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SURFACE SEDIMENTARY UNITS OF THE GULF OF ALASKA CONTINENTAL SHELF: MONTAGUE ISLAND TO YAKUTAT BAY

BRUCE F. MOLNIA

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ABSTRACT

Four major sedimentary units occur on the sea floor of the continental shelf in the northern Gulf of Alaska. These units, defined on the basis of seismic and sedimentologic data, are: (1) Holocene sediments, (2) Holocene end moraines, (3) Quaternary glacial marine sediments, and (4) Tertiary and and Pleistocene lithified deposits.

A wedge of Holocene fine sand to clayey silt covers most of the inner shelf, reaching maximum thicknesses of about 350 m seaward of the Copper River and about 200 m seaward of Icy Bay. Holocene end moraines are found at the mouth of Icy Bay, south of Bering Glacier, and at the mouth of Yakutat Bay. Quaternary glacial marine sediments are found in a narrow arc that borders on the north and west side of Tarr Bank and in a large arc 20 km or more offshore that parallels the shoreline between Kayak Island and Yakutat Bay. Tertiary or Pleistocene stratified sedimentary rocks, which in profile commonly are folded, faulted, and truncated, crop out on Tarr Bank, offshore of Montague Island, and in several localities southeast and southwest of Cape Yakataga. The lack of Holocene cover on Tarr Bank and Middleton, Kayak and Montague Island platforms may be due to the scouring action of swift bottom currents and large storm waves.

West of Kayak Island the Copper River is the primary source of Holocene sediment. East of Kayak Island the major sediment sources are streams draining the larger ice fields, notably the Malaspina and Bering Glaciers. Transport of bottom and suspended sediment is predominantly to the west.

If deglaciation of the shelf was completed by 10,000 years B.P., maximum rates of accumulation of Holocene sediment on the inner shelf may be as high as 10-35 m per 1000 years.

INTRODUCTION

Two U. S. Geological Survey research cruises that investigated the continental shelf of the northern Gulf of Alaska (Fig. 1) have provided a substantial quantity of high-resolution single-channel seismic data and bottom sediment samples that have been interpreted to map the types and distribution of continental shelf surface sediment and sedimentary rocks in the northern Gulf of Alaska between Montague Island and Yakutat Bay (Fig. 2). A geophysical cruise on the R/V THOMAS G. THOMPSON and a bottom sediment sampling cruise on the NOAA Fisheries Research Ship TOWNSEND CROMWELL produced about 6,400 km of seismic profiles of the shelf (Fig. 3) and about 400 bottom sediment samples from the shelf between Montague Island and Yakutat Bay (Fig. 4).

Later seismic research cruises on the NOAA Ship SURVEYOR, R/V ACONA, M/V CECIL GREEN and U. S. Geological Survey R/V SEA SOUNDER have confirmed and enhanced the interpretation of the THOMPSON high-resolution seismic data. Additional bottom sediment samples, which were collected by NOAA Ship DISCOVERER, R/V ACONA and R/V SEA SOUNDER, were examined to enhance interpretation of the CROMWELL data.

High-resolution seismic data were collected using 3.5-kHz echo profilers, sparkers, and a uniboom system. The sparker systems varied in power from 400 Joules to slightly over 1 kJ. The Uniboom system consisted of four hull- mounted plates with a power output of 600-800 Joules. Bottom sediment samples were collected with dart, gravity, and box corers and Van Veen and Shipek grabs. These samples are routinely analyzed for size, mineralogy, and faunal content.

TYPES OF SEDIMENT

Analyses of the high-resolution seismic profiles and the sediment samples suggest that four major sedimentary units crop out on the continental shelf in the northern Gulf of Alaska. These units, which are characterized by distinctive morphology in seismic profile, are: (1) Holocene sediment, (2) Holocene end moraines (3) Quaternary glacial marine sediments, and (4) a Tertiary and Pleistocene stratified unit.

The ages used for describing this material are based on relative stratigraphic positions and not on isotopic dates. The term Holocene is applied to sediment accumulating today and to end moraines formed in historic time. The term Quaternary is applied to glacial marine sediment interpreted as being deposited on the continental shelf primarily during eustatic Pleistocene low stands of sea level. This unit may also include Holocene ice-rafted sediment and Neoglacial tills. The Tertiary and Pleistocene ages are applied to the stratified sedimentary rocks, commonly folded, faulted, and truncated, that are similar in lithology and structure to onshore lithified deposits (Plafker, 1967, 1971).

CHARACTERISTICS OF SEDIMENTARY UNITS IN SEISMIC PROFILE

In seismic profile Holocene sediment is well stratified, with continuous reflectors frequently extending for many kilometers. A typical profile of an area with Holocene sediment cropping out on the sea floor is shown in Figure 5. Sources of Holocene sediment appear to be the Copper River, the rivers draining the Bering and Malaspina Glaciers, Icy Bay and Yakutat Bay. Bottom samples of Holocene sediment are predominantly greenish-gray mud and sandy mud with a varied infauna. The maximum observed thickness of Holocene sediment, over 325 m, is found just south of the Copper River (Fig. 6). Other thick accumulations are: offshore of Icy Bay (> 250m), in the Bering Trough (> 100 m), in Kayak Trough (> 150 m), and in the Hinchinbrook Sea Valley near the entrance to Prince William Sound (> 225 m).

In seismic profile, Holocene end moraines have very irregular surfaces with hummocky lobes exhibiting rapid changes in depth and discontinuous subbottom reflectors (Fig. 7). Pockets of flat-lying sediment are commonly ponded behind morainal lobes. Samples of end moraine deposits are quite varied in character, ranging from cobbles to pebbly mud and from sandy mud to silty clay in ponded pockets.

In seismic profile glacial marine deposits show many hummocky discontinuous subbottom reflectors. In many places glacial marine sediment has filled parts of glacially carved U-shaped bedrock valleys (Fig. 8). Where sampled, glacial marine sediment is characteristically a greenish-gray pebbly mud. The glacial marine sedimentary unit was probably deposited as lodgment till and end moraine as the ice sheets advanced, as ablation tills as the ice stagnated, and later as ice-rafted sediment after the ice sheets retreated. The glacial marine unit has probably been reworked by bottom currents and storm waves.

The Tertiary and Pleistocene unit is characterized in seismic profile by folding, faulting, and angular erosional surfaces. Many of the folded structures are breached, and the faults have as much as 20 m of offset at the sea floor, possibly with throws greater than 100 m. Differences in bed erodability commonly produce numerous small hogback ridges in the truncated folded structures. A profile of the Tertiary and Pleistocene stratified unit in the Tarr Bank area is shown in Figure 9.

SEDIMENT DISTRIBUTION

Mapping of the four surface sediment units from seismic profiles and bottom samples has yielded a distribution map of the surface sedimentary material between Montague Island and Yakutat Bay (Fig. 10). West of Kayak Island, Holocene sediment blankets the entire nearshore area between Hinchinbrook Island and the south end of Kayak Island. In addition, Holocene sediment forms the surface fill in Hinchinbrook Sea Valley and covers the area south of Tarr Bank and north of Middleton Island.

East of Kayak Island, Holocene sediment also blankets the nearshore area with the exception of Holocene morainal areas at Icy Bay and the Bering Glacier and an area of Tertiary and Pleistocene bedrock that crops out southwest of Cape Yakataga between Cape Suckling and Icy Bay. Holocene sediment also occurs in a series of isolated pods towards the outer edge of the continental shelf. These pods are very thin, generally less than 3 m thick. Holocene sediment east of Kayak Island is over 200 m thick south of Icy Bay and more than 175 m thick in the north end of the Bering Trough (Fig. 6).

Holocene end moraines are found at the mouths of Icy Bay and Yakutat Bay and south of Bering Glacier. A 20-km^2 area of kame and kettle like morphology has been found south of the area mapped as the Bering Glacier Holocene end moraine (Molnia, 1976). It is suspected that this kame and kettle morphology represents in situ submarine melting of a grounded glacial toe. The age of the ice involved is unknown, but thermodynamic calculations indicate that the ice could be either Holocene - Neoglacial or late Pleistocene-Wisconsin.

Historic data indicate that the Holocene end moraine at the mouth of Icy

Bay dates from the early part of the twentieth century, with ice retreat beginning about 1904 (Austin Post, pers. commun., 1976, Miller, 1964). The Yakutat Bay end moraine probably dates from the late thirteenth century (DeLaguna et al.,1964).

Quaternary glacial marine sediments are found in a narrow arc on the north and west side of Tarr Bank and in a large arc 20 km or more offshore that parallels the shoreline between Kayak Island and Yakutat Bay. Thicknesses range from a thin veneer covering areas near the shelf edge to more than 50 m of glacial marine sediment filling glacially scoured bedrock channels.

Tertiary and Pleistocene stratified sedimentary rocks crop out on Tarr Bank, offshore of Montague Island, in a series of exposures in Hinchinbrook Sea Valley, on the Middleton Island Platform, on the Kayak Island Platform, in two exposures of the shelf edge south of Cape Suckling, on Pamplona Ridge, and at a number of locations near Cape Yakataga. Two groups of samples collected from Seal Rocks and Wessels Reef, on the shelf, were determined to be Paleocene Orca Group and Tertiary Poul Creek-Katalla Formation, respectively (G. L. Winkler, pers. commun., 1975).

DISCUSSION AND SUMMARY

The four sedimentary units that crop out on the continental shelf are the key to the sequence of geologic events that contribute to the present form of the outer continental shelf. The deformed stratified unit predates the more recent major advances of the continental ice sheet in Quaternary time and owes its eroded and beveled nature to scour by major advances of continental shelf ice as well as to preglacial erosion. The Quaternary glacial marine unit is composed largely of lodgment and ablation tills deposited by advancing and wasting ice sheets on the shelf. It is too widespread in its distribution and too thick to represent isolated ice-rafted sediments. However, the bedrock troughs or valleys cut into the continental shelf (Fig. 1) all possess glacially carved morphologies and generally shoal seaward, indicating the limit of bedrock scour by ice. The discovery of terminal moraines further seaward would help confirm this interpreted origin. The Holocene end moraine unit represents recent readvances of small segments of the ice sheet that previously blanketed the shelf.

Holocene sediment is actively accumulating. Satellite photographs (Fig. 11) and ship and aerial observations confirm the presence of plumes of new material entering the Gulf of Alaska from numerous sources. The Holocene sediment forms a wedge that thins seaward, as it overrides the Tertiary stratified unit and the Quaternary glacial marine unit. The absence of Holocen sediment cover on Tarr Bank and other bedrock outcrops may be due to intense bottom currents and reworking by storm waves. Bottom television and side-scan sonar coverage of Tarr Bank indicates the presence of boulders and large cobbles that probably represent lag deposits resulting from the removal of fine-grained Quaternary glacial marine and Holocene sediments.

No information on depositional rates has been confirmed, but if the deglaciation of the continental shelf paralleled that of other comparable medium-high-latitude regions, ice sheet retreat from the continental shelf was completed by 10,000 years B.P. Assuming this is true, then maximum nearshore deposition rates of 30-35 m per 1,000 years are indicated. If the time interval between deglaciation and the present were shorter, then the rates would be correspondingly higher.

Further investigation should yield more definite information on which to base calculation of shelf sediment deposition rates and also from which to determine further the depositional history and distribution of surface sedimentary units for the northern Gulf of Alaska.

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FIGURE CAPTIONS

Figure 1. Map of Alaska showing the area studied. The area in the striped rectangle is shown in greater detail in Figure 2.

Figure 2. General location map showing detailed bathymetry of the continental shelf and slope in the area studied (bathymetry from Molnia and Carlson 1975a).

Figure 3. Map showing the location of tracklines on which seismic profiles were obtained during the September - October 1974 cruise of the R/V THOMAS G. THOMPSON. The length of lines is approximately 6,400 km.

Figure 4. Map showing the locations of bottom sediment samples collected during the May - June 1975 cruise of the NOAA F.R.S. TOWNSEND CROMWELL.

Figure 5. Typical high-resolution seismic profile of the Holocene surface sediment unit. In this photo the Holocene overlies the folded Tertiary and Pleistocene stratified unit. The profile is from an area north of Tarr Bank and south of the Copper River.

Figure 6. Isopach Map of the Holocene surface sediment unit between Montague Island and Yakutat Bay. Maximum thickness mapped is 325 meters south of the Copper River (modified from Carlson and Molnia, 1975).

Figure 7. Typical high-resolution profile of the Holocene end moraine unit. The hummocky surface is the most distinctive characteristic in seismic profile. The profile is a portion of the Bering Glacier end moraine.

Figure 8. Typical seismic profile of the glacial marine surface sedimentary unit. Note the hummocky, discontinuous subbottom reflectors. This profile is from the northern Bering Trough.

Figure 9. Typical seismic profile of the Tertiary and Pleistocene lithified unit. Note the intense folding, the truncated strata and the minor faulting. This profile is from a part of Tarr Bank.

Figure 10. Map of the distribution of the four surface sedimentary units for area between Montague Island and Yakutat Bay (modified from Molnia and Carlson, 1975b).

Figure 11. 12 October 1972 Land-sat image of Gulf of Alaska between Cape Suckling and Montague Island showing surficial sediment plumes entering the Gulf from numerous onshore sources.

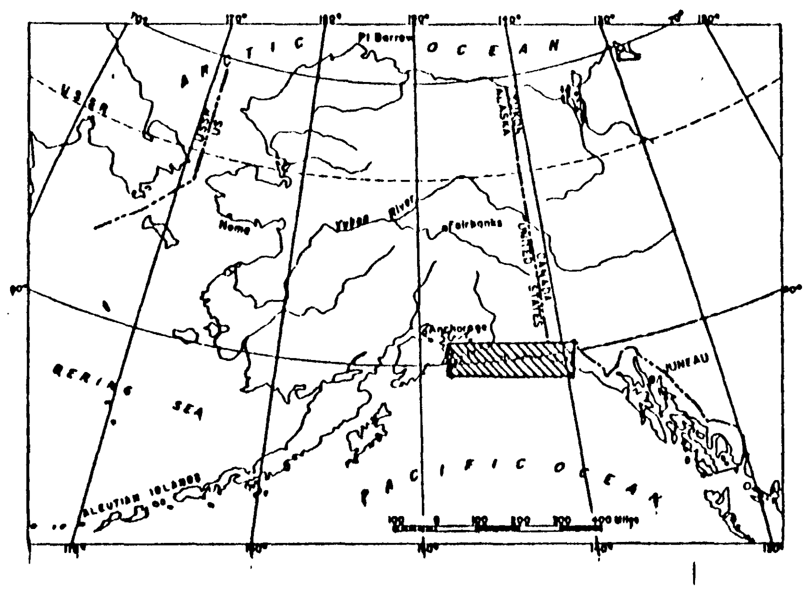
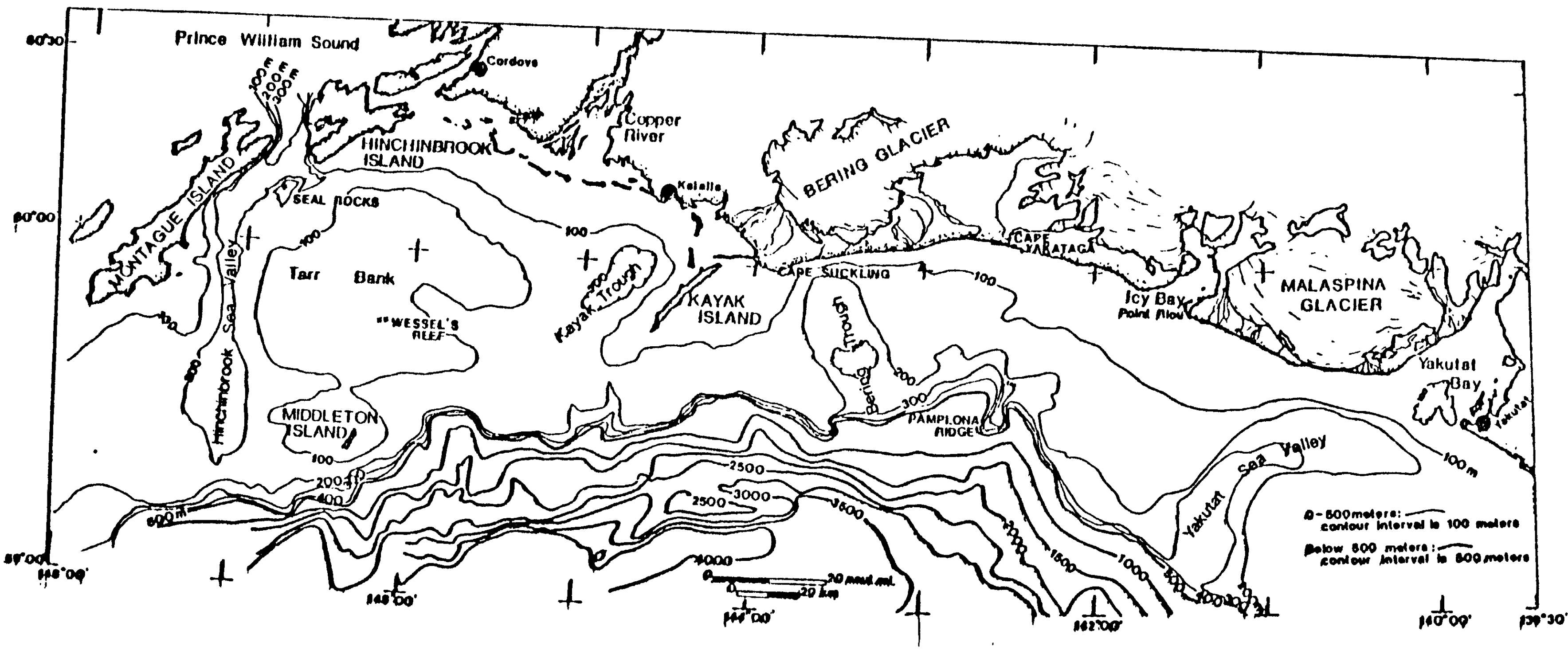
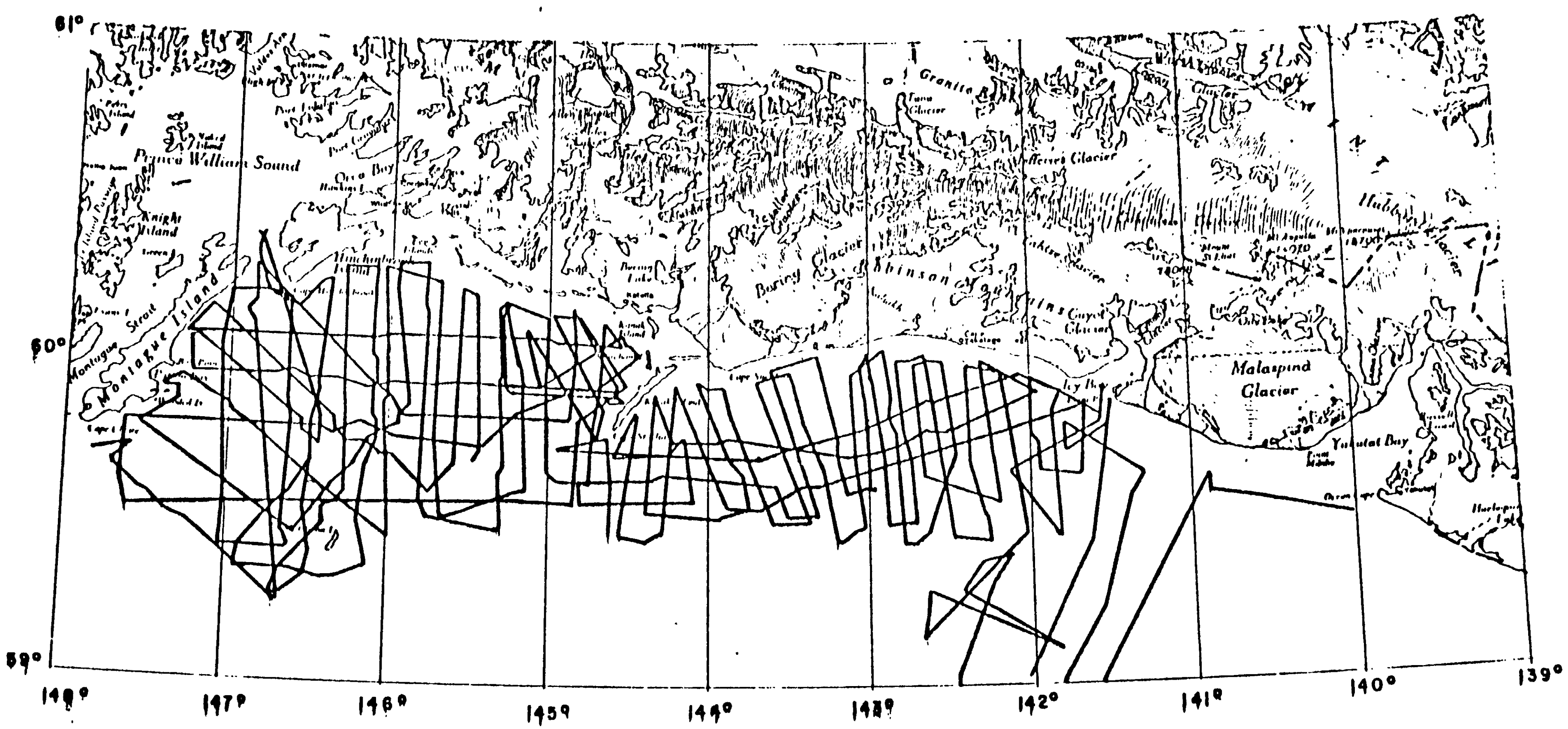

Pt Barrow
ARCTIC OCEAN
U.S.S.R.
ALASKA
CANADA
UNITED STATES
Nome
Yukon River
Fairbanks
Anchorage
JUNEAU
BERING SEA
ALEUTIAN ISLANDS
PACIFIC OCEAN
Miles

FIG 1



Prince William Sound
Cordova
Copper River
Katalla
HINCHINBROOK ISLAND
MONTAGUE ISLAND
SEAL ROCKS
Tarr Bank
"WESSEL'S REEF"
MIDDLETON ISLAND
Hinchinbrook Sea Valley
Kayak Trough
KAYAK ISLAND
BERING GLACIER
CAPE SUCKLING
Bering Trough
PAMPLONA RIDGE
CAPE YAKATAGA
Icy Bay
Point Riou
MALASPINA GLACIER
Yakutat Bay
Yakutat
Yakutat Sea Valley
0-500 meters: contour interval is 100 meters
Below 500 meters: contour interval is 500 meters
20 naut. mi.
20 km
60°30'
60°00'
59°00'
148°00'
146°00'
144°00'
142°00'
140°00'
139°30'

FIG. 2



61°
60°
59°
148°
147°
146°
145°
144°
143°
142°
141°
140°
139°
Prince William Sound
Knight Island
Montague Island
Montague Strait
Orca Bay
Bering Glacier
Malaspind Glacier
Yakutat Bay

FIG. 3

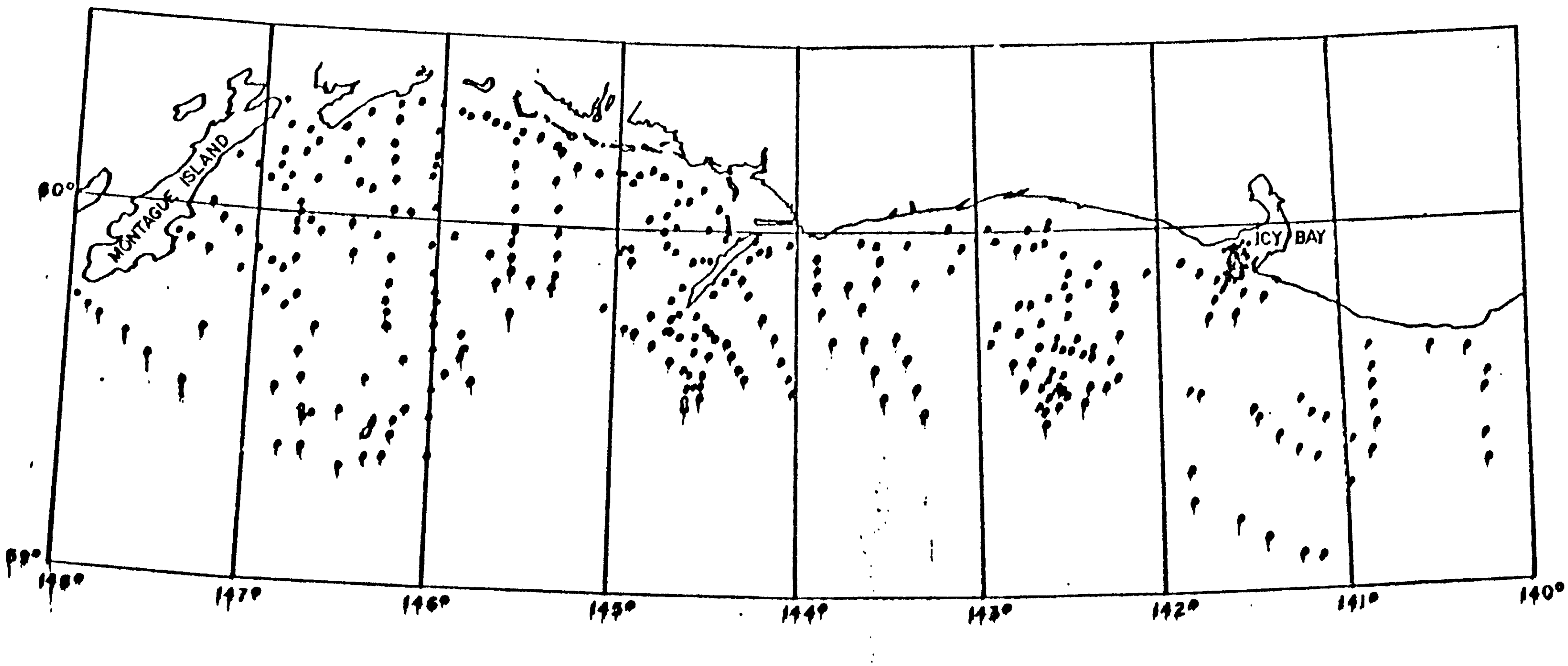

MONTAGUE ISLAND
ICY BAY
60°
59°
148°
147°
146°
145°
144°
143°
142°
141°
140°

FIG 4

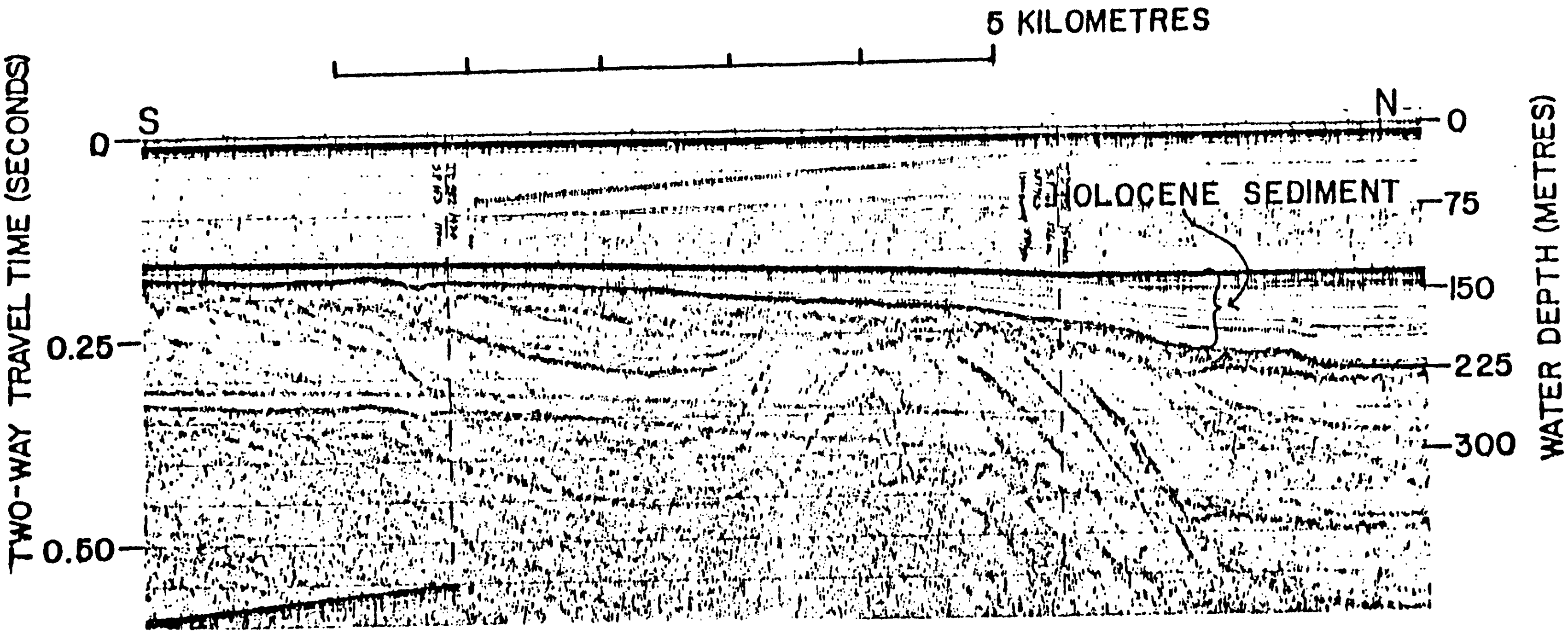

5 KILOMETRES
S
N
HOLOCENE SEDIMENT
TWO-WAY TRAVEL TIME (SECONDS)
0
0.25
0.50
WATER DEPTH (METRES)
0
75
150
225
300

FIG 5

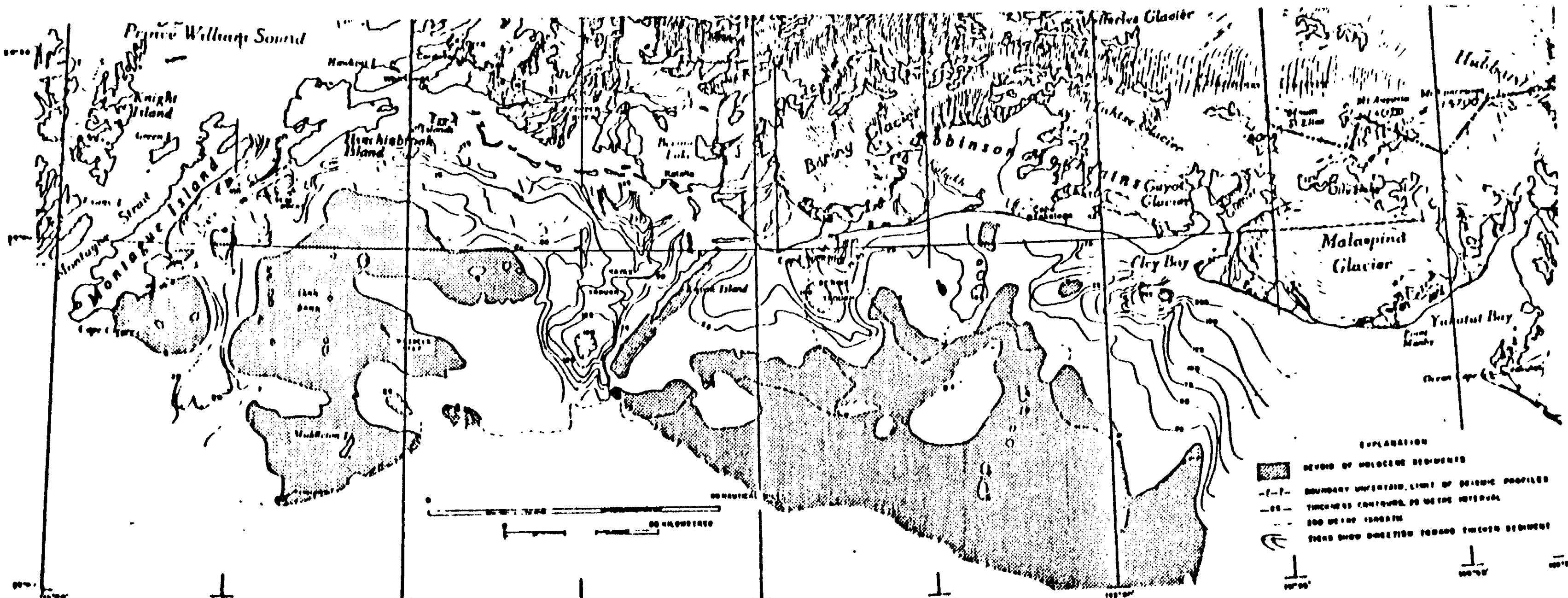

Prince William Sound
Knight Island
Hinchinbrook Island
Montague Island
Montague Strait
Baring Glacier
Robinson
Guyot Glacier
Icy Bay
Malaspina Glacier
Yakutat Bay
EXPLANATION

FIG 6

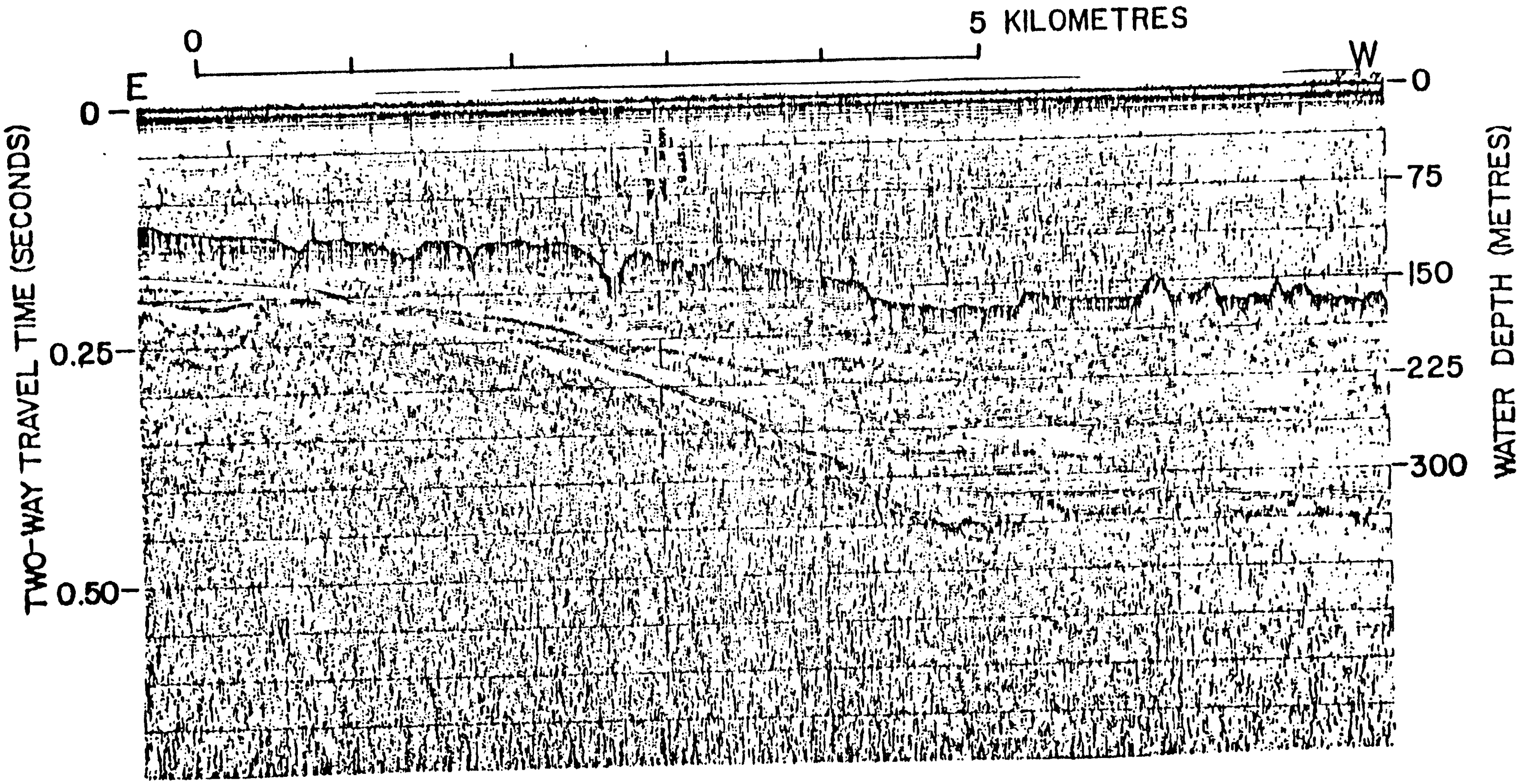

5 KILOMETRES
0
E
W
0
0.25
0.50
TWO-WAY TRAVEL TIME (SECONDS)
0
75
150
225
300
WATER DEPTH (METRES)

FIG 7

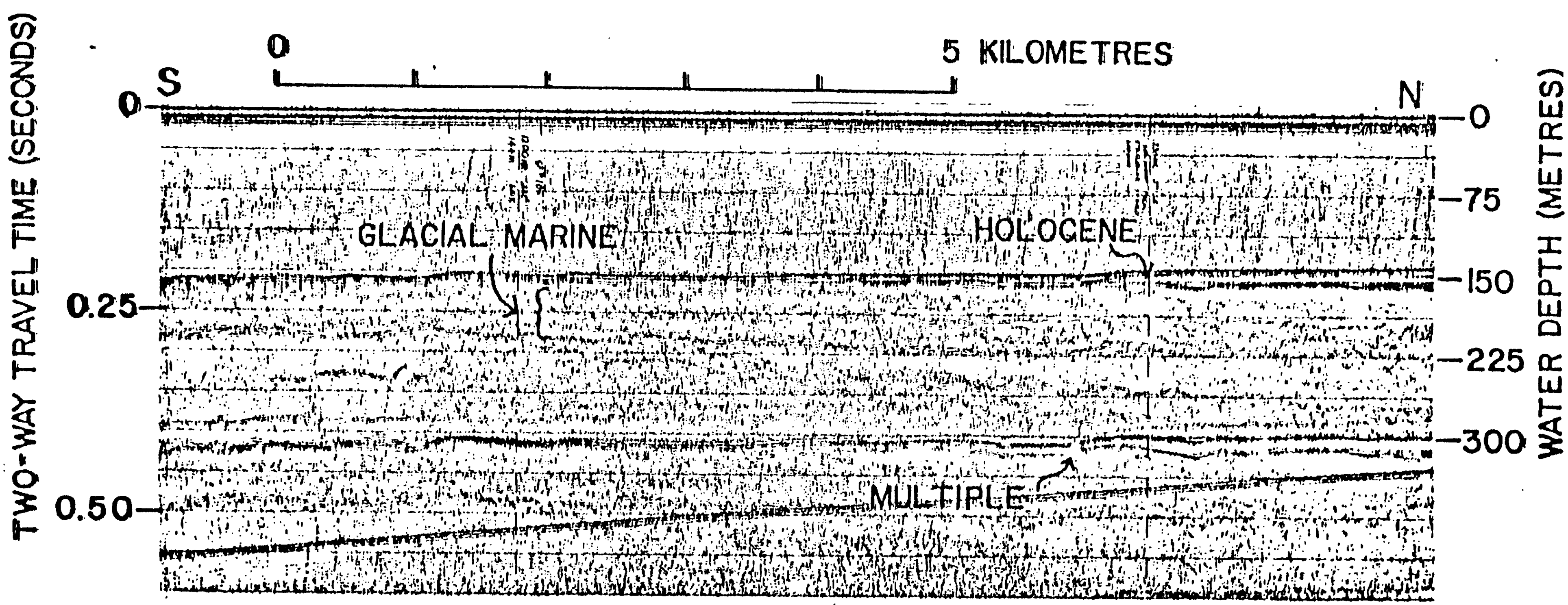

TWO-WAY TRAVEL TIME (SECONDS)
0
0.25
0.50
S
0
5 KILOMETRES
N
GLACIAL MARINE
HOLOCENE
MULTIPLE
0
75
150
225
300
WATER DEPTH (METRES)

FIG 8

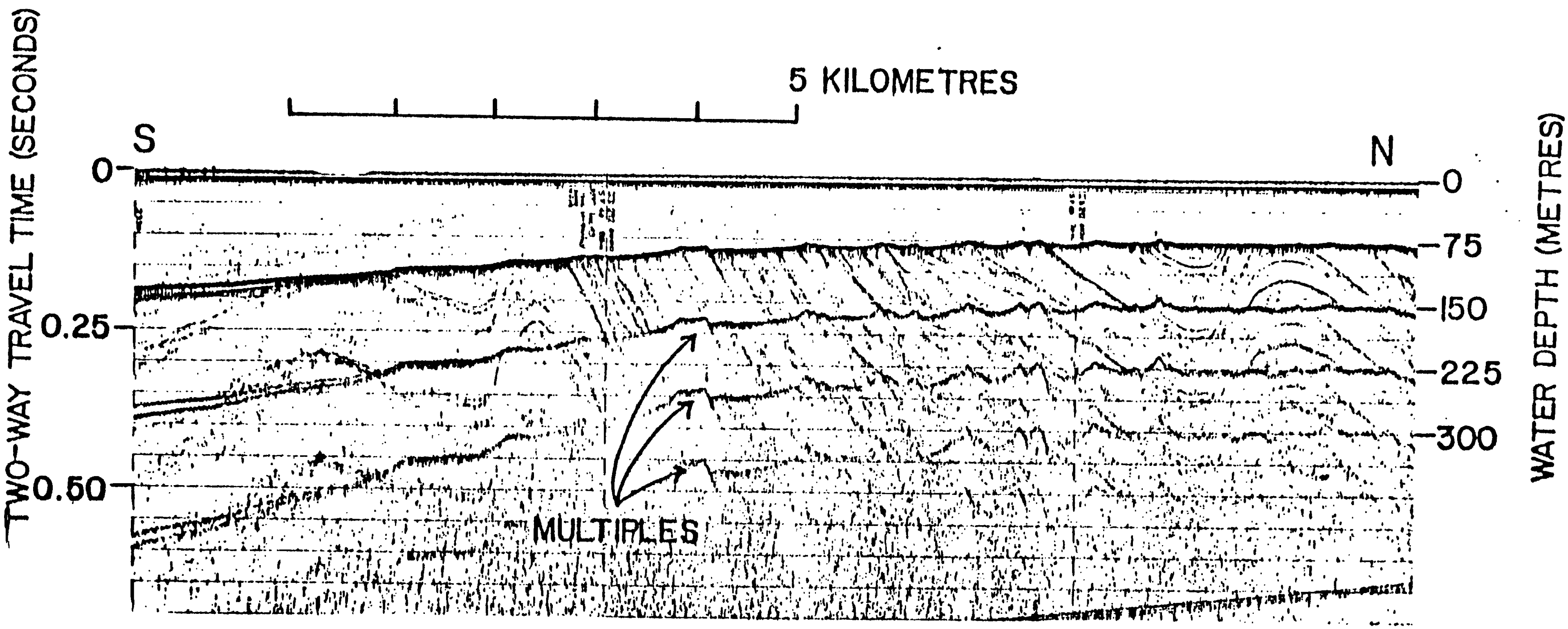

5 KILOMETRES
S
N
TWO-WAY TRAVEL TIME (SECONDS)
0
0.25
0.50
WATER DEPTH (METRES)
0
75
150
225
300
MULTIPLES

FIG 9

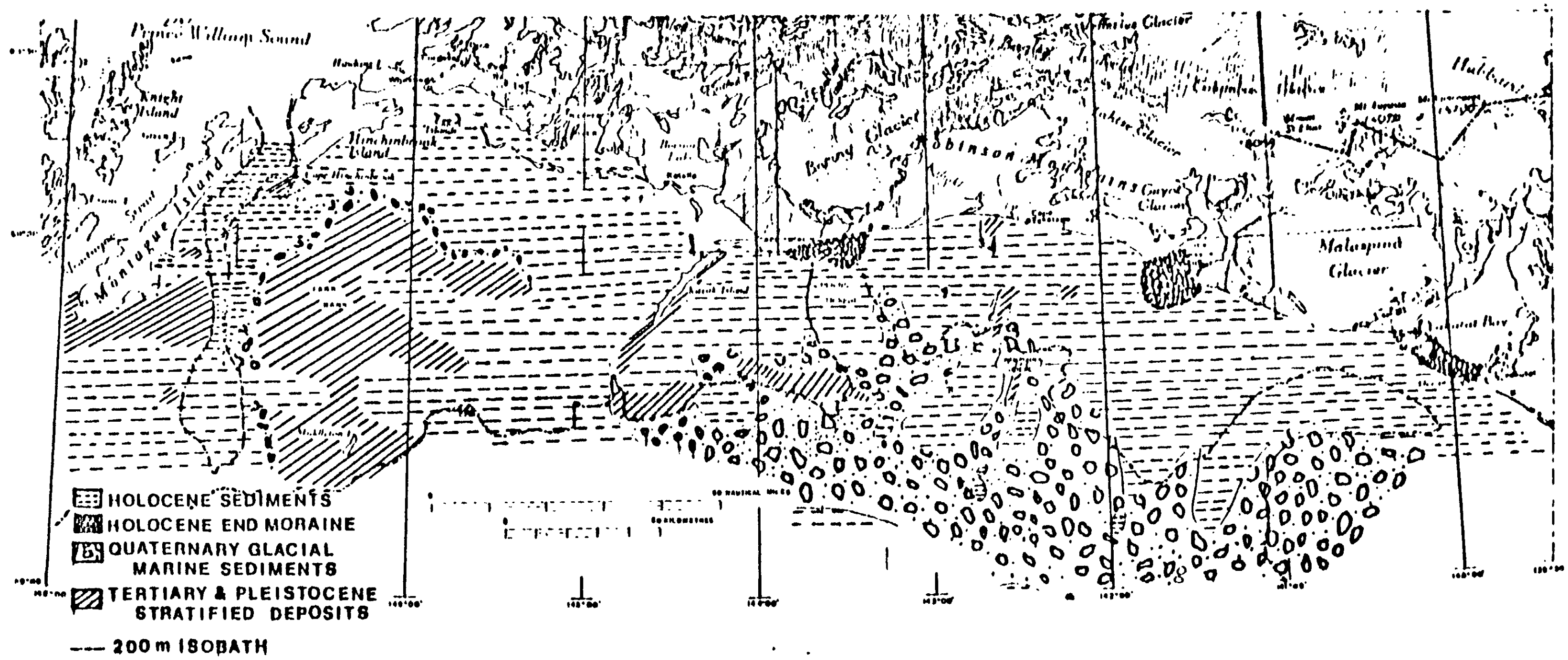

Prince William Sound
Knight Island
Montague Island
Hinchinbrook Island
Bering Glacier
Robinson Mountains
Malaspina Glacier
HOLOCENE SEDIMENTS
HOLOCENE END MORAINE
QUATERNARY GLACIAL MARINE SEDIMENTS
TERTIARY & PLEISTOCENE STRATIFIED DEPOSITS
200 m ISOBATH

FIG 10

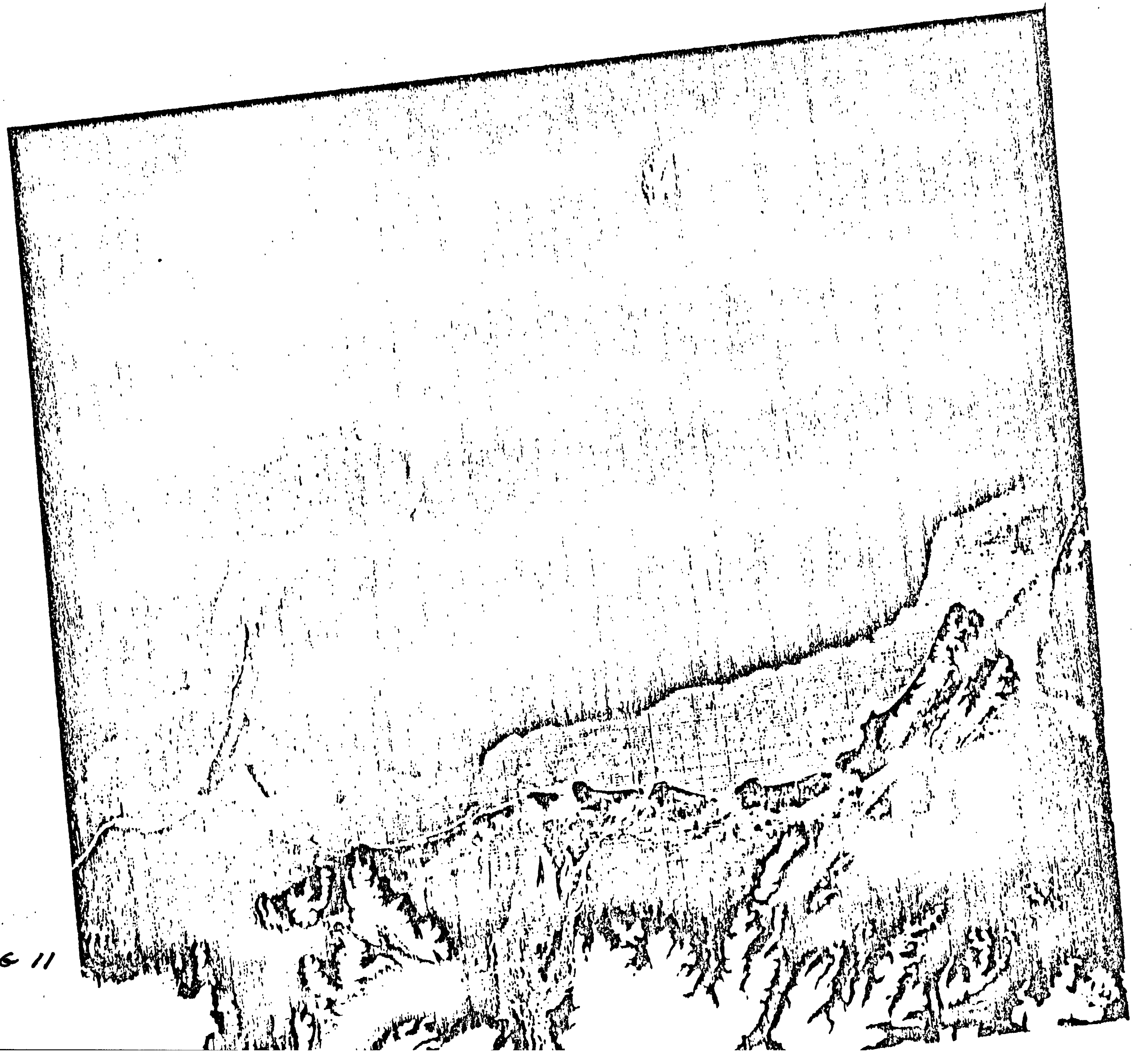


FIG 11