression of the land and during the first part of emergence of the land after the ice sheet had retreated and marine waters occupied the depressed fiords in this part of southeastern Alaska.

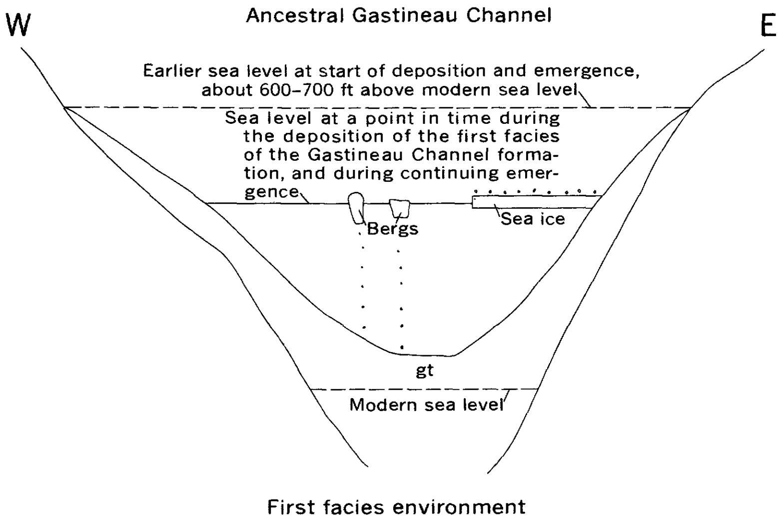
As the land continued to rebound and the upper parts of the glaciomarine deposits gradually emerged from the water, waves reworked the uppermost part of the material and deposited a thin blanket of beach gravels on the newly emerged surface. These beach gravels are found throughout the Juneau area overlying the Gastineau Channel Formation at altitudes as high as 500–600 feet above sea level.

About midway through the emergence, a slowing or halt of unknown duration apparently occurred. Most of the delta deposits accumulated at that time, and so, also, did the second facies of the formation, in this case apparently as near-shore barrier bars.

During the interval that permitted the deltas and barrier bars to accumulate, the rise in sea level apparently exceeded uplift of the land, and relatively quiet waters existed along the shore. Diamicton accumulated over the deltaic beds under these quiescent conditions in some localities. In most places, however, the third facies of the formation accumulated at this time in near-shore tidal zones. As the land uplift accelerated and exceeded the rise in sea level, the deltas and barrier bars were carried above sea level to eventually lie as emerged deposits along the mountain slopes. The third facies deposits were in part reworked from the first facies that in most places underlies the somewhat younger third facies.

Eventually, the land rose at least 500 feet, and locally at least 750 feet, above present mean sea level. This emergence carried the first, and oldest, facies to the highest altitudes along the slopes bordering Gastineau Channel.

Based on radiocarbon determinations from marine shells in the three facies of the formation, the Gastineau Channel Formation is considered to be late Pleistocene and early Holocene in age.



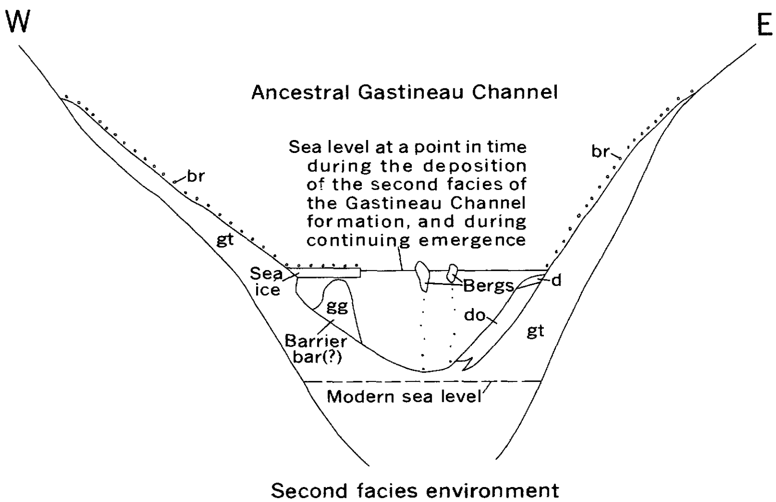
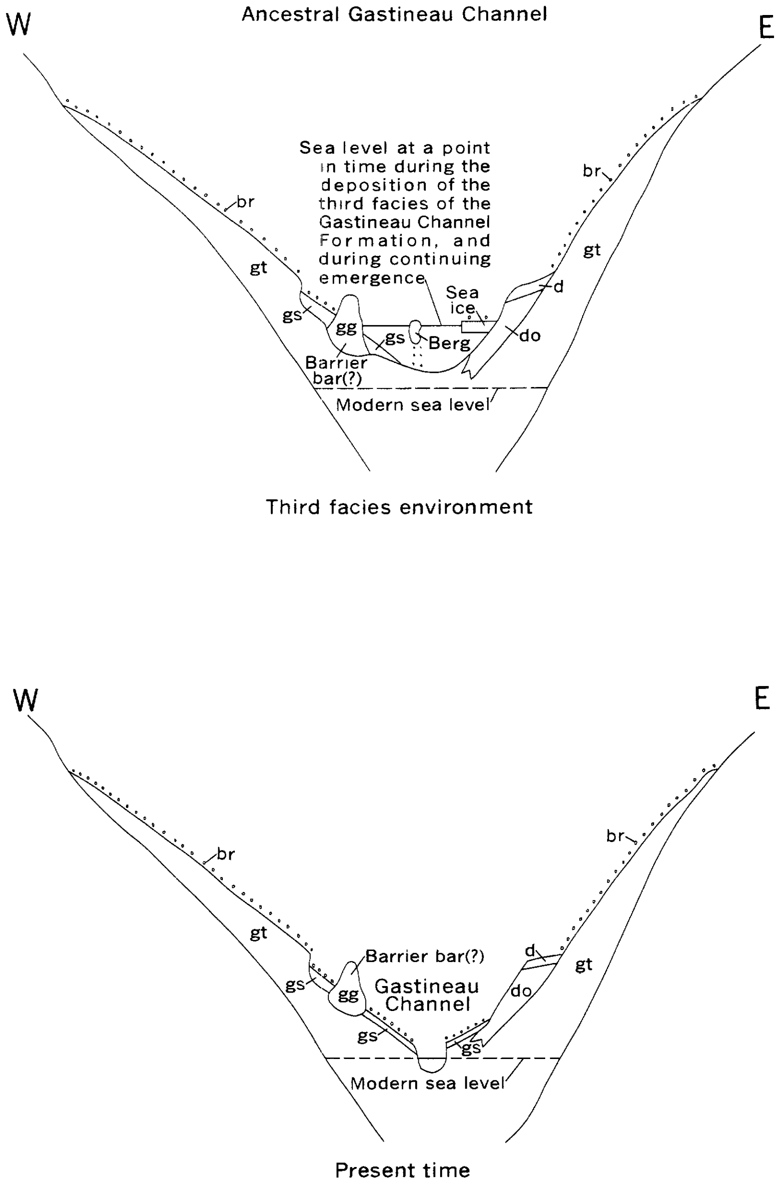


FIGURE 2.—Diagrammatic sketches showing interpretations of the manner of glaciomarine deposition and accumulation of related deposits during the three depositional facies of the Gastineau Channel Forma-



tion. gt, Gastineau Channel Formation, first facies; gg, Gastineau Channel Formation, second facies; gs, Gastineau Channel Formation, third facies; do, emerged delta deposits; d, diamicton layer on top of delta deposits; br, raised beach deposits.

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