Attachment A

INNER-SHELF GEOLOGY OF THE NORTH SIDE OF KOTZEBUE SOUND--HOPE BASIN

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INTRODUCTION

The bight of the Chukchi Sea between Cape Prince of Wales and Point Hope has received no single name. The inner part of the bight is Kotzebue Sound, and the geologic basin underlying large parts of the bight is Hope basin. We have made reconnaissance surveys of the north side of this bight during two cruises of the R/V KARLUK, one in 1975 on which Peter Barnes was chief scientist, and one in 1981 on which Ralph Hunter was chief scientist (Fig. 1). The tracklines referred to in this report are numbered separately for the two cruises. Bad weather and a shortage of time have so far prevented the collection of data from the south side of the bight.

ENVIRONMENTAL SETTING

The stretch of coast from Kotzebue northwestward to Point Hope is exposed to waves from the south and west, Waves from these directions are generated by the relatively mild summer winds and by occasional storms during the fall. Because of its orientation, this stretch of coast is not severely affected by the strong northerly and easterly winter winds.

The strength and direction of tidal currents are not well known in Kotzebue Sound. Given the low tidal ranges (the diurnal range is only 2.7 feet at Kiwalik, at the head of Kotzebue Sound, and is even lower toward the open Chukchi Sea), the currents are probably not strong except in constricted channels, such as Hotham Inlet. The Alaskan Coastal Water Current is probably not strong in the eastern part of the area but becomes stronger towards the west because of the constricting effect of Point Hope. This effect is well shown by the current measurements reported by Creager (1963). Those measurements show weak currents southeast of Kivalina and near-bottom currents sometimes stronger than 25 cm/sec from Kivalina northwest to Point Hope.

This stretch of coast is relatively unaffected by sea ice being driven ashore, because the winter winds blow predominantly offshore, from the north and east. Ice drifting alongshore, however, affects the bottom.

BATHYMETRY

No detailed navigation charts of Kotzebue Sound and adjacent parts of the Chukchi Sea are available. The most detailed bathymetric map available is that by Creager (1963). Creager's map shows nearly shore-parallel isobath lines out to the 60-feet isobath, which is located 4 to 8 nautical miles offshore. The shoal off Cape Krusenstern shown on Navigation Chart 16005 (National Ocean Survey, 1980) does not seem to exist now, if it ever did. A wide shoal does exist off Kotzebue; this poorly charted shoal is transected by a single large channel, which is an extension of Hotham Inlet.

SEDIMENT CHARACTER

The beaches along this entire stretch of coast are composed of gravel and sand (Moore, 1966; Hayes and others, 1979). Offshore sediments have been sampled extensively by Creager (1963). According to Creager, coarse sand and gravel extend to distances of 3-12 nautical miles offshore along the stretch of coast from Kivalina to near Point Hope. Sand forms a nearshore zone a few nautical miles wide from Kivalina southeast to Cape Krusenstern, and sandy silt forms the nearshore zone from Cape Krusenstern to Kotzebue. High-resolution seismic data suggest that the thickness of Holocene sediment decreases shoreward along the stretch of coast from Point Hope to Cape Krusenstern, becoming less than 2 m on the inner shelf (Holmes, 1975).

SHOALS AND CHANNEL NEAR KOTZEBUE

The very shallow (water depth less than 2 m as far as 13 km offhsore) shoal west of Kotzebue is an ebb-tidal delta formed by deposition at the point where flow from Hotham Inlet enters Kotzebue Sound. No data have been gathered yet from the shoal areas, but aerial photographs reveal a complex pattern of sand bars, which can be expected to shift rapidly due to wave and current action. The channel that extends through Hotham Inlet and runs southwestward past Kotzebue through the shoal was studied in 1975 (Lines 1 and 2). Uniboom seismic records show locally a subhorizontal reflector that lies near the level of the channel floor and extends beneath the adjacent channel sides (Fig. 2); this suggests that at least parts of the shoal are a recent depositional feature formed during lateral migration of the channel.

Monographs of the channel floor southwest of Kotzebue show closely spaced furrows parallel to one another and to the channel axis (Fig. 3a). These furrows have a vertical relief of less than 0.3 m. Some of the furrows bend sharply and cross others (Fig. 3b) and therefore must be ice gouges, but many of the furrows may be current-generated; current-generated furrows have been described from estuarine muds in England (Flood, 1981). Some of the furrows extend downchannel from small irregularities on the monographs (Fig. 4). If the furrows are “comet marks” formed by current scour or deposition downcurrent from the irregularities, which may be gravel concentrations and isolated boulders, the flow was seaward (to the southwest). Besides the furrows, the monographs locally show “pockmarks,” flat-bottomed depressions of undetermined origin a few meters wide and less than 0.3 m deep (Fig. 5).

KOTZEBUE SOUND FROM SHOALS TO CAPE KRUSENSTERN

The part of Kotzebue Sound from the edge of the ebb-tidal delta (18 km southwest of Kotzebue) to Cape Krusenstern was traversed along a single trackline (Line 2d-3) in 1975. The seafloor along this line is nearly flat, at water depths of 12-16 m. Monographs show ice gouging that is locally fairly dense and “fresh” looking, but fathograms show that the gouging is nowhere more than 0.3 m deep. The dominant trend of the gouges is northwest-southeast (parallel to isobaths), but the range of directions is fairly wide. At least one gouge was formed by an ice mass that reversed its direction of movement (Fig. 6a), possibly as a result of reversing tidal flow.

The 7 kHz seismic records from parts of this line show a flat to irregularly wavy reflecting horizon at a depth of 1 to 6 m below the flat seafloor (Fig. 7). The material underlying this contact is presumed to be bedrock or sediment that is older and more consolidated than the overlying sediment of presumed Holocene age.

CAPE KRUSENSTERN AREA

In 1981 as we skirted skirted Cape Krusenstern at a distance of 1 to 2 km from shore (Line 6). Ice gouging was virtually absent north of Cape Krusenstern (along the west side of the foreland whose tip is formed by Cape Krusenstern), where the line was in water depths of 4-7 m, but was locally intense and fresh looking (Fig. 6b) southeast of the cape (along the south side of the foreland), where the line reached water depths as great as 14 m. The gouges, most of which trend nearly parallel to shore, are not visible on the depth records and therefore are less than 0.5 m deep. A poorly defined reflecting horizon 2-6 m below the seafloor is visible on 7 kHz seismic records from this area.

KIVALINA AREA

One trackline in 1981 (Line 5) zigzags along the coast southeastward from Kivalina, reaching water depths of as much as 19 m, at a point 3.5 km offshore. Ice gouges occur commonly more than' 1 km from shore (Fig. 8). Most of these gouges trend at small angles to the shoreline and appear fresh. The deepest gouge is only 0.6 m deep. Gouges are rare or absent closer than 1 km to shore; here, the monographs show light and dark mottled areas that are interpreted as patchwork of relatively fine sand and relatively coarse sand or gravel. Some of the dark patches contain symmetrical, wave-formed ripples that are spaced about 1.2 m apart and that trend northwest-southeast, at a low angle to the shoreline. The patches and large wave ripples in this area, like those in nearshore areas of the Bering Sea (Hunter and others, in press), were probably shaped by storm waves. A faint reflecting horizon visible on the 7 kHz records suggests that the shoreface off Kivalina is underlain by a Quaternary sediment body that thins seaward.

CAPE THOMPSON AREA

The inner shelf from Cape Thompson southeast to Kisimilok Creek, a distance of 27 km, was studied in great detail by Scholl and Sainsbury (1966). In 1975 we ran a single shore-normal trackline out to a water depth of 20 m (6 km from shore) in this area (Line 4), and in 1981 we skirted Cape Thompson along a single trackline 0.5-2 km from shore (last part of line 4). The monographs from both these tracklines show bedrock and/or gravel patches close to shore (Fig. 9) and few if any visible features farther offshore; however, the quality of the offshore parts of the 1975 monographs was degraded by the presence of features interpreted to be internal waves along a pycnocline. A few ice gouges are visible, and a few "pockmarks" (steep-sided, flat-floored, shallow depressions as much as 25 m in length) are visible close to the bedrock near Cape Thompson (Fig. 10a). The pockmarks are of unknown origin.

Uniboom seismic records from this area showed no subbottom reflectors. Paleozoic bedrock probably lies very near the seafloor throughout the area (Scholl and Sainsbury, 1966).

POINT HOPE AREA

We ran zigzag tracklines (Line 5 in 1975 and line 4 in 1981) reaching a water depth of 23 m at a point 2.2 km offshore. The monographs from parts of this area more than 1 or 2 km offshore show sparse to moderate ice gouging (Fig. 10b). Most of the gouges trend at small angles to the shoreline and are not deep enough to be visible on the depth records. The monographs also show some dark patches, which are probably formed by coarse sand or gravel. The dark patches closest to Point Hope are associated with vertical relief of as much as 3 m (Fig. ha) and may be bedrock, as may other dark patches (Fig. 11b). Some of the patches of coarse sediment contain symmetrical wave ripples that are spaced about 1 m apart and that trend at small angles to the shoreline (Fig. 10b). Barnes observed some of these ripples by underwater television; they had spacings of 0.3-0.5 m, heights of 3-5 cm, and were in gravelly sediment with mud filling the troughs. The ripples are of such size that they must have been formed by storm waves. Uniboom seismic records from this area locally show gently dipping reflecting layers in presumed Cenozoic bedrock. The gently folded beds extend up to or very near the seafloor, though locally the Quaternary sediment cover is thick enough (more than 1 or 2 m) to be measurable (Fig. 11).

CONCLUSIONS

(1) Ice gouging was not found to be intense anywhere on the inner shelf (at water depths less than on the inner shelf (at water depths less than 12-23m); locally the gouges are moderately dense, but nowhere was a gouge deeper than 0.6 m found. A possible exception is in the channel that cuts through the shoal southwest of Kotzebue, where erosional furrows of undertermined origin are abundant. It should be remembered that ice gouges may be obliterated by wave or current activity, so that ice effects on the seafloor may be more intense than the existing gouges suggest.

(2) Patches of material that appears dark on monographs and is commonly ripple-marked are common in very shallow water and occur locally on the deeper parts of the inner shelf. The ripple-marked patches must be coarse sand or gravel. Patches that are not ripple-marked may be gravel that is too coarse or too poorly sorted to be ripple-marked, coarse sand or gravel in which ripple marks have been destroyed by the activity of animals or by ice action, fine-grained cohesive sediment, or bedrock outcrops. The ripples in the coarse sediment patches are of symmetrical, wave-generated type and are spaced about a meter apart. Their size and occurrence only in coarse material indicate that they were generated by storm waves. When the sediment grain size is known, it will be possible to estimate the sizes of the waves that produced the ripples.

(3) Pockmarks (relatively small depressions) of unknown origin occur locally in the area. Some pockmarks in other areas have been attributed to the escape of gas from the sediment, but origins by current scour, ice action, or the activity of animals are also possible.

(4) Sand waves were not found in the area. Their absence along the coast southeast of Kivalina is probably due to insufficient current strength, whereas their absence along the coast northwest of Kivalina may be due to insufficient sand-sized material.

(5) High-resolution seismic data suggest that the thickness of unconsolidated sediment of Holocene and/or Pleistocene age is thin (less than 10 m) on much of the inner shelf. The large shoal southwest of Kotzebue, however, is a major depositional area for sediment supplied by the Kobuk and Noatak Rivers.

(6) All of the above conclusions are based only on reconnaissance surveys and need to be tested by additional data. The conclusions should not be assumed to apply to the south side of Kotzebue Sound-Hope basin.

(7) In Kotzebue Sound it becomes apparent that both ice-related and wave- and current-related seabed event will be important in determining the stability and geologic history of the seafloor. Several seafloor features are at present unexplained, except in conjecture: furrows, pockmarks, textural patterns on monographs, to name a few. The nearshore seafloor environment of Kotzebue Sound is apparently a complex and unique result of ice, wave and current, and pre-Holocene events.

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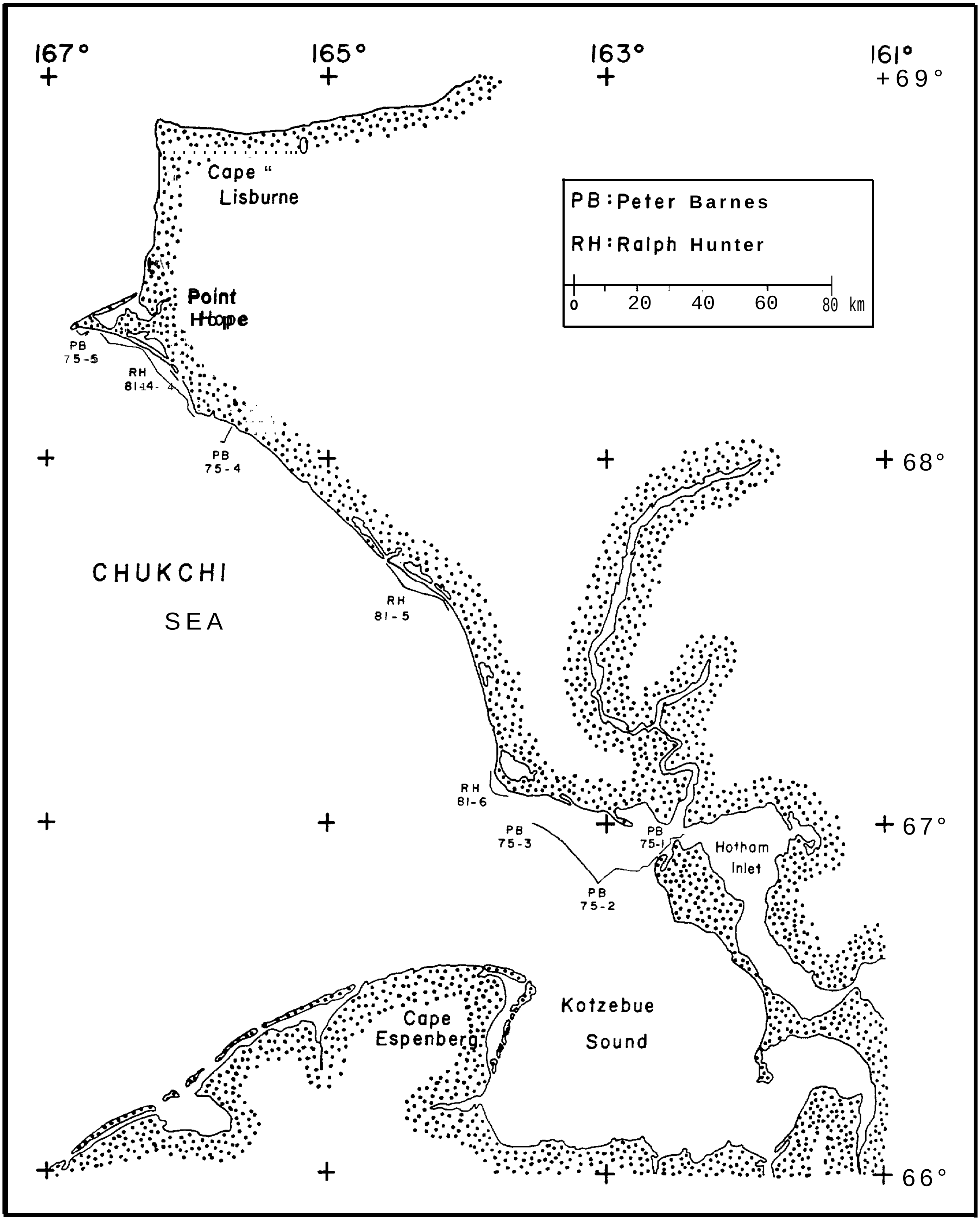
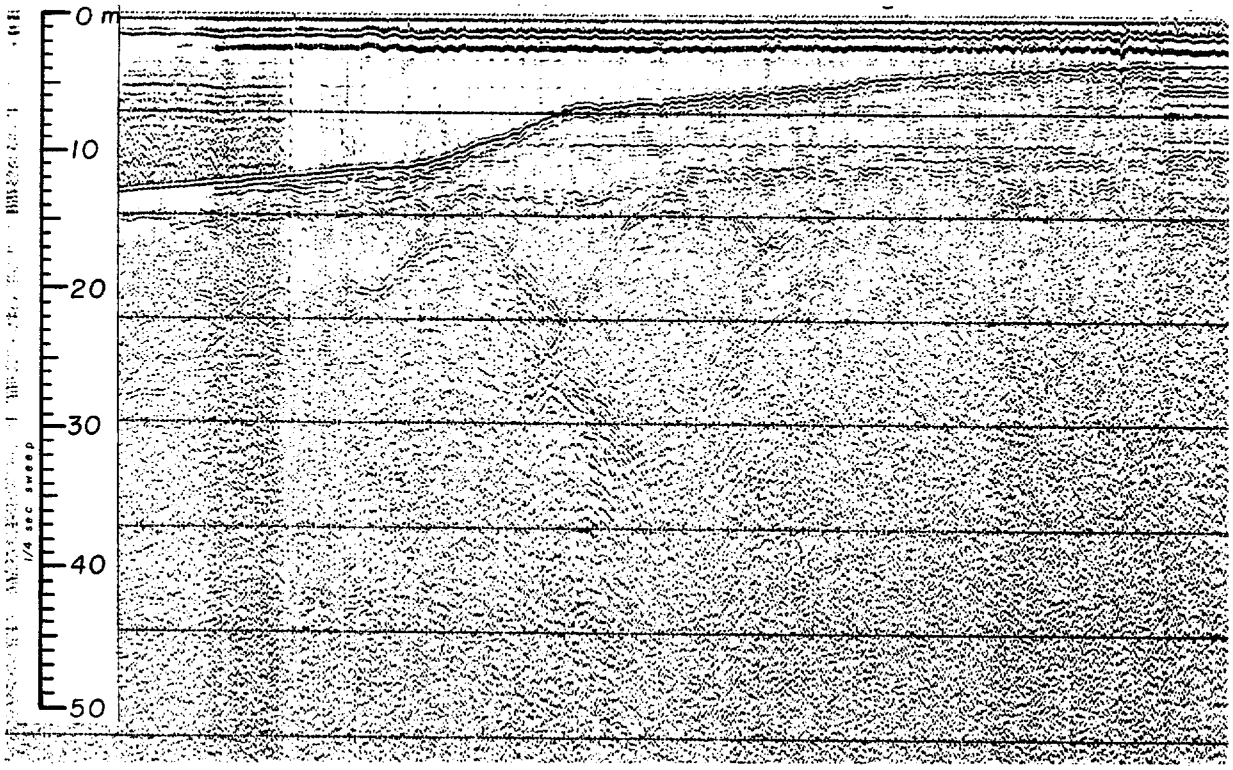


Fig. 1. Index map showing tracklines on the north side of Kotzebue Sound - Hope basin.



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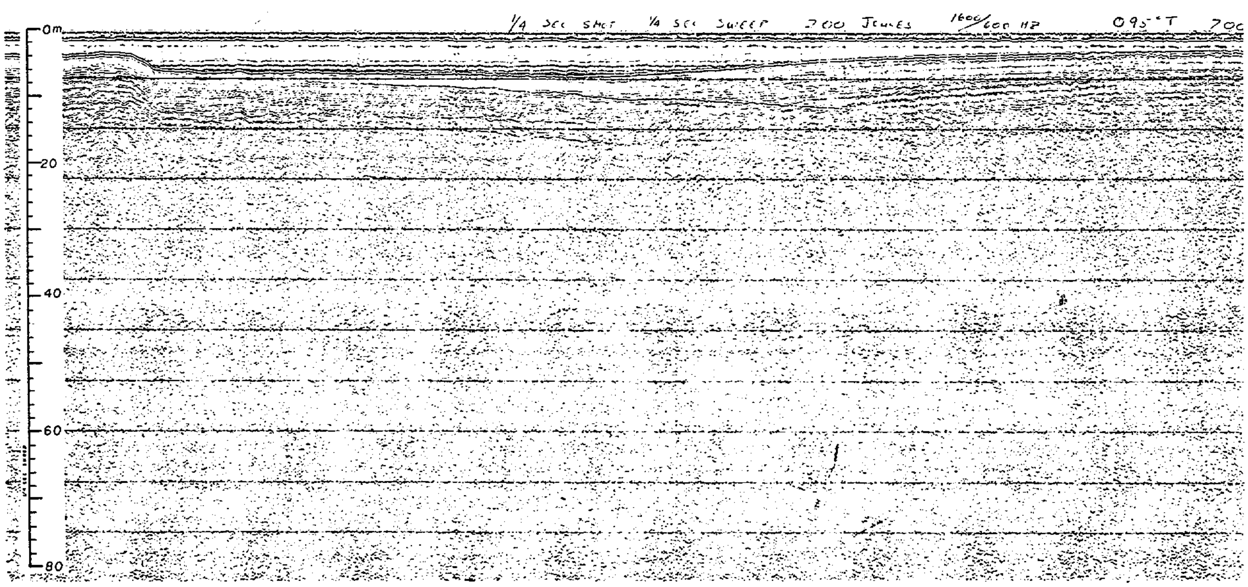

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Fig. 2. **Uniboom** seismic profiles across floor and side of channel in **Hotham** Inlet and its seaward extension near **Kotzebue.** (a. 1975, line 1, 1701-1707 hrs. b. 1975, line 1, 1536.6-1538.5 **hrs).**

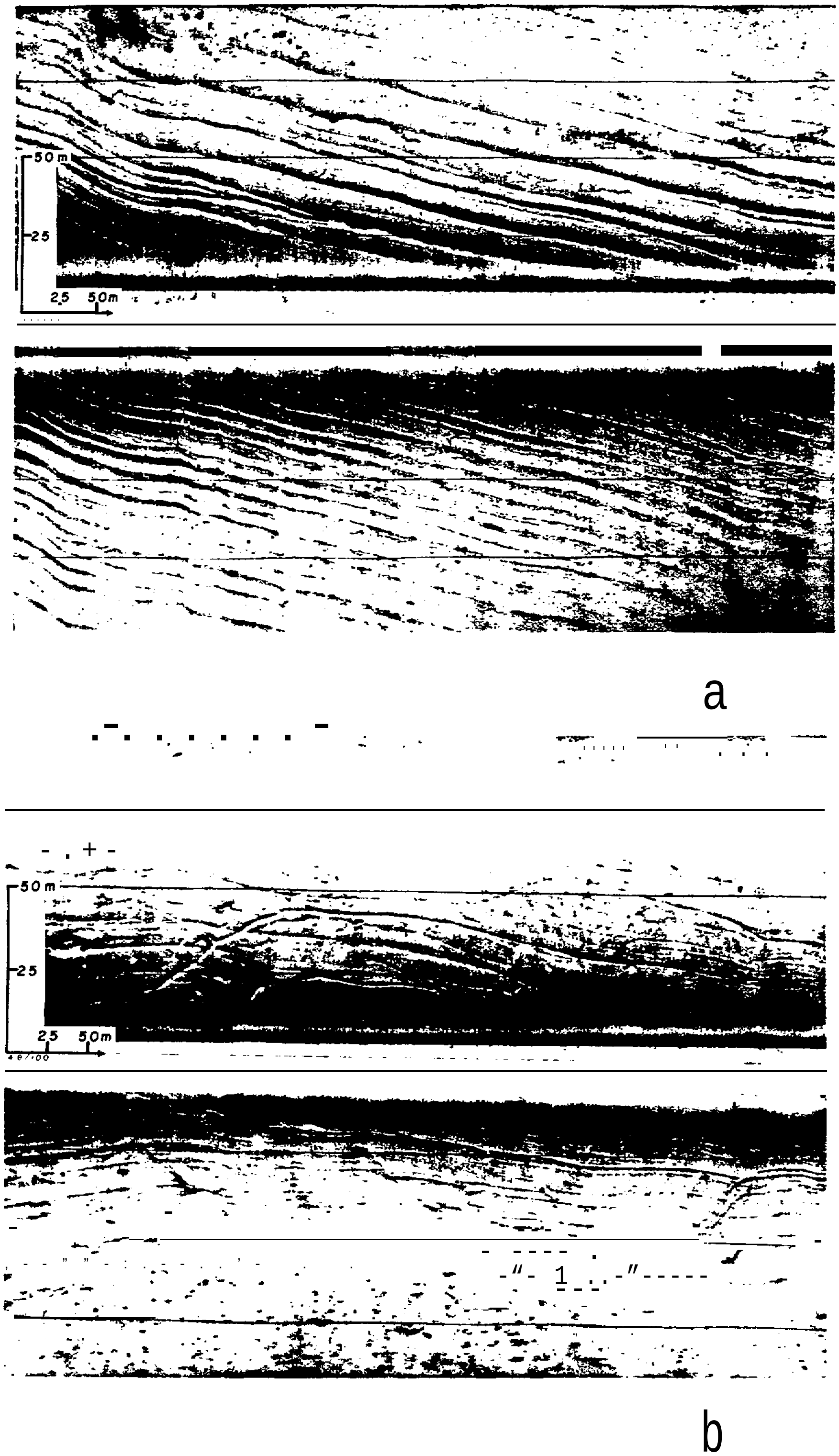
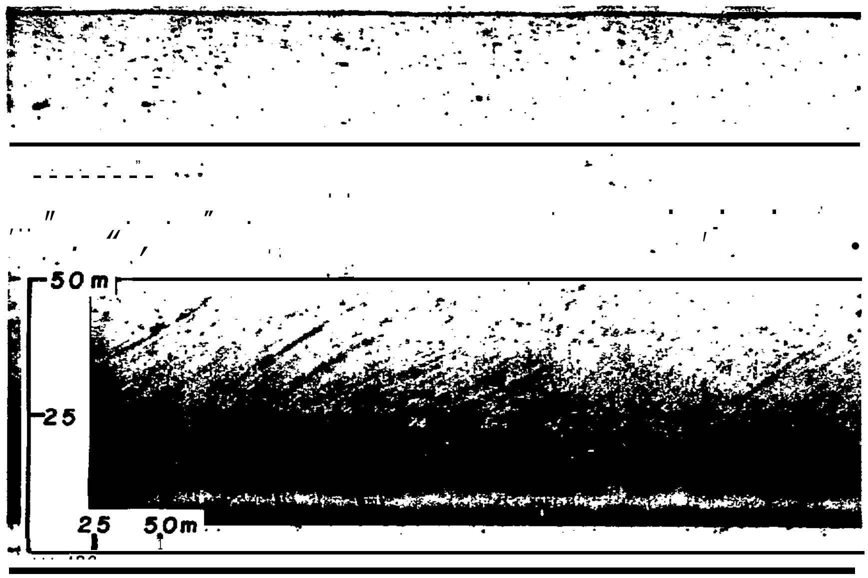


Fig. 3. Monographs showing furrows in channel that cuts through shoals southwest of Kotzebue. a. Large parallel furrows in deepest part of channel (1975, line 2b, 1045-1049 hrs, water depth 5 m). b. Furrows, some of which bend and cross others and therefore must be ice gouges (1975, line 2b, 1032-1036 hrs, water depth 3½ m).



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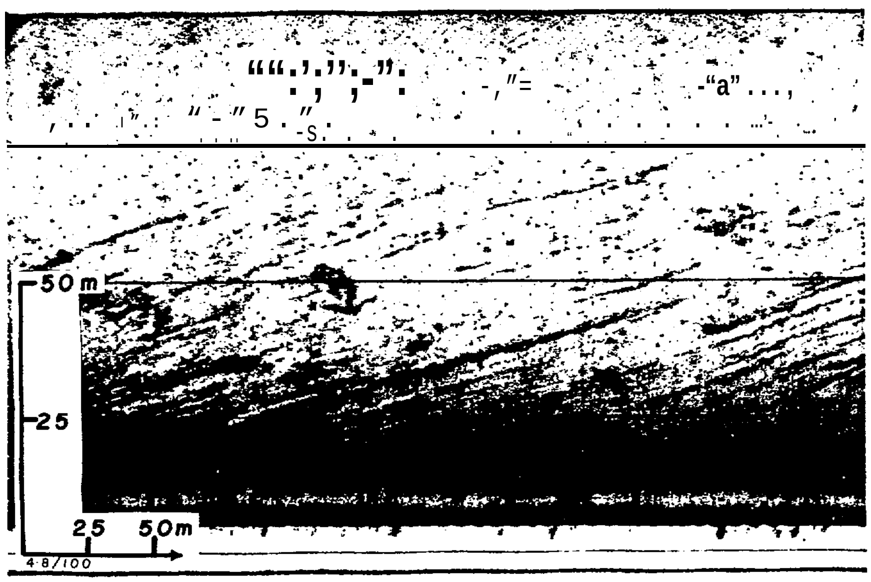

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Fig. 4. Monographs showing furrows, some of which terminate at seafloor irregularities, in channel that cuts through shoals southwest of Kotzebue. Furrows are parallel to channel axis and, if generated by current scour or deposition downstream of the irregularities, indicate seaward **flow.**
a. Furrows terminating at relatively small irregularities that may be isolated boulders (1975, line 26, 1019-1021 hrs, water depth 4 m). b. Furrows terminating at relatively large irregularities that may be concentrations of gravel (1975, line 26, 1052-1054 hrs, water depth 4 m).

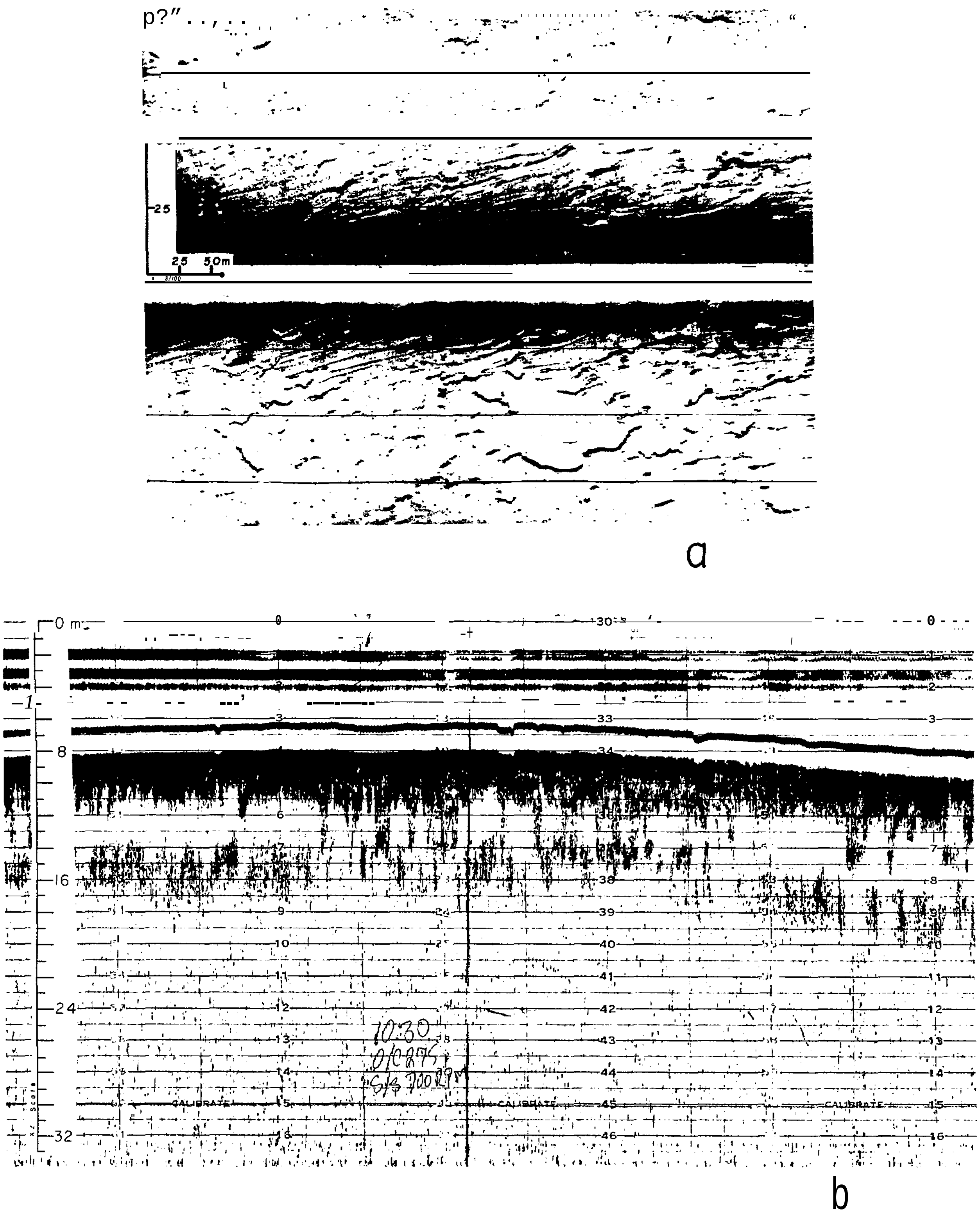


Fig. 5. Pockmarks associated with furrows in channel that cuts through shoals southwest of **Kotzebue.** The pockmarks (relatively small depressions) are of undetermined origin. a. Sonograph (1975, line 2b, **1026½-1030 hrs,** water depth 3 m). b. Fathogram from same location, showing several **flat-**floored pockmarks.

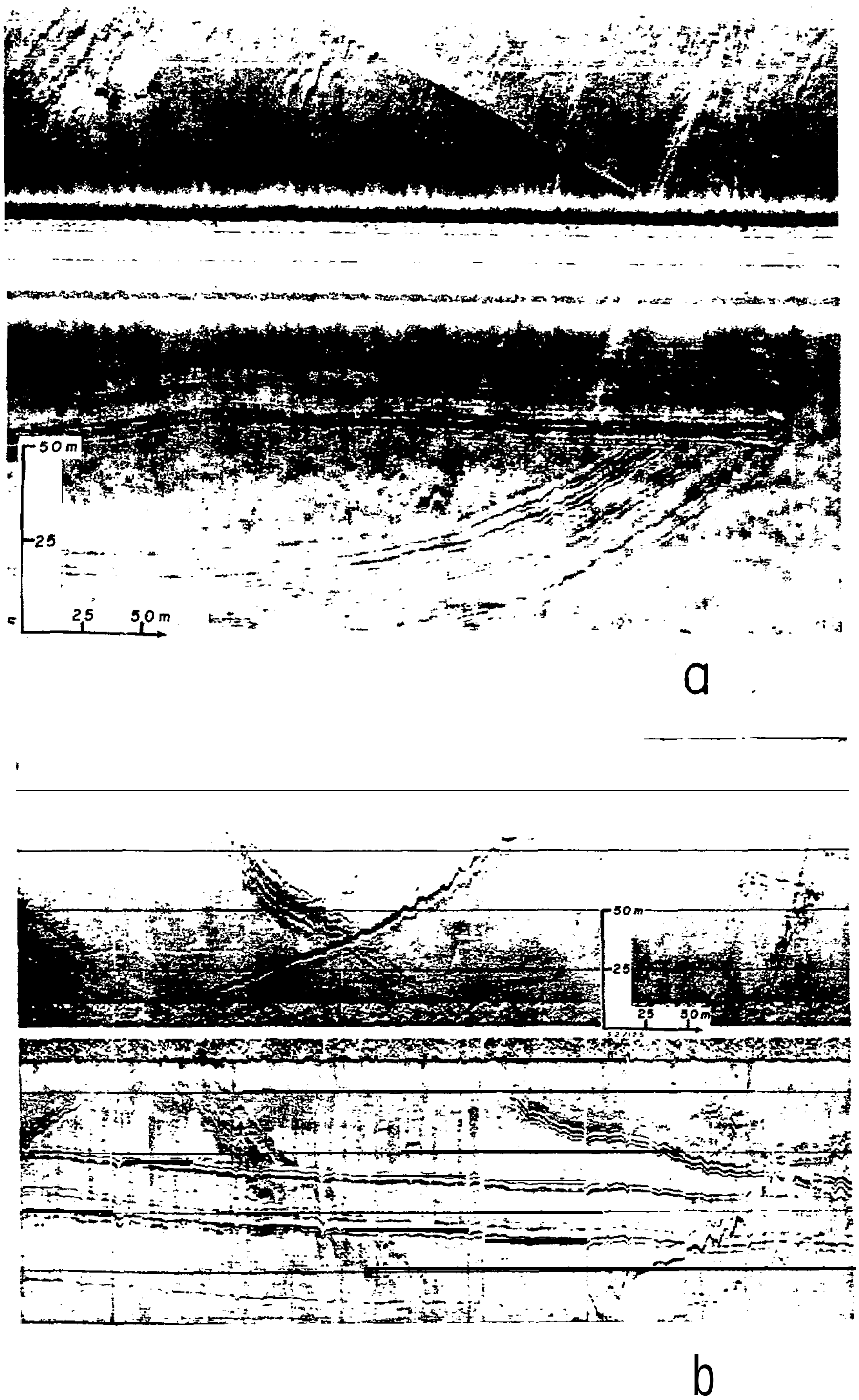


Fig. 6. Monographs showing ice gouges in area between Kotzebue and Cape Krusenstern. a. Gouge formed by ice mass that reversed its direction of movement (1975, line 2d, 1347-1350 hrs, water depth 14 m). b. Gouges near Cape Krusenstern (1981, line 6, 1555-1600 hrs, water depth 14 m).

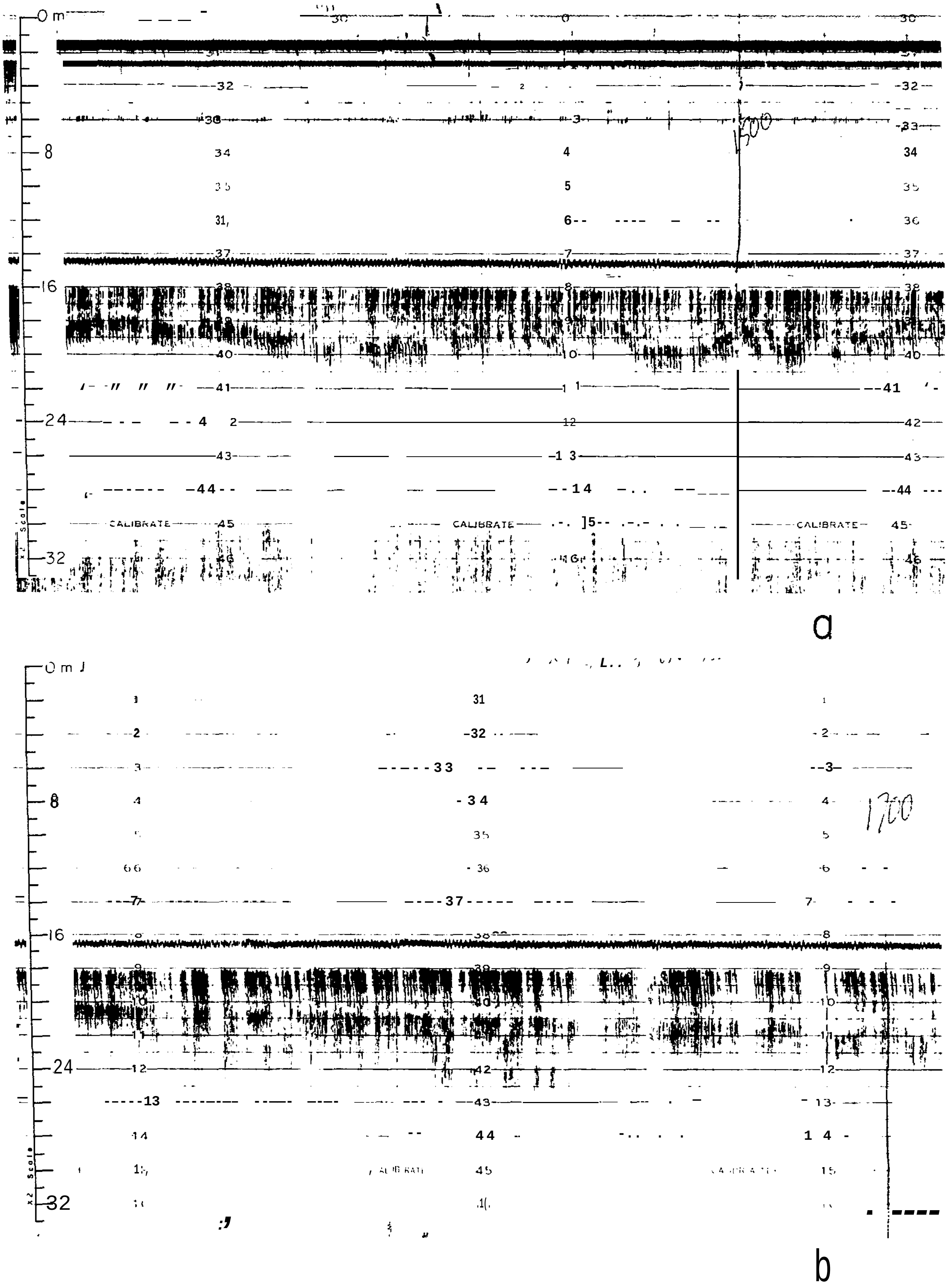
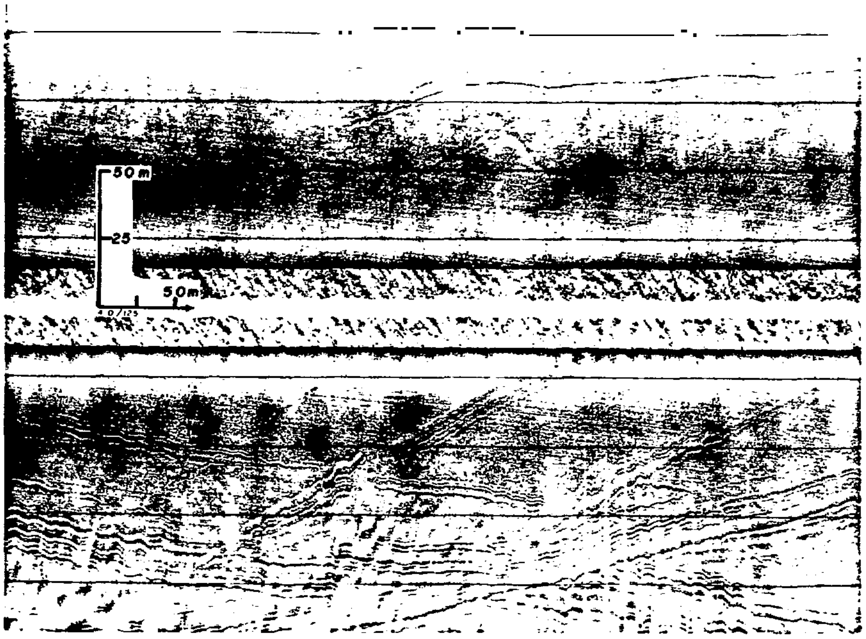


Fig. 7. 7 kHz seismic profiles showing reflector at depth of a few meters below the seafloor, in area between Kotzebue and Cape Krusenstern. a. Reflector irregular (1975, line 2d, 1452-1500 hrs) . b. Reflector relatively smooth (1975, line 3, 1650-1700 hrs).



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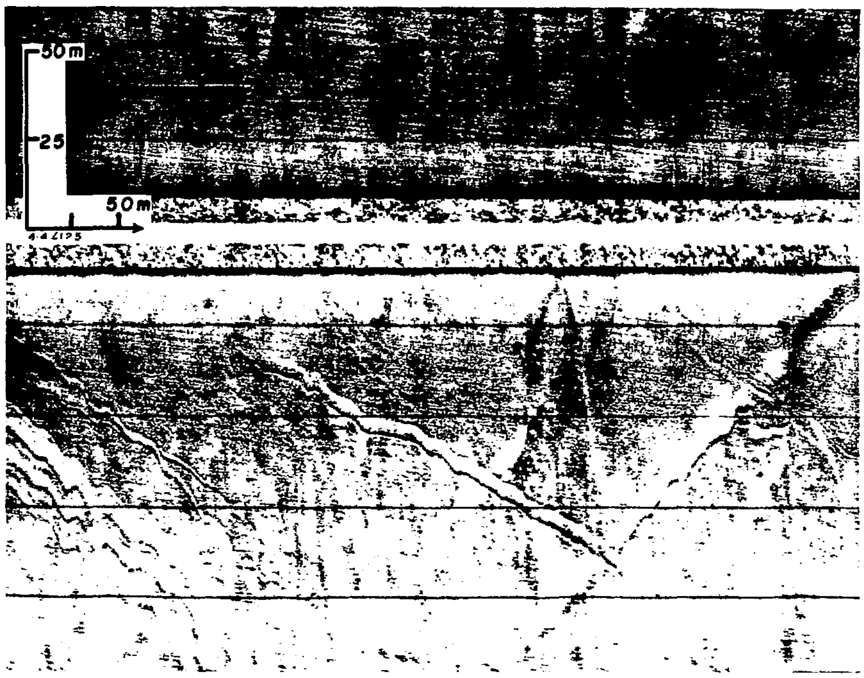

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Fig. 8. Monographs showing ice gouges in Kivalina area. a. Gouges nearly parallel to shore (1981, line 5, 0841-0845 hrs, water depth 11 m). b. Gouges variable in orientation (1981, line 5, 1020-1023 hrs, water depth 12 m).

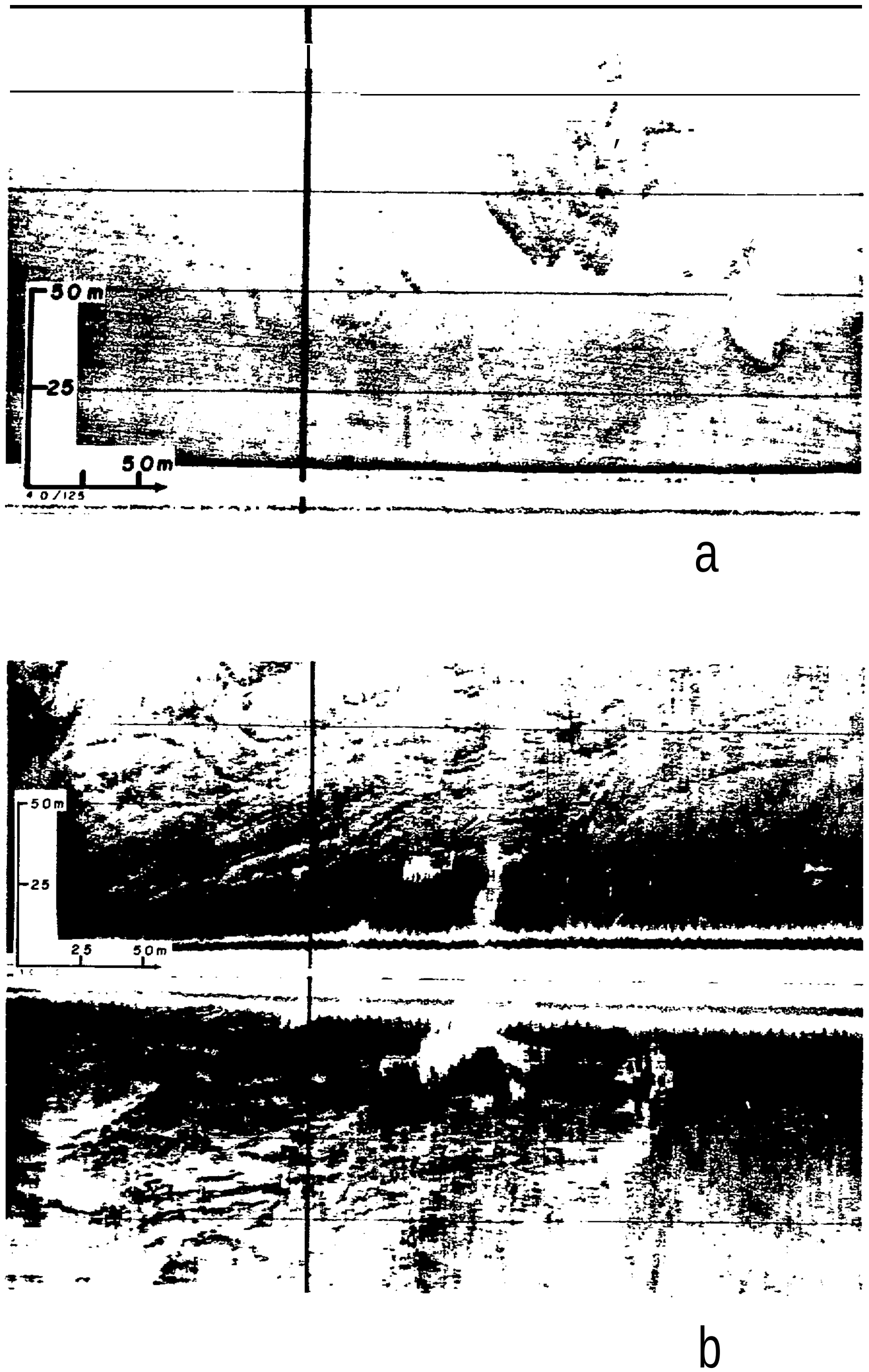


Fig. 9. Monographs showing bedrock and/or gravel patches close to shore in Cape Thompson area. a. 1981, line 4, 1309-1312 hrs, water depth 9 m. b. **1975,** line 4, 1149-1153 hrs. water depth 4 m at left, increasing to right.

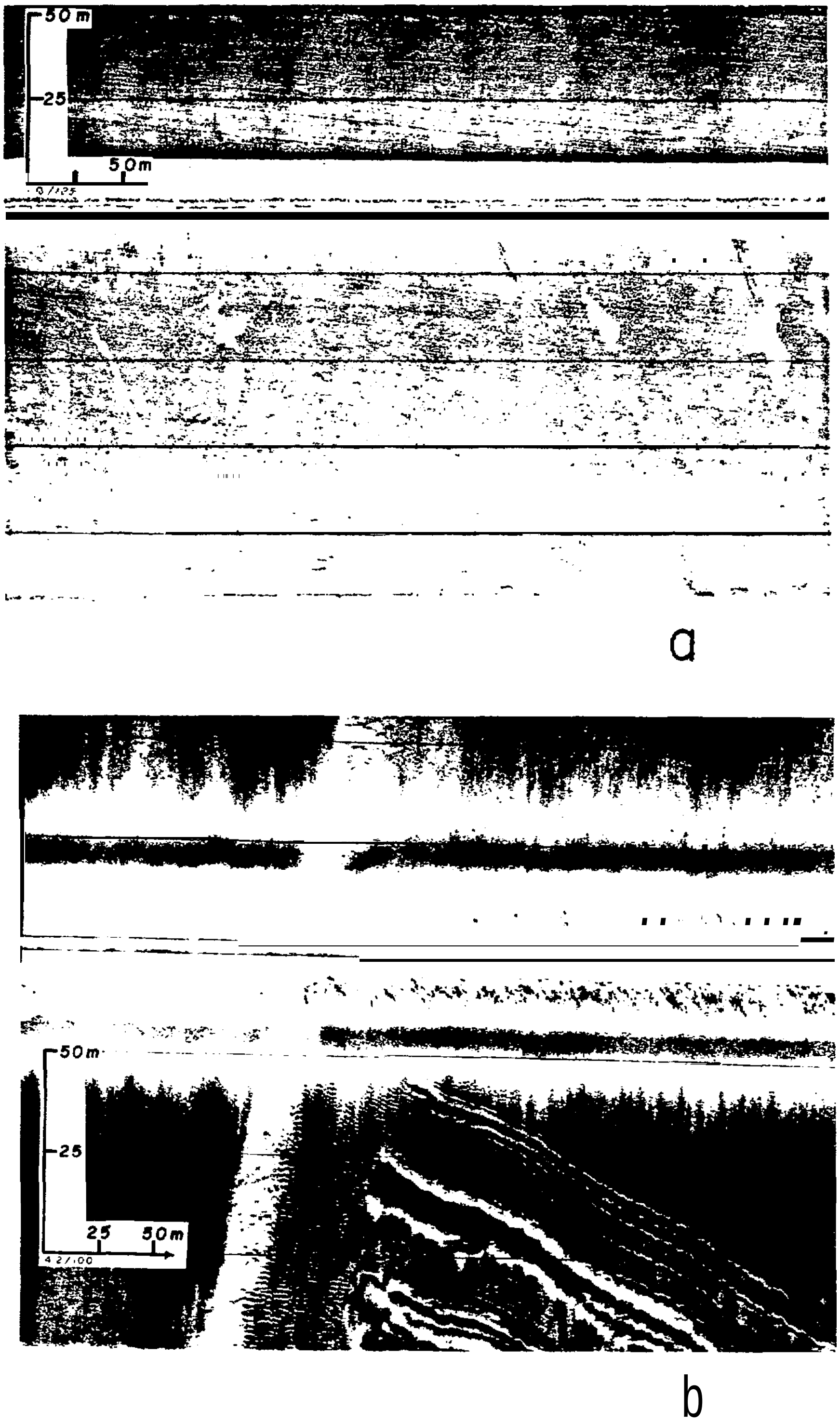
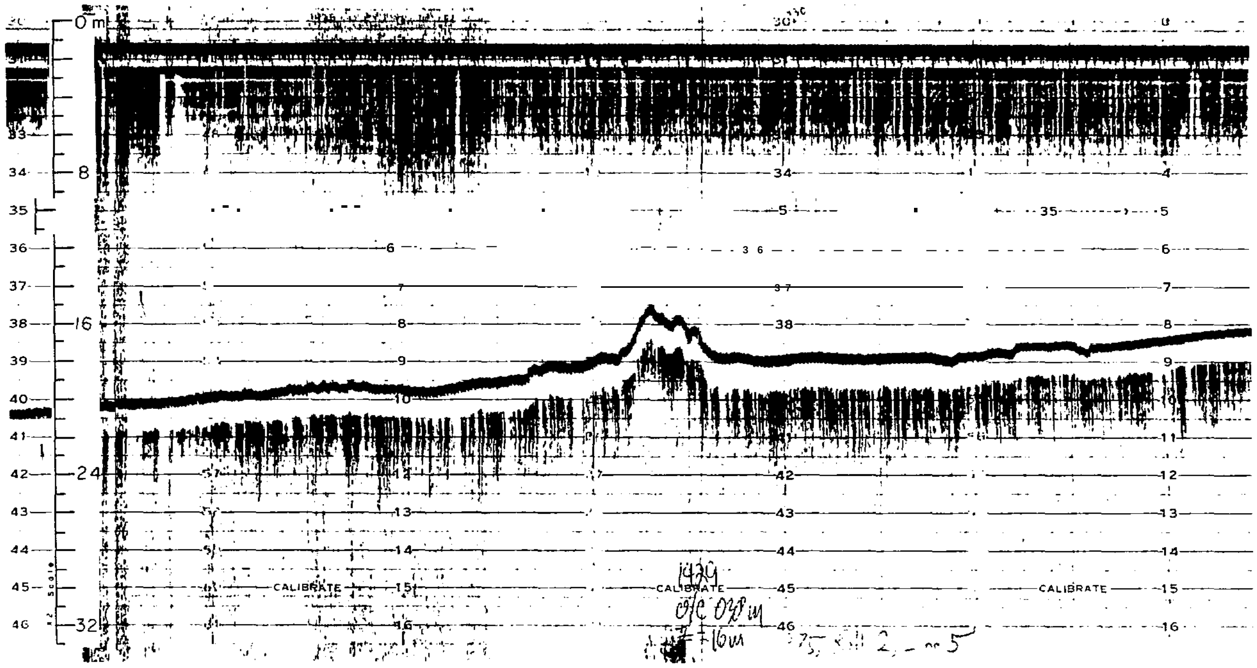


Fig. 10 Monographs showing features between Cape Thompson and Point Hope. a. Pockmarks (relatively small depressions, here visible as light-toned areas) of undetermined origin and a few ice gouges near Cape Thompson (1981, line 4, 1305 1/2-1308 1/2 hrs, water depth 11 m). b. Ice gouges and wave ripples near Point Hope (1975, line 5a, 1353 1/2-1356 hrs, water depth 20 m).



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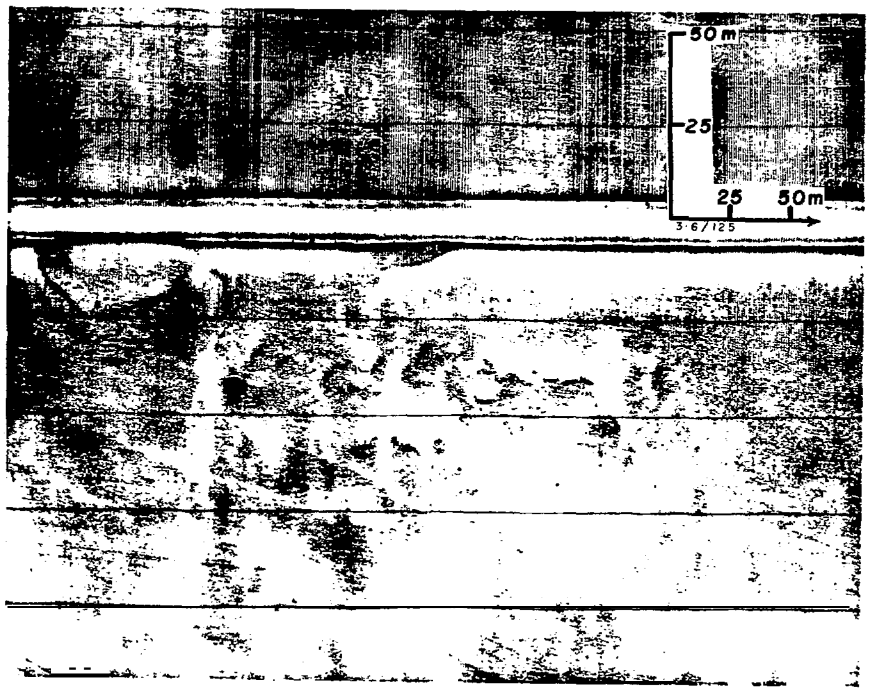

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Fig. 11. Possible bedrock outcrops on seafloor southeast of Point Hope. a. Fathogram showing ridge with relief of 3 m (1975, line 5b, 1423-1434 hrs). b. Monographs showing raised, platforms (dark-toned areas) that mav be outcrops of nearly flat bedded rock or relatively consolidated sediment (1981, line 4, 0945-0947 1/2 hrs, water depth 9 m).