ATTACHMENT C

INNER-SHELF GEOLOGY OF SOUTHEASTERN CHUKCHI SEA

by

Ralph E. Hunter and Thomas E. Reiss

INTRODUCTION

During the summer of 1982 the R/V KARLUK obtained data from both the north and south sides of the southeastern bight of the Chukchi Sea, whose inner part is known as Kotzebue Sound (Figs. 1-4). Geologically, much of the bight is occupied by Hope Basin. So far as we know, this is the first time that side-scan sonar and high-resolution seismic-reflection data have been obtained from the south side of the bight.

ENVIRONMENTAL SETTING

The environmental setting, bathymetry, and sediment character of the north side of the bight were described in last year's annual report, and in this year's report we describe the setting of the south side only. The south side of the bight is divided into two distinct regions: the barrier coast between Cape Prince of Wales and Cape Espenberg, and Kotzebue Sound, the embayment east of Cape Espenberq. The barrier coast is exposed to large waves from the open Chukchi Sea to the north and west and to drifting pack ice, whereas Kotzebue Sound is relatively protected from large waves and drifting pack ice.

The tidal range is low (only 2.7 feet at Kiwalik, at the head of Kotzebue Sound, and probably even lower to the west), and therefore tidal currents must be weak except in constricted inlets or straits. Very strong nontidal currents flow through Bering Strait and affect the seafloor near Cape Prince of Wales, but currents elsewhere along the south side of the bight are weak (Creager, 1963).

BATHYMETRY

No detailed navigation charts ara available for most of the bight. Detailed bathymetric data on the south side of the bight are available only for the area near Cape Prince of Wales (National Ocean Survey Bathymetric Map 1215 N-10). Elsewhere in the area, the most detailed bathymetric map available is that by Creager (1963).

SEDIMENT CHARACTER

The surficial sediment of the coastal barriers between Cape Prince of Wales and Cape Espenberg is fine-grained sand, and the adjacent nearshore waters are also underlain by fine-grained sand (Creager, 1963). In Kotzebue Sound the surficial sediment is mostly mud, but sand and gravel occur on the beaches and in a narrow nearshore zone. The gravel occurs only in the vicinity of bedrock cliffs, which are common along the south and southeast sides of Kotzebue Sound, or in the vicinity of bluffs of Pleistocene sediment, which occur on Baldwin Peninsula.

KIVALINA AREA

Data were obtained from the Kivalina area to supplement data obtained last *year* (Hunter and others, 1982). The trackline extended from Kivalina to a Point 26 km southeastward along the coastline and reached a water depth of as much as 18 m, at a point 8 km offshore (Fig. 1) . Sediment samples indicate that the boundary between sand and mud occurs at or near the boundary between the relatively steep shoreface and the relatively gently sloping offshore shelf, at a water depth of 11-13 m (about 1 km from shore). The sand closest to shore is coarse and pebbly, but farther offshore the sand is fine grained.

Monographs support last year's finding that ice gouges are fairly common offshore (Fig. 5) but rare at points closer than 1 to 3 km from shore. However, this difference may result from the fact that gouges are more easily erased from sand than from mud by wave reworking. None of the gouges in the Kivalina area were deeper than 0.3 m. Mottled dark-toned patterns on monographs from nearshore areas were again found and are interpreted as patches of coarse sand or gravel.

Uniboom profiles from the Kivalina show prominent reflecting horizons to depths of as much as 30 m (assuming a two-way sound velocity of **750** m/s) below sea level. Near Kivalina, the most prominent reflectors are horizontal or dip seaward less steeply than the seafloor. Near the southeastern end of the area surveyed in the vicinity of Kivalina, in contrast, the reflectors dip seaward more steeply than the seafloor; a shallow reflector dipped seaward about 1.7 m per km, whereas a deeper reflector dipped as steeply as 10 m per km.

AREA FROM CAPE KRUSENSTERN TO KOTZEBUE SHOAL

Additional data from the area between Cape Krusenstern and the large shoal off Kotzebue were collected to supplement earlier data (Hunter and others, 1982). The trackline in this area reaches points as far as 18 km offshore, and the seafloor is nearly flat, at water depths of 12-16 m, except near the cape. Monographs show that ice gouging is moderate to intense near Cape Krusenstern (Fig. 6) but becomes less common to the southeast, reaching a minimum just west of the shoal off Kotzebue. Gouges deep enough to be visible on the depth profiles are rare; the deepest gouge found was 0.5 m deep. The dominant trend of the gouges is northwest-southeast in most of the area; those off Cape Krusenstern therefore tend to be parallel to isobaths.

Patterns thought to be caused by internal waves along pycnoclines in the water column are 'visible on the monographs in this area (Fig. 7). such features were found in other parts of Kotzebue Sound also, and care had to be exercised to distinguish such features from sandy bedforms on the seafloor. Features that were found useful in identifying such patterns as internal waves instead of bedforms are: (1) disappearance of the features when the side-scan fish is lowered beneath the pycnocline; (2) flatness of the bottom as seen in a depth profile; (3) muddy character of the seafloor as demonstrated by sampling; and (4) presence of distinct stratification in the water column as demonstrated by temperature or salinity measurements. Identification of the features shown in figure 7 as internal waves is based on -the first two of those criteria.

SHOALS AND CHANNEL NEAR KOTZEBUE

Data from the shoal and channel just offshore from Kotzebue (Fig. 2) were collected to supplement data collected in previous years (Hunter and others, 1982). Geologically, this shoal is an ebb-tidal delta, formed at the point where ebb-tidal currents from Hotham Inlet (plus river outflow from the Kobuk and Noatak Rivers) spread out into Kotzebue Sound and deposit their sediment load. In part, this shoal may represent the shallow offshore platform of an arctic river delta, for such platforms seem to be typical of arctic rivers such as the Yukon and Colville.

A sediment sample from the shoal platform consisted of fine-grained sand, whereas a sample from the adjacent channel floor was an organic-rich mud. Another sample from the sloping westerm margin of the shoal was sandy mud. Furrows visible on monographs (Fig. 8) were found in the channel, as in a previous survey (Hunter and others, 1982), and a current-generated origin of these features is even more strongly favored than before. Very similar features have recently been found in a muddy tidal channel in South San Francisco Bay, California, where an ice-gouge interpretation is impossible. Apparently such furrows are common where a cohesive mud bottom is affected by strong unidirectional or diametrically opposed currents. Ice gouges are fairly common on the sloping western margin of the shoal. Most of these trend more nearly at riqht angles than parallel to isobaths. The deepest gouge found was 1 m deep (Fig. 9).

SOUTHEASTERN KOTZEBUE SOUND

Data were collected for the first time from the southeastern part of Kotzebue Sound and from the water bodies connected to it: Chamisso Anchorage, Eschscholtz Bay, and Spafarief Bay (Fig. 3). These subsidiary bays reach water depths of 10 to 15 m.

Ice gouging is apparently rare in this area; only one shallow (less than 0.3 m deep) gouge was found on monographs. Closely spaced, parallel lineations were found trending northeast-southwest at the east end of Chamisso Anchorage (the strait joining Kotzebue Sound and Eschscholtz Bay), but these features are probably current-generated furrows rather than ice gouges.

Uniboom records from this area show a multitude of reflecting horizons. Many of these are delta-like foreset layers confined to a zone between relatively flat-lying upper and lower boundaries (the upper boundary is commonly the seafloor) . At the east end of Chamisso Anchorage, the delta-like buildout has not filled the deeper water body beyond, so that the youngest foreset layer forms the sloping part of the seafloor between the shallow platform to the west and the deeper basin to the east (Fig. 10). This delta-like body of sediment is obviously not a river delta; it must have been formed by tidal or other marine currents flowing through Chamisso Anchorage.

Other delta-like buildouts 5 to 15 m thick occur in the area, but differ from the one at the east end of Chamisso Anchorage in having filled their basins completely, so that they now lie beneath a flat seafloor. Most of the delta-like sediment bodies were built out toward the centers of the bays in which they occur (Figs. 11-13). For example, the areas in the vicinity of Chamisso Island (on the northwest side of Spafarief Bay) were built out to the east or south, towards the middle of Spafarief Bay. Those on the mainland side (southeast side) of Spafarief Bay, on the other hand, were built out to the northwest. The buildouts in the vicinity of Chamisso Island can probably be explained in the same way as the one at the east end of Chamisso Anchorage, but the ones on the mainland side of Spafarief Bay can not be explained without additional data.

The parts of the uniboom records with distinct subbottom reflecting horizons change abruptly in many places to records with no visible reflectors (Figs. 11-13). The lack of seismic penetration in the latter areas may be caused by gas-charged sediment.

SOUTHERN KOTZEBUE SOUND

Several lines were run along the southern edge of Kotzebue Sound between Goodnews Bay on the west and Kiwalik Lagoon on the east. The seafloor in much of this area is characterized by a relatively steep, narrow, rocky or gravelly nearshore zone which abruptly gives way at a water depth of 6-7 m to a nearly flat offshore zone in which water depths reach 10-11 m at distances of 5-8 km offshore. The offshore sediment is mud or sandy mud.

Ice gouges were rarely seen on monographs from southern Kotzebue Sound. None of those seen was deep enough (0.3 m) to be visible an depth profiles. Nearshore areas had a dark, mottled appearance on monographs, due to either gravelly sediment or rock outcrops (Fig. 14). Internal waves were visible on the monographs locally. Measurements of temperature and salinity at one such point revealed a pycnocline in which the temperature and salinity changed from 14.7°C and 24.2 ppt at a depth of 6 m to 1.5°C and 31.4 ppt at a depth of 8 m.

Several subhorizontal reflecting horizons were visible on uniboom records from the area, at depths of as much as 30 m or locally even 60 m beneath sea level. At their shoreward ends, the shallower reflectors can be seen to curve upward abruptly, suggesting wave-cut shoreline bluffs. The shallowest and best defined of these shoreline angles occurs very close to the present shoreline (1 or 2 km offshore) at a depth of about 12 m below sea level.

CAPE ESPENBERG AREA

Lines were run from Cape Espenberg to as far as 12 km west alongshore and to as far as 6 km offshore (water depth 18 m). A series of longshore bars and troughs extends 1.0-1.4 km offshore, but beyond these bars the seafloor slopes offshore very gently and smoothly. Sampling indicates that the transition from nearshore fine-grained sand to offshore mud occurs at a water depth of about 13 m. Very few ice gouges were visible on monographs. The few gouges visible were narrow, indistinct, no more than 0.3 m deep, and restricted to areas more than 4 km offshore.

Subhorizontal reflecting horizons were visible on uniboom records to depths of 30-40 m below sea level. One prominent reflector, which dips seaward less sleeply than the seafloor, merges with the seafloor at a water depth of 14-15 m.

SHISHMAREF AREA

Lines were run from the southwest entrance of Shishmaref Inlet to the town of Shishmaref and to a point 12 km offshore, where the water depth was 15 m. Sampling revealed a nearshore zone of fine-grained sand extending to a

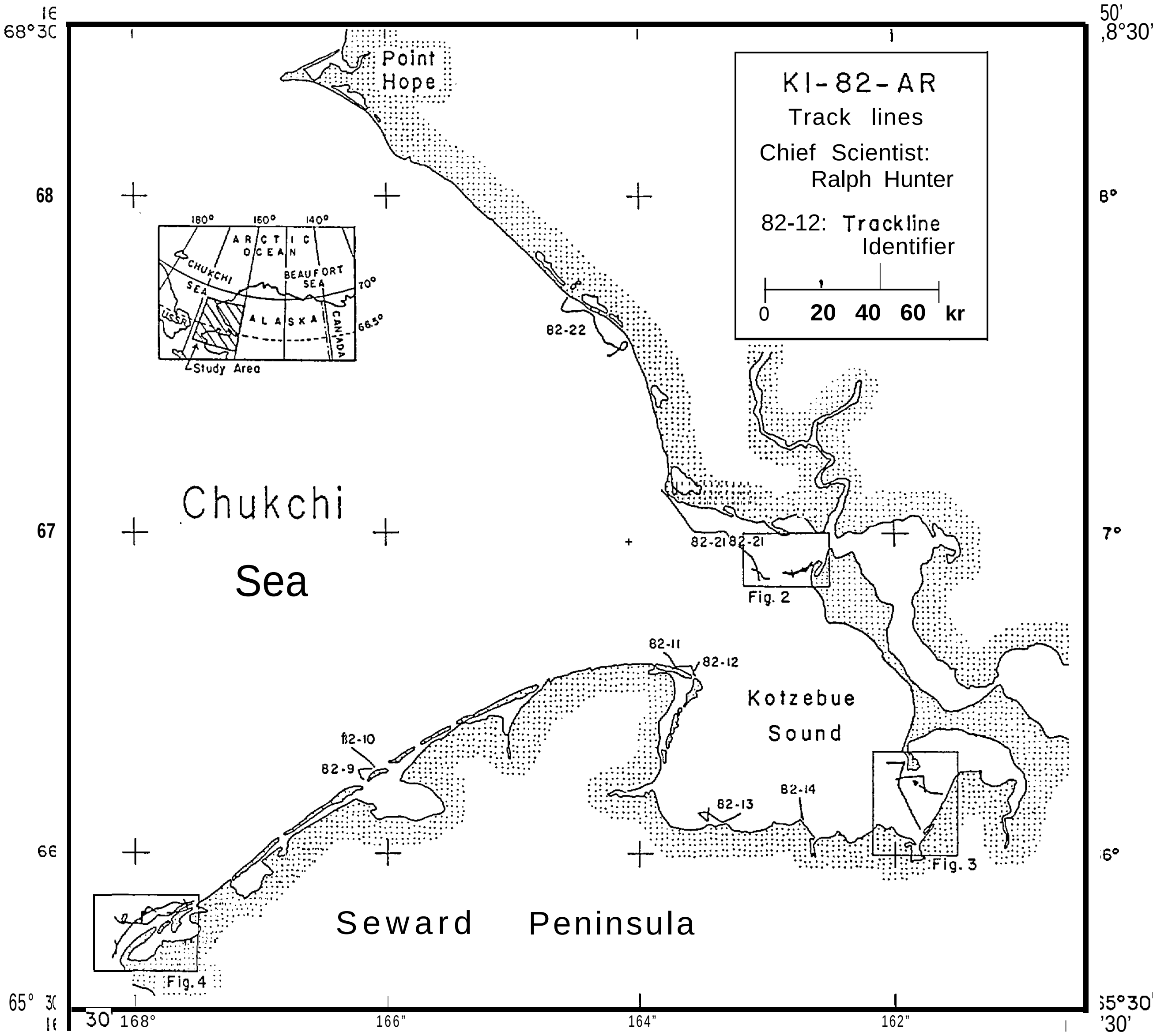


Fig. 1. 1982 tracklines of the R/V KARLUK in the southeastern Chukchi Sea. Detailed maps of local areas are shown in figures 2, 3, and 4.

water depth of about 8 m and, farther offshore, a zone of muddy sand extending to a depth of at least 15 m. No ice gouging or other features were seen an monographs from the area. Several nearly horizontal reflecting horizons can be seen at depths of as much as 60 m below sea level on uniboom records.

PRINCE OF WALES SHOAL AND VICINITY

The area in the vicinity of Prince of Wales Shoal was surveyed in moderate detail (Fig. 4). The shoal itself is a long, narrow sand body that extends north-northeastward from the shoreline just north of Cape Prince of Wales. It is composed of sediment that was swept northward through Bering Strait and then deposited at the lateral margin of the strong current core, where the flow ceases to be confined by the shoreline of the strait. Between the shoal crest and the northeast-trending shoreline is a northward-widening and northward-deepening crotch-like trough. The shoreline is formed by a barrier that separates Lopp Lagoon from the open water to the northwest. Relatively detailed bathymetric mapping of the shoal and adjacent areas is available on National Ocean Survey Bathymetric Map 1215 N-10.

The bathymetric map reveals a complex system of nearshore bars and troughs in this area. The outermost longshore bar is about 1 km offshore and has a water depth of 4-6 m along its crest. Landward of this bar is a trough that has a water depth of 7-8 m, and the relief from trough axis to bar crest is as much as 4 m. The bars are not long and continuous but rather broken into short segments by channels cutting across them (Fig.15). Sampling indicates that the bars and adjacent beaches are composed of fine-grained sand. Undoubtedly bars such as these must change in form rapidly. Monographs reveal dark mottled patterns in many of the troughs (Fig. 15); these probably represent current-scoured surfaces cut into cohesive mud or partly consolidated sediment, but additional sampling is needed for confirmation.

The crestal platform of Prince of Wales Shoal is composed of fine-grained to very fine-grained sand (McManus and Creager, 1963). No ice gouges or other features were seen on monographs from the crestal platform of the shoal or on the very gentle landward slope east of the crest. One faint ice gouge was seen at the western edge of the crestal platform. On the relatively steep western slope of the shoal, a linear pattern formed by ice gouging or current scour is visible on monographs (Fig. 16).

In the crotch-like trough between the shoal and the shoreline is an area of irregular ridges and troughs These features have a relief of 2 to 4 m from ridge crest to trough bottom, a spacing of about 400 m between ridge crests, a northwest-southeast trend, and northeast-facing slopes that are steeper than southwest-facing slopes (Fig. 17). A sample from a ridge crest was fine-grained sand, whereas a sample from a trough was sandy mud. Monographs show dark mottled patterns from the troughs (Fig. 18), suggesting that the mud is an older deposit that is being scoured by curents. The ridges are probably current-produced sand waves, though many of them differ from more typical sand waves in being relatively wide, flat-crested ridges separated by narrow troughs rather than roughly triangular features. The currents that formed the features were directed toward the northeast.

Just north of the westernmost bulge of shoreline, which is located just north of Cape Prince of Wales, is an area of sand waves at water depths of 4 to 8 m, on the narrow shelf between shore and the relatively steep slope that descends to the floor of Bering Strait. These sand waves have a relief of 2 to 4 m, a spacing of about 500 m, a northeast-southwest trend, and southeast sides that are steeper than northwest sides (Fig. 19) . A sample indicates that the sand waves are composed of fine-grained sand. The asymmetry of these sand waves clearly indicates that they were formed by southward-flowing currents. This is surprising, for the currents through Bering Strait are predominantly to the north. The southward flow that produced the sand waves

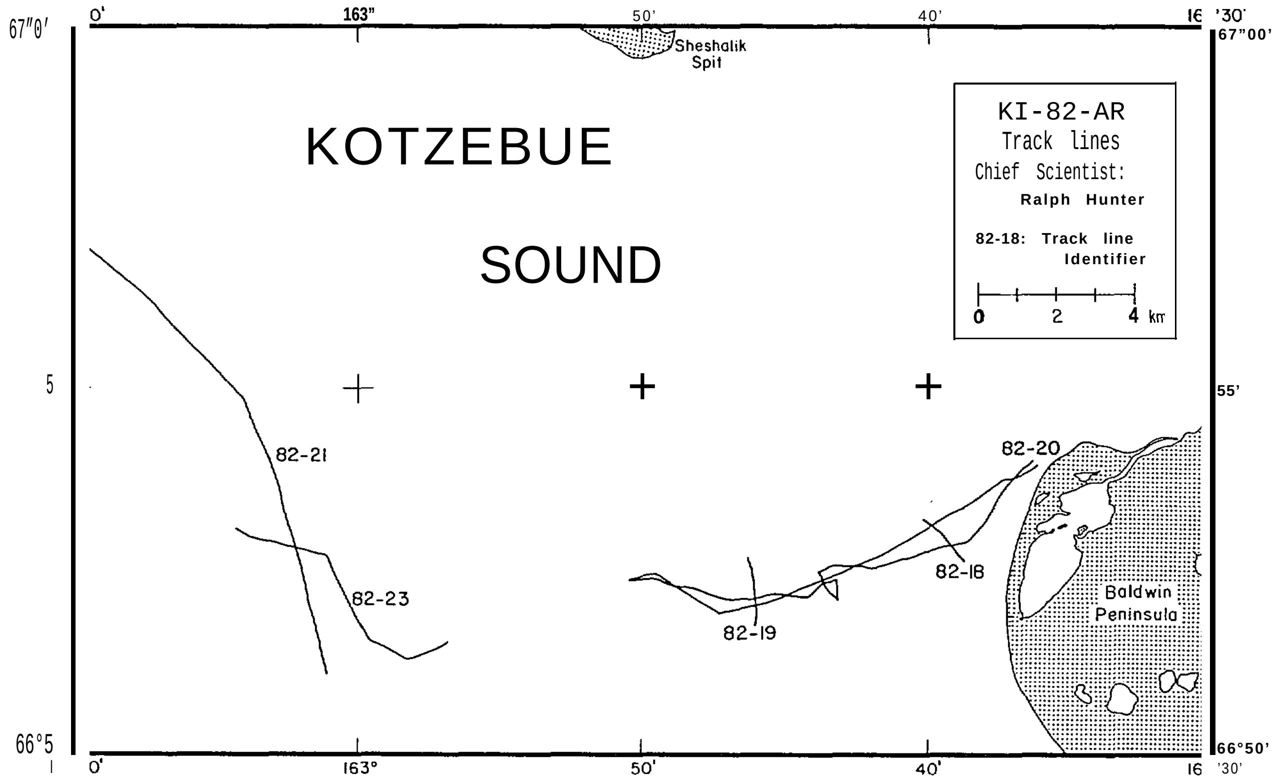


Fig. 2. 1982 tracklines of the R/V KARLUK in the vicinity of Kotzebue.

may be a local countercurrent in the area where the main northward current separates from the coast; current measurements are needed to test this hypothesis.

Uniboom records from the crestal part of Prince of Wales Shoal show poorly defined subhorizontal reflecting horizons in the upper 15 m of the sediment. A strong, nearly horizontal reflector can be seen beneath the western slope of the shoal, at a water depth of 38-45 m (Figs. 20-21). This reflector merges with the seafloor to the west and cannot be traced as far east as the shoal crest.

REFERENCES

Creager, J.S., 1963, Sedimentation in a high energy, embayed, continental shelf environment: Jour. Seal. Petrology, v. 33, p. 815-830

Hunter, R.E., Barnes, P.W., Kempema, E.W., and Reiss, Tom, 1982, Inner-shelf geology of the north side of Kotzebue Sound -- Hope basin, in Barnes, Petor, Reimnitz, Erk, Hunter, Ralph, and Phillips, Larry, Geologic processes and hazards of the Beaufort and Chukchi Sea shelf and coastal regions, Annual report: U.S. Geological Survey Administrative Report, Attachment A, p. Al-A6.

McManus, D.A., and Creager, J.S., 1963, physical and sedimentary environments on a large spitlike shoal: Jour. Geology, v. 71, p. 498-512.

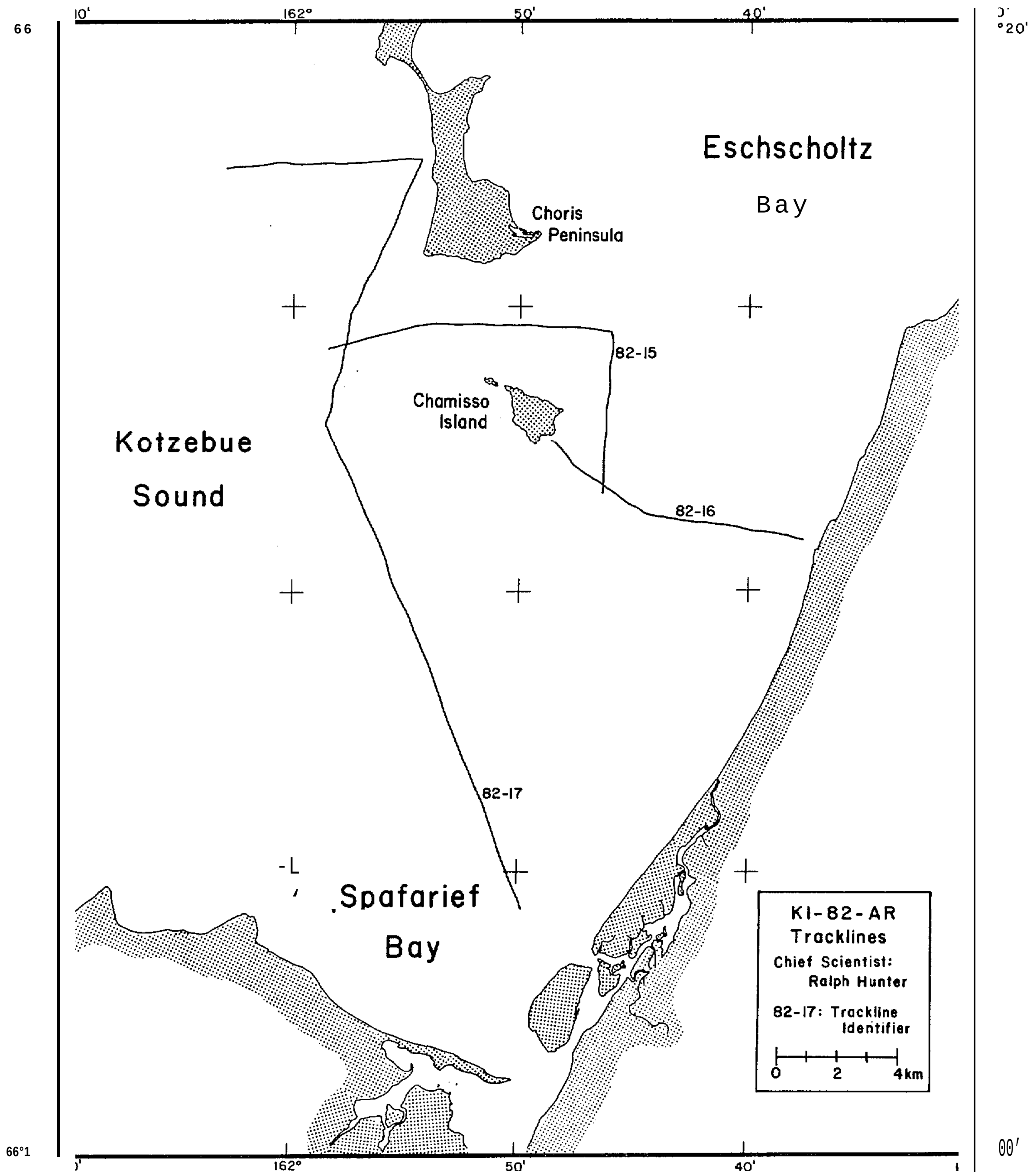


Fig. 3. 1982 tracklines of the R/V KARLUK in southeastern Kotzebue Sound and adjacent bays.

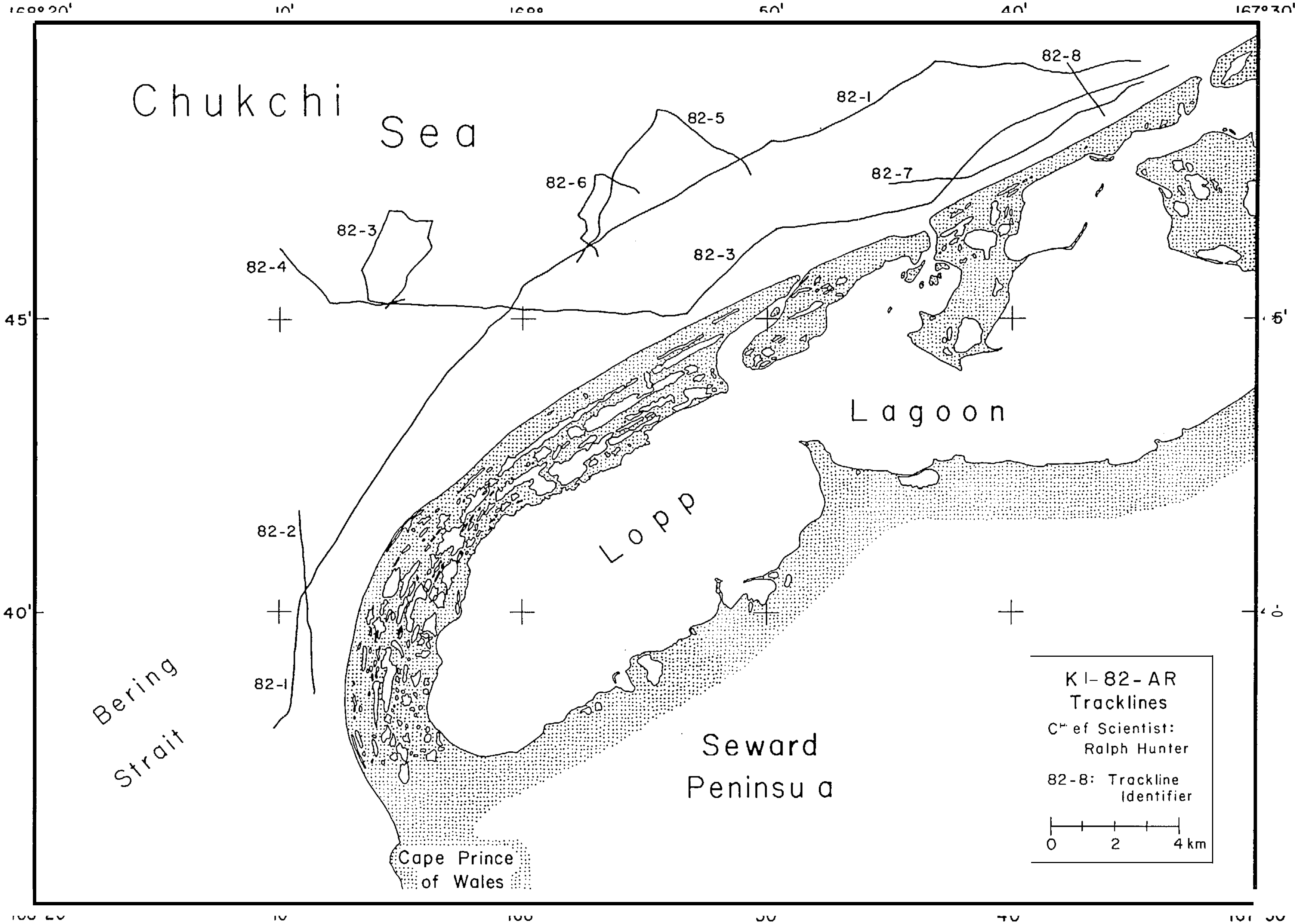


Fig. 4. 1982 tracklines of the R/V KARLUK in the vicinity of Prince of Wales Shoal.

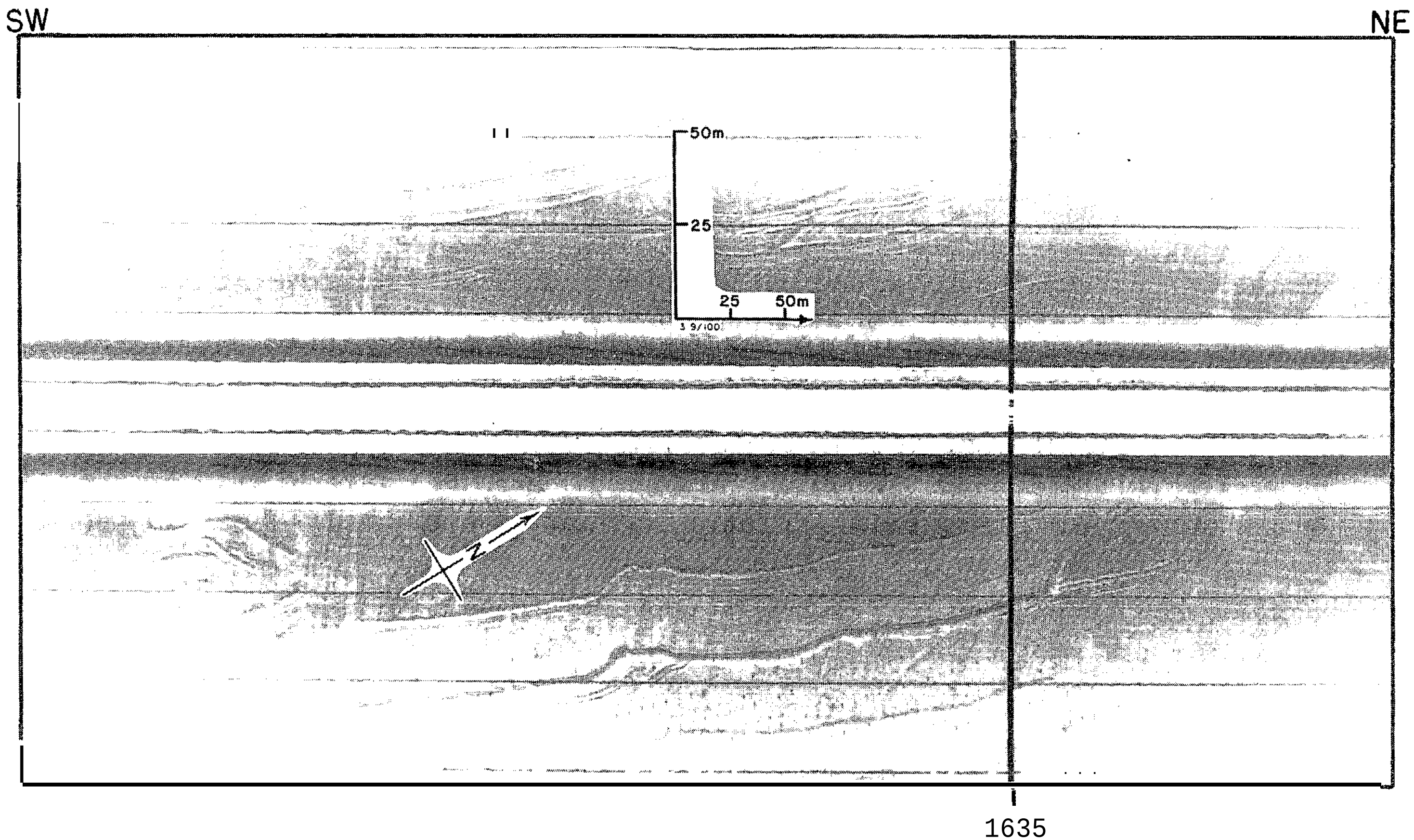
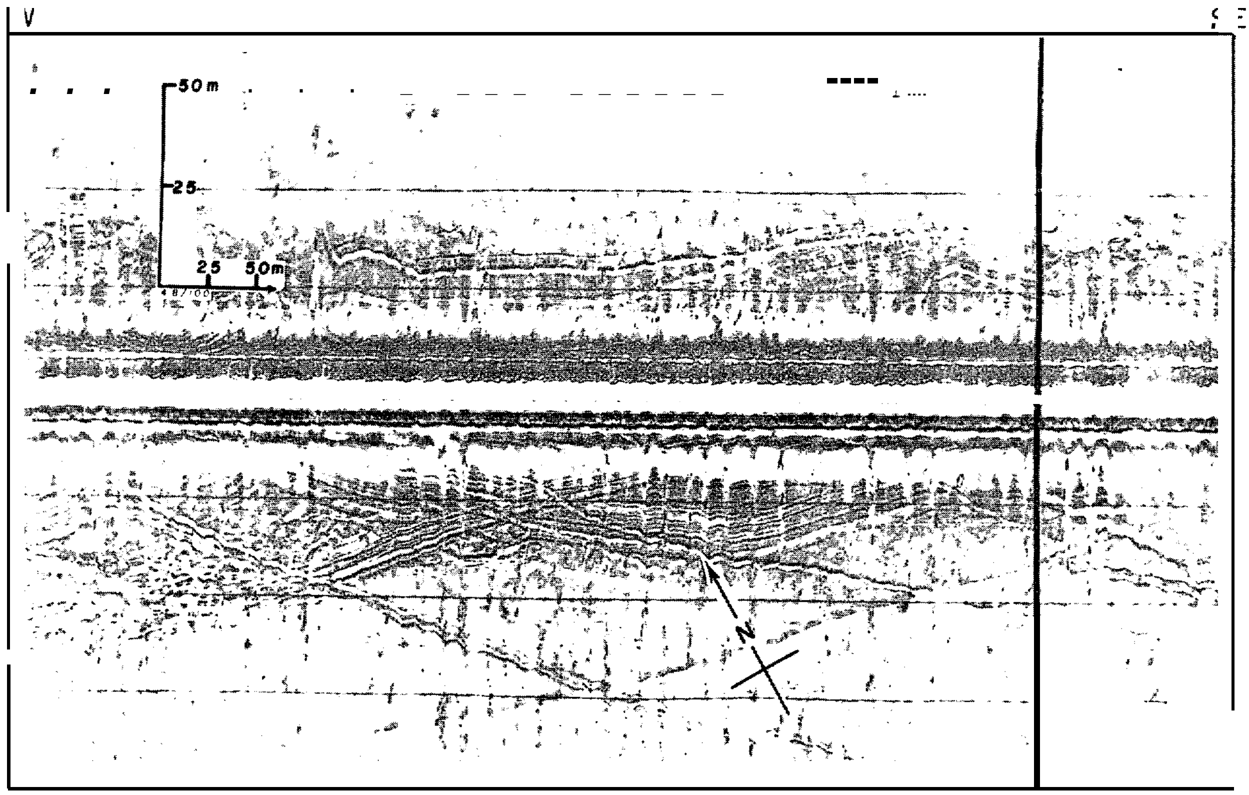


Fig. 5. Monographs of ice gouges from Kivalina area. Line 22, time: 1631-1637.



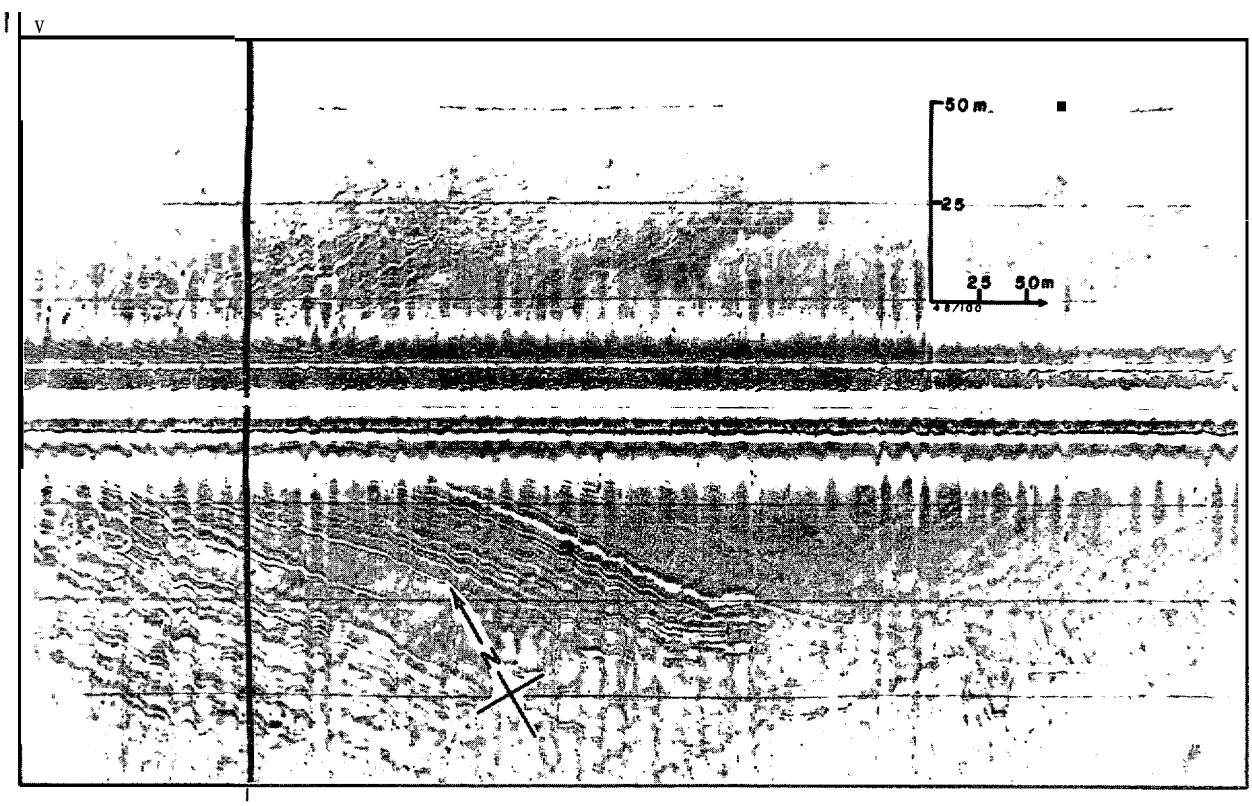


Fig. 6. Monographs of ice gouges near Cape Krusenstern (near east end of line 21). Top: time: 1325-1332; bottom: time: 1334-1338.

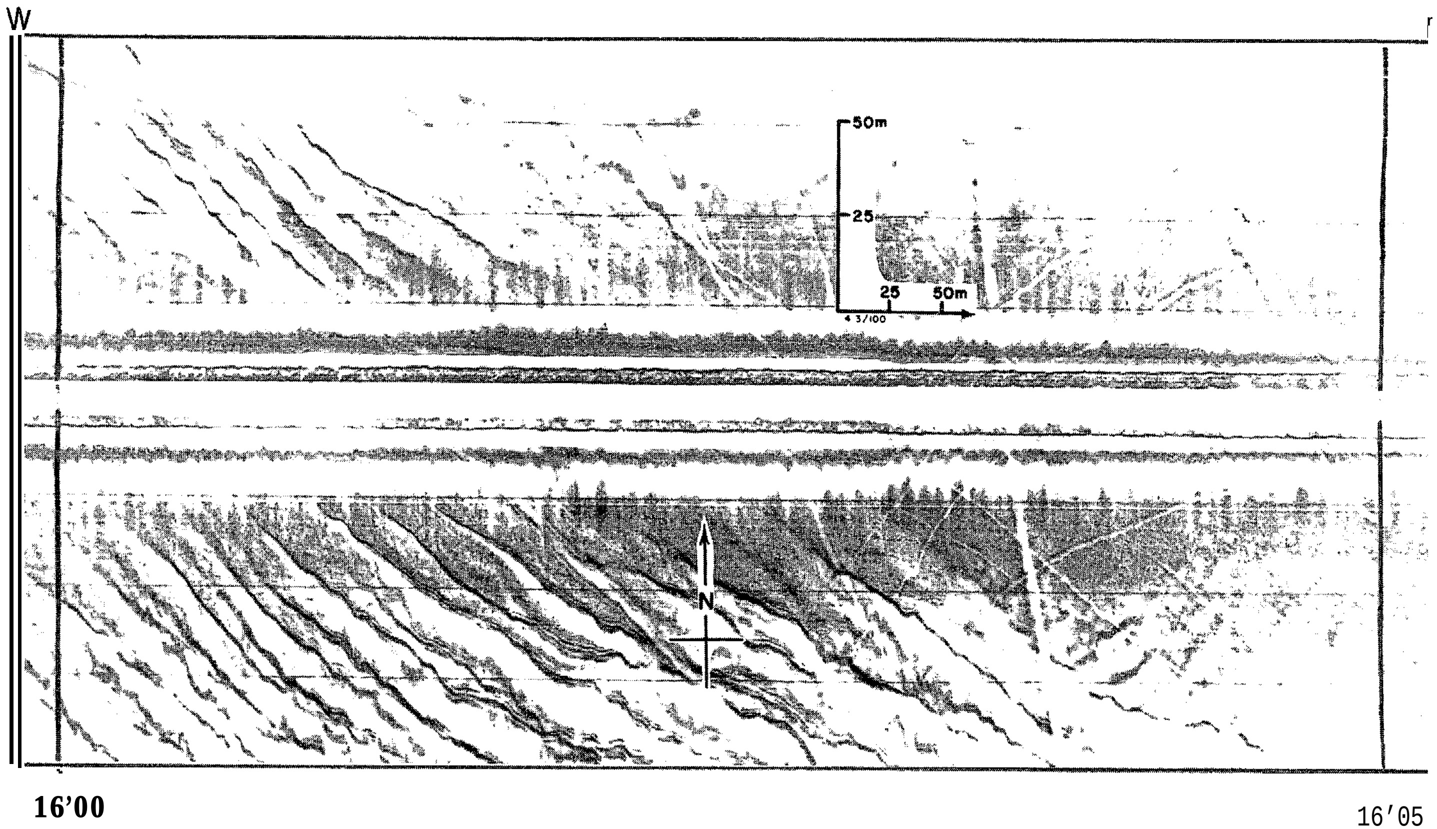


Fig. 7. Sonograph of internal waves between Cape Krusenstern and Kotzebue. Line 21, time: 1600-1605. Side-scan fish was lowered at about 1603, causing internal waves to become fainter and ice gouges on seafloor to become better defined on right side of figure.

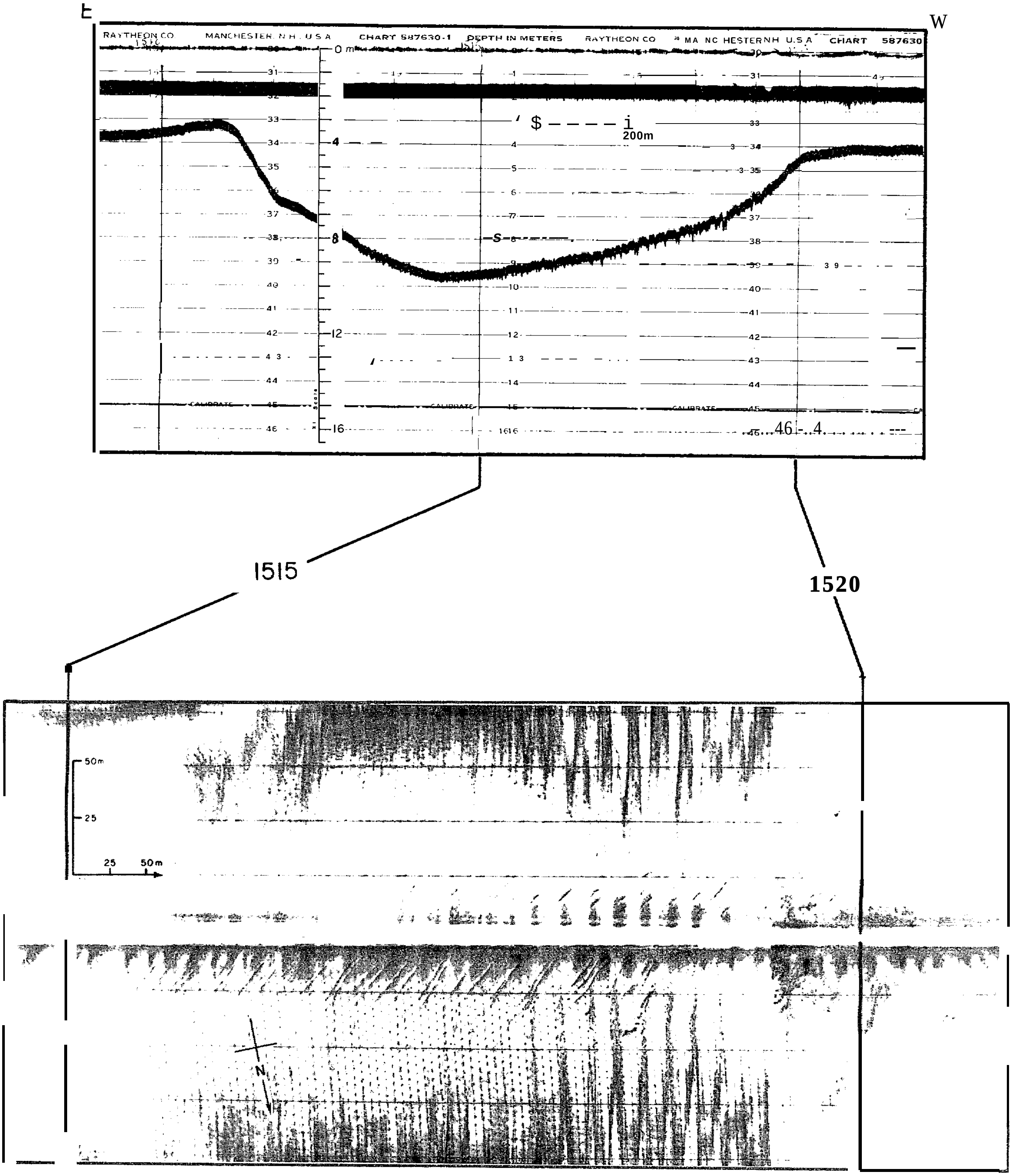


Fig. 8. Depth profile (top) and sonograph (bottom) of furrows in channel that cuts through shoal j ust offshore from Kotzebue. Line 20, time: 1510-1520.

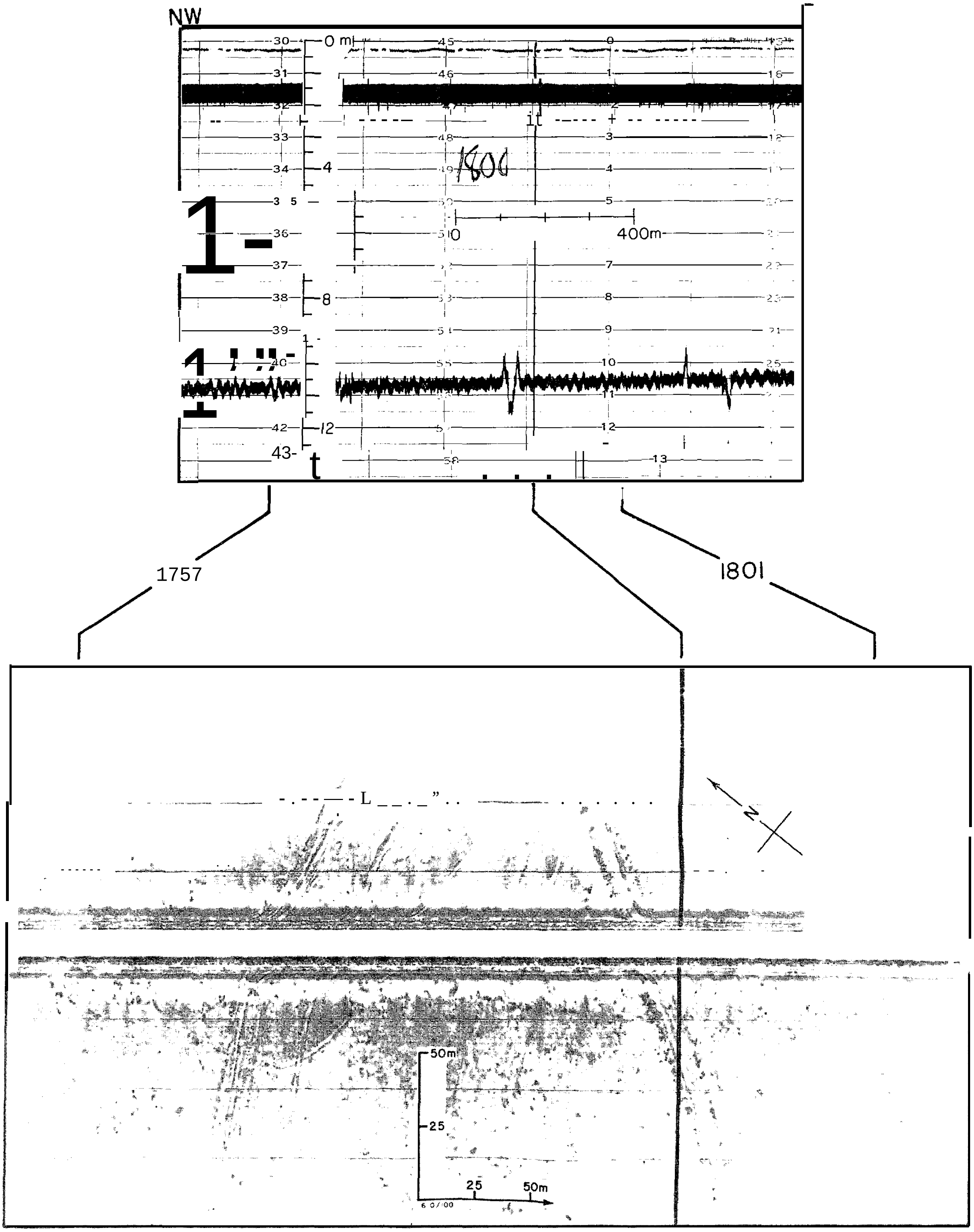


Fig. 9. Depth profile (top) and sonograph (bottom) of ice gouges on the western slope of the shoal off Kotzebue. Line 21, time: 1757-1801.

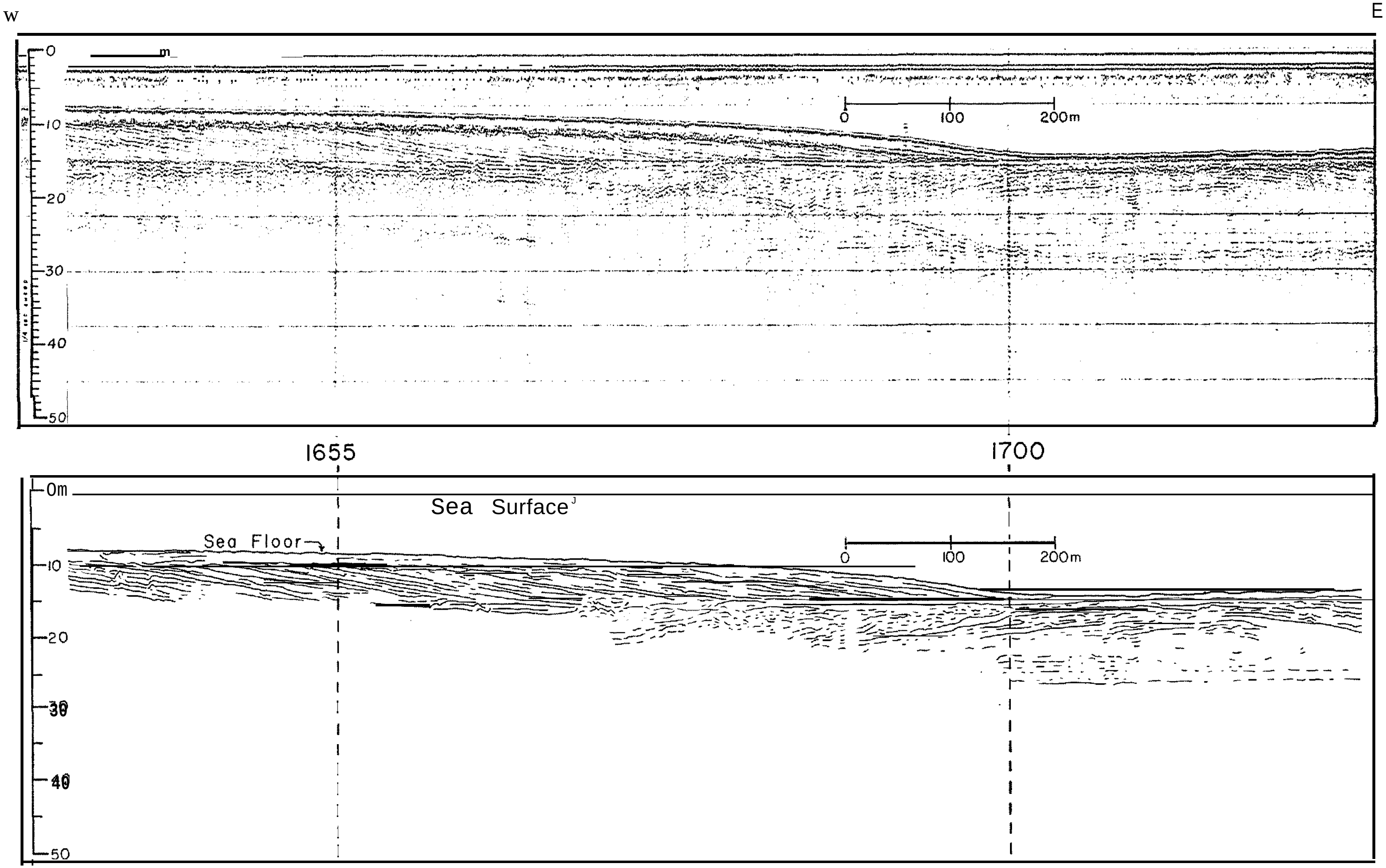


Fig. 10. Uniboom record (top) and interpretive drawing of delta-like sediment body at east end of Chamisso Anchorage. Line IS, time: 1653-1703.

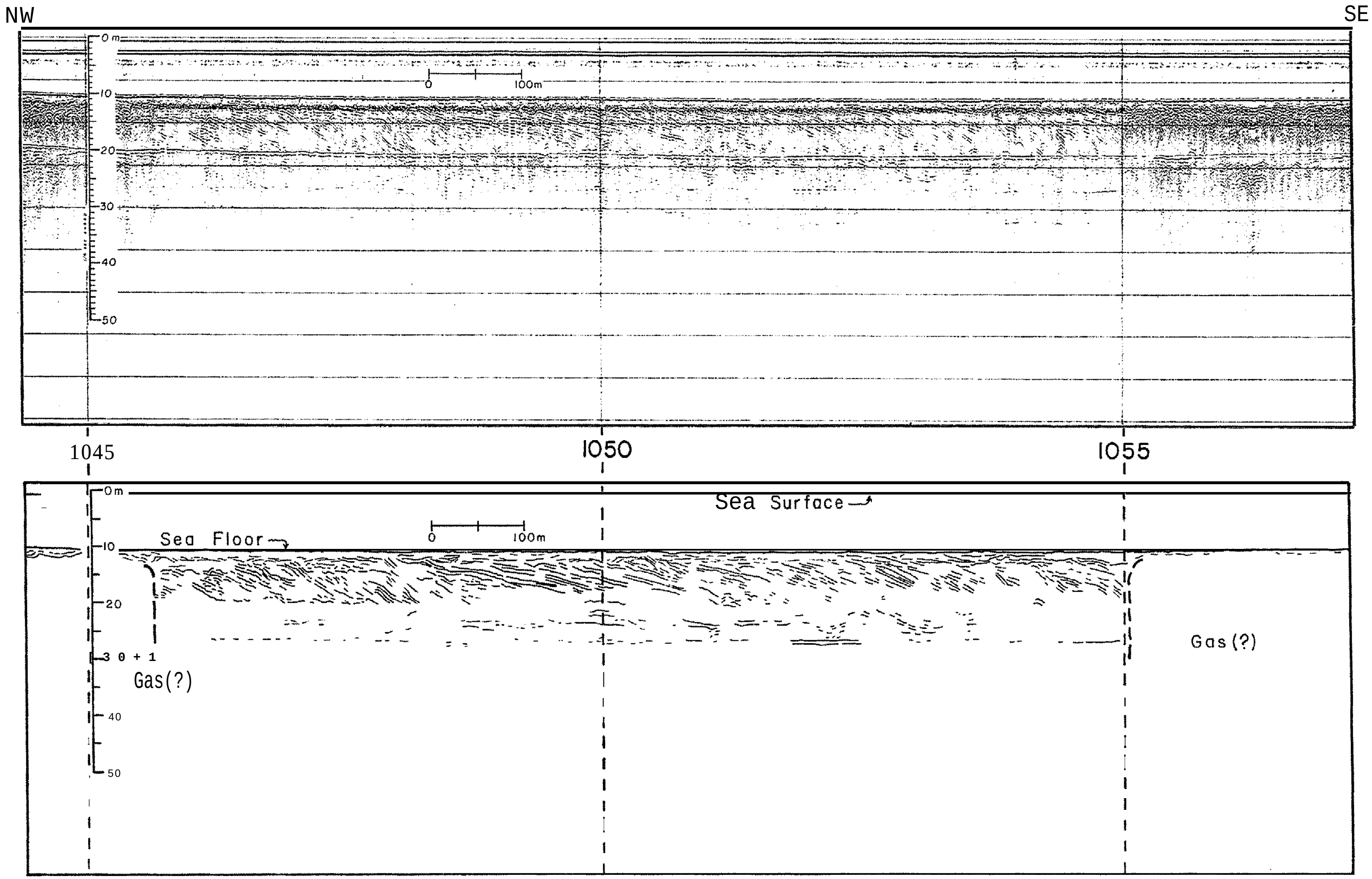


Fig. 11. Uniboom record (top) and interpretive drawing (bottom) of delta-like foresets east of Chamisso Island. Line 16, time: 1045-1055.

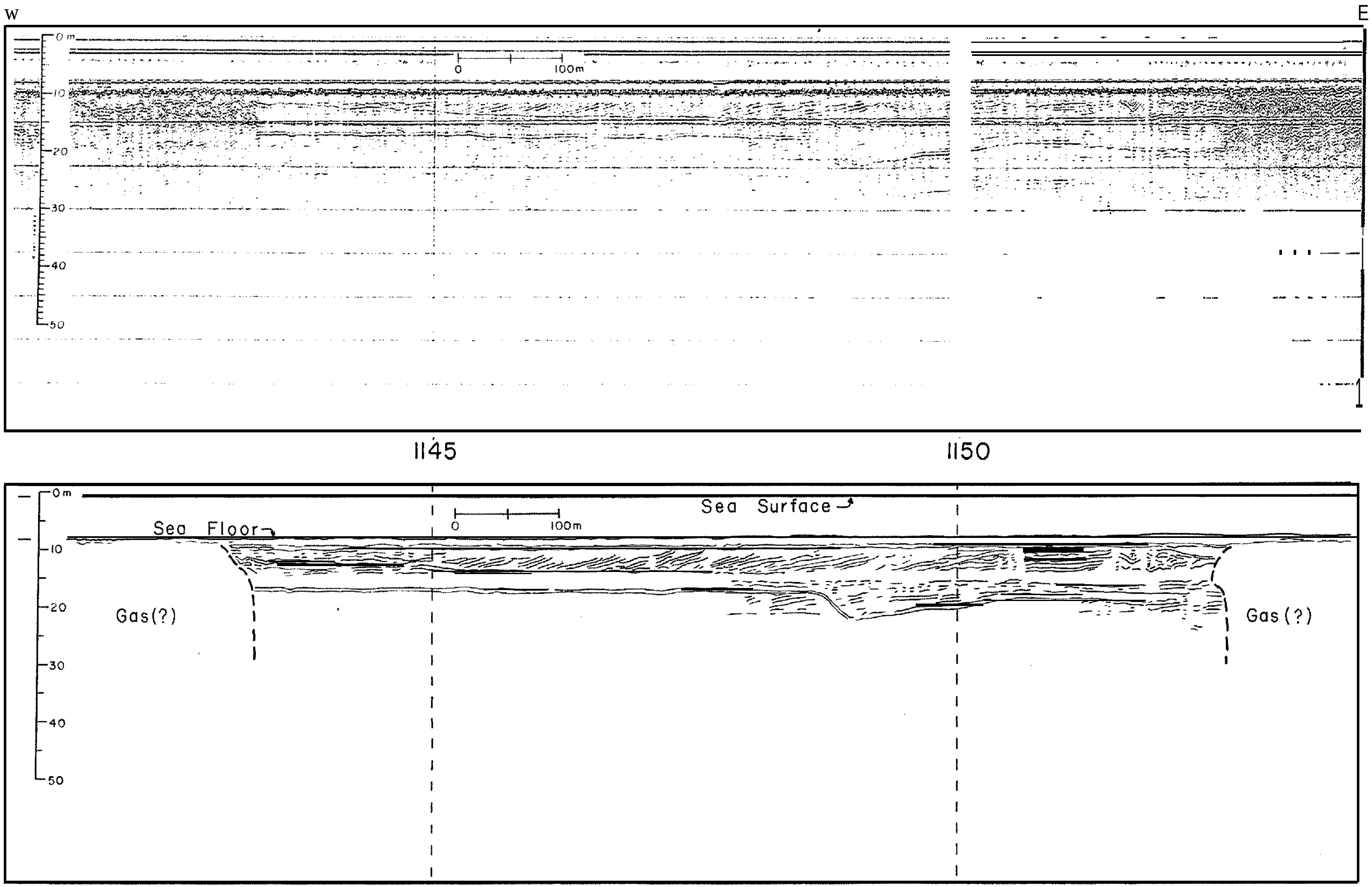


Fig. 12. Uniboom record (top) and interpretive drawing (bottom) of delta-like foresets on east side of Spa farief Bay. Line 16, time: 1142-1153.

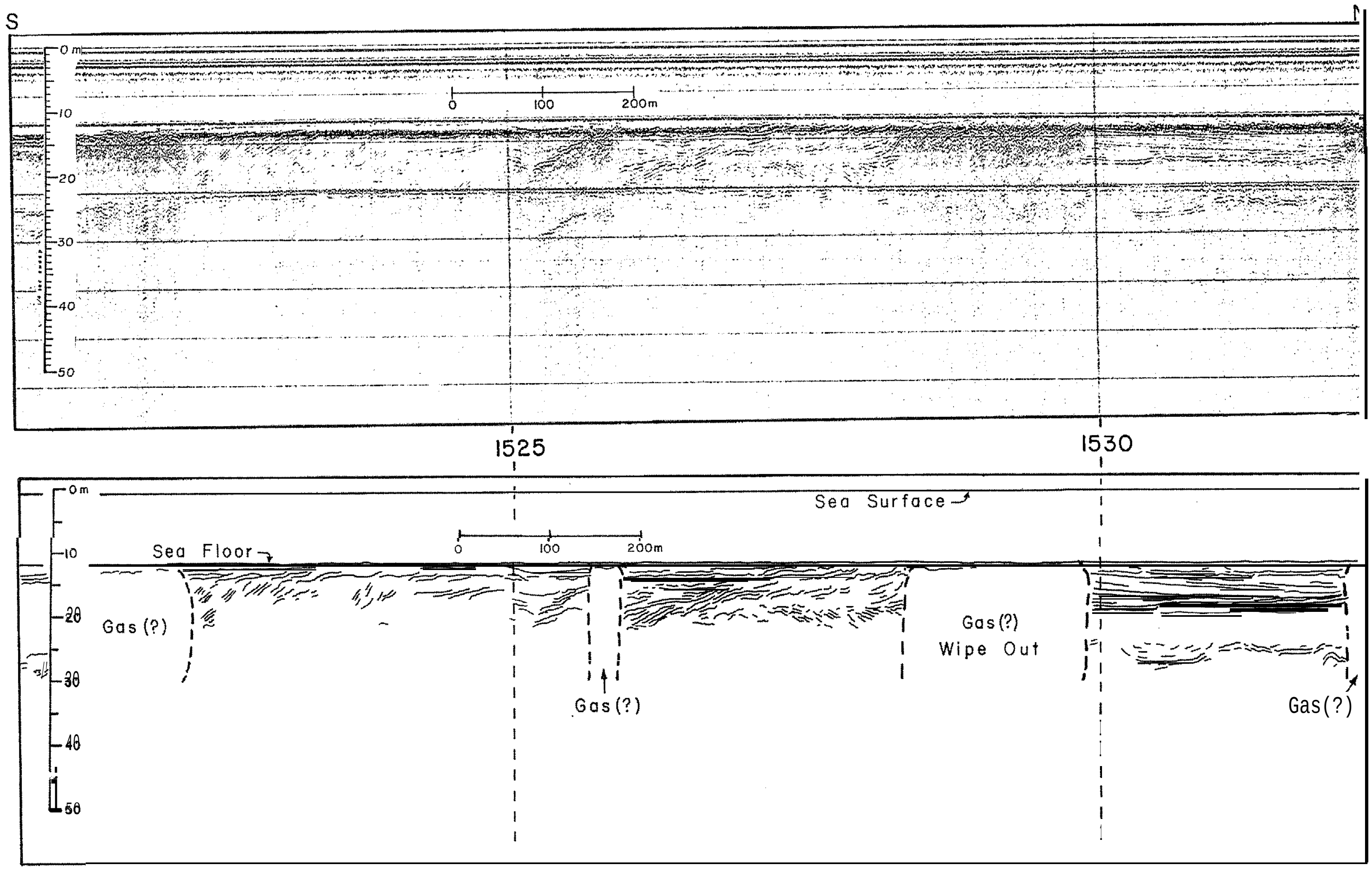


Fig. 13. Uniboom record (top) and interpretive drawing (bottom) of delta-like foresets southwest of Chamisso Island. Line 17, time: 1522-1532.

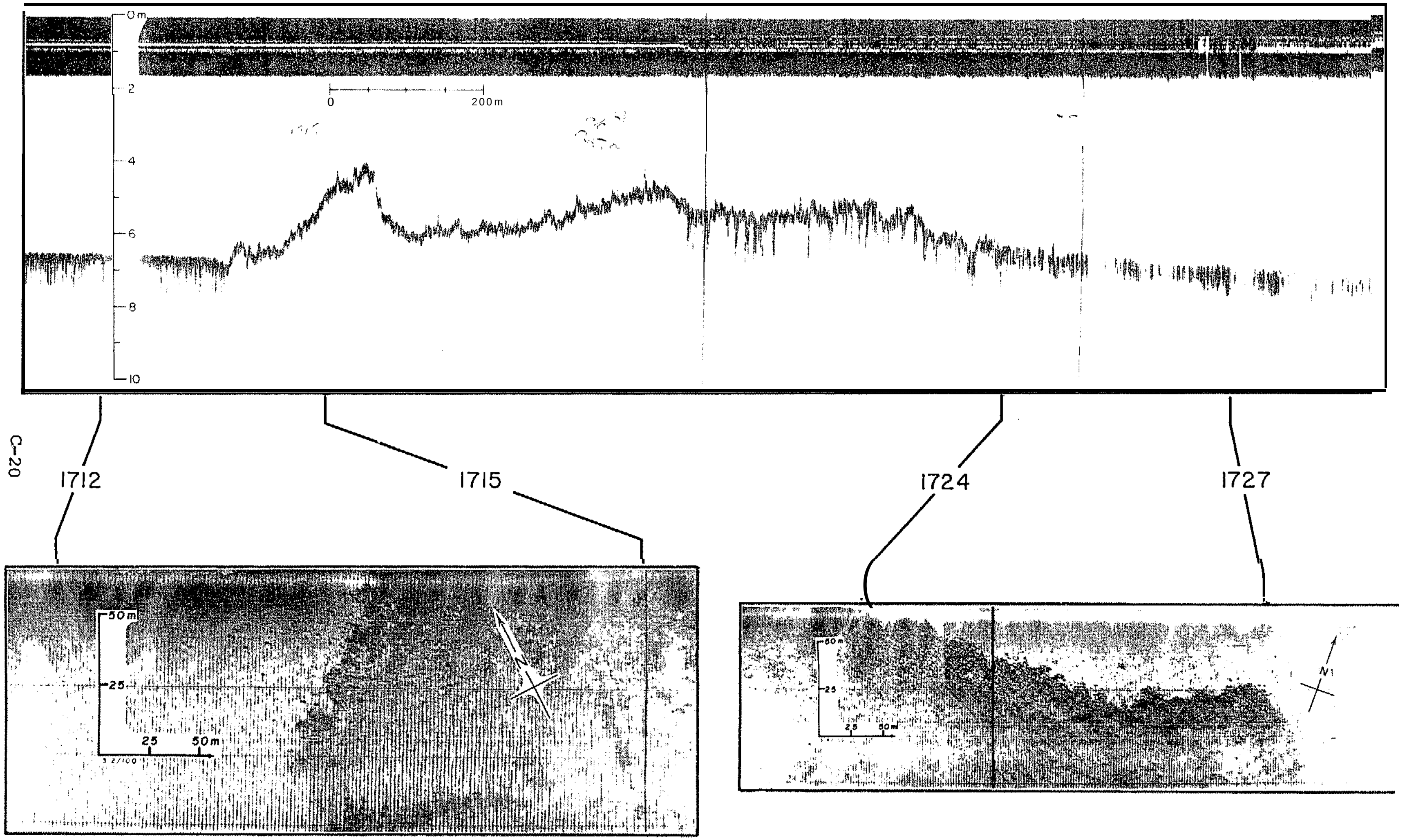


Fig. 14. Depth profile (top) and sonograph (bottom) of near shore area between Clifford Point and Rex Point, southern Kotzebue Sound. Line 13, time: 1711-1729.

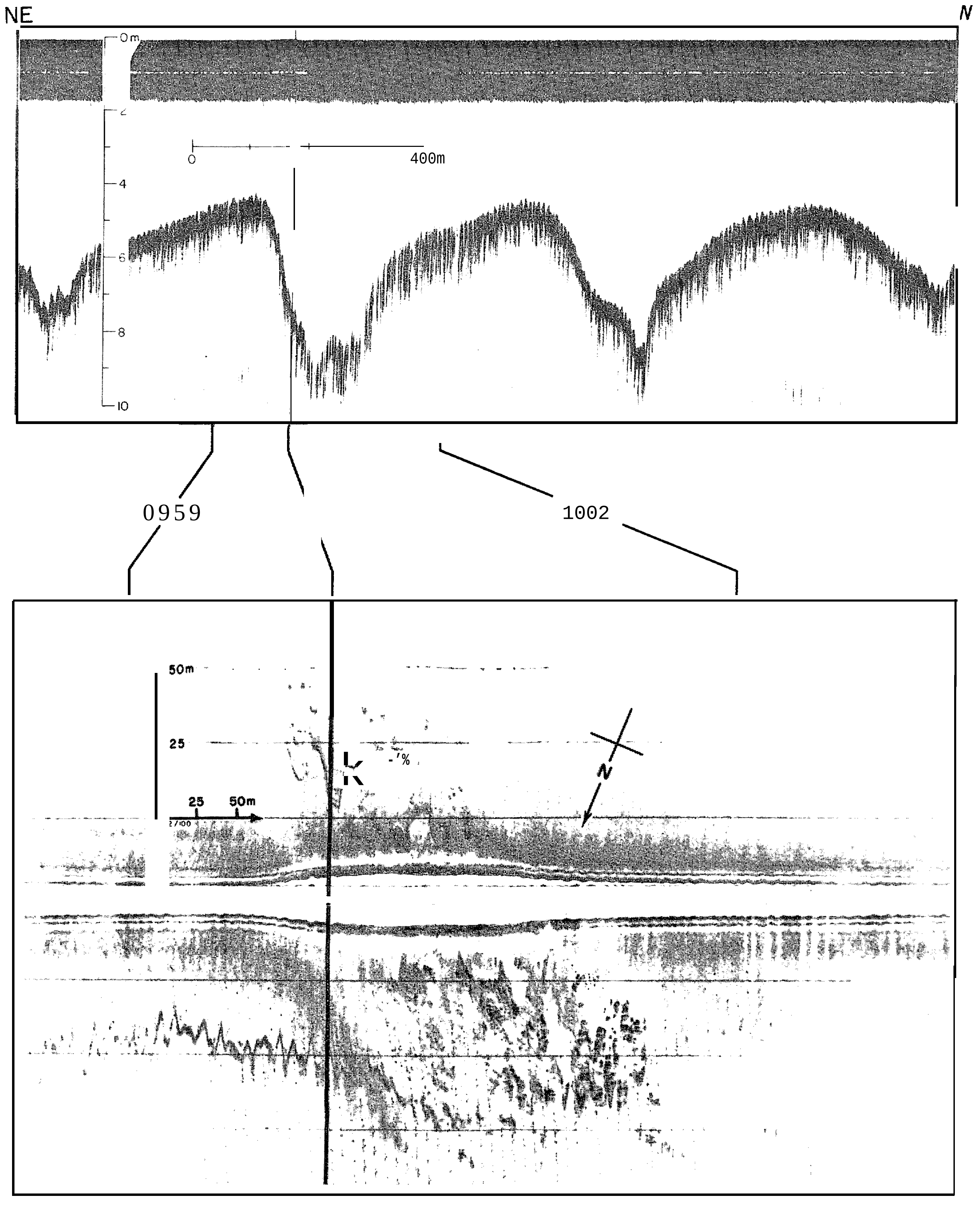


Fig. 15. Depth profile (top) and sonograph (bottom) of bars and troughs near shoreline of barrier separating Lopp Lagoon from open sea. Line 3, time: 0955-1009.

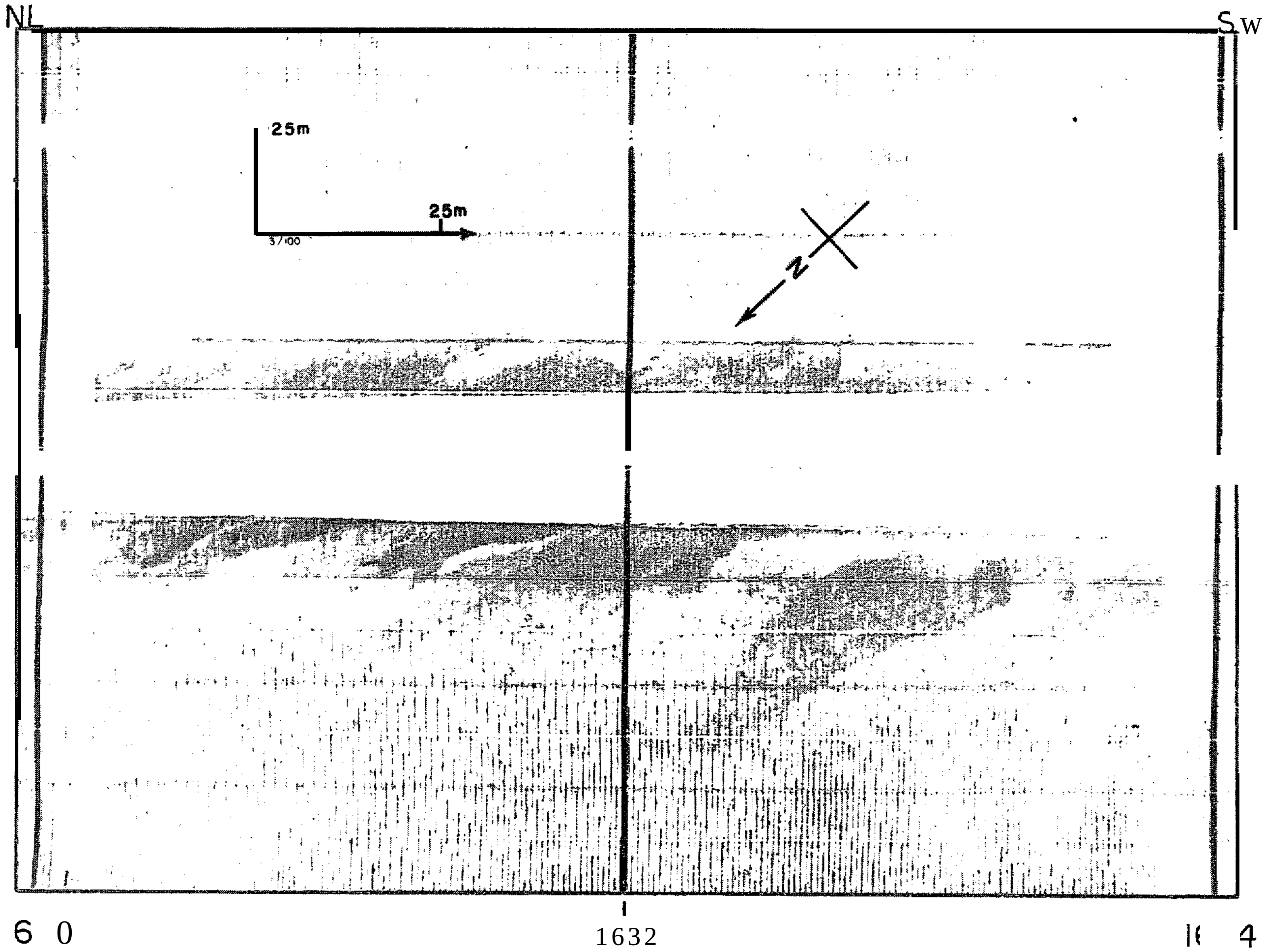


Fig. 16. Sonograph of linear features (ice gouges or current scours) on the western slope of Prince of Wales Shoal. Line 1, time: 1630-1634.

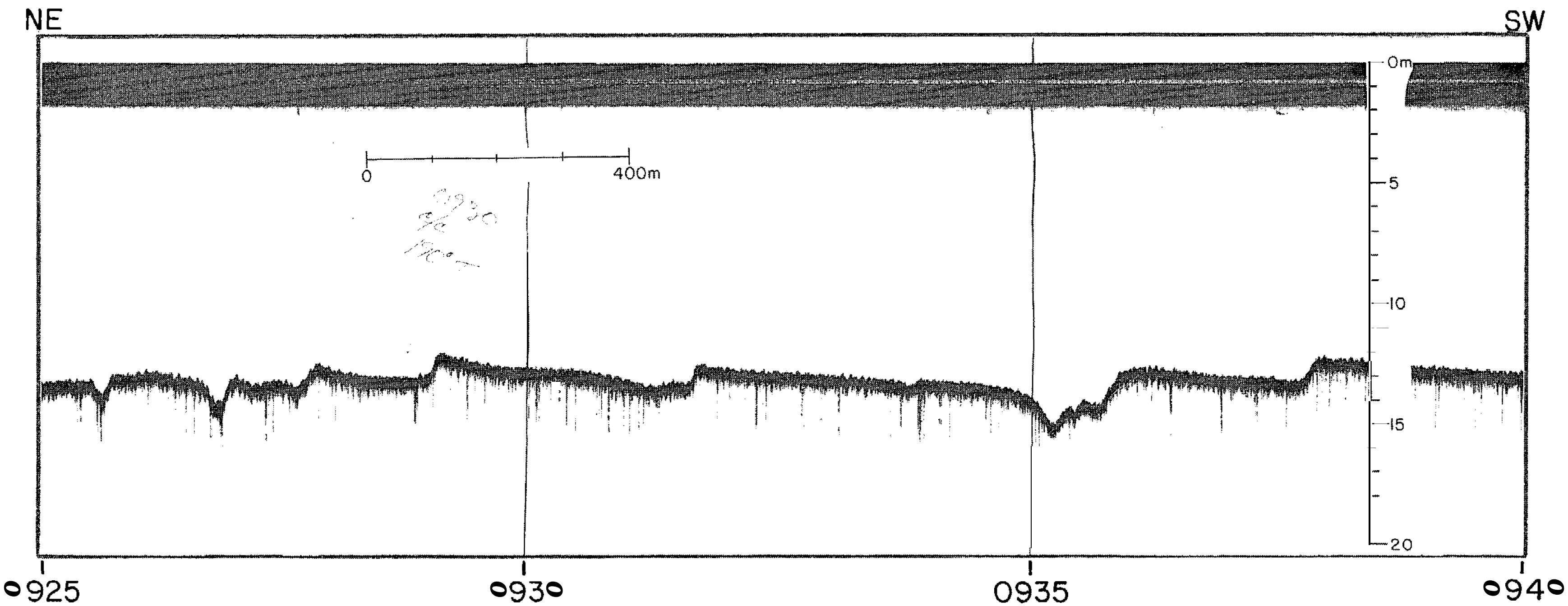


Fig. 17. Depth profile across probable sand waves in the crotch-like trough between Prince of Wales Shoal and the shoreline. Line 5, time: 0925-0940.

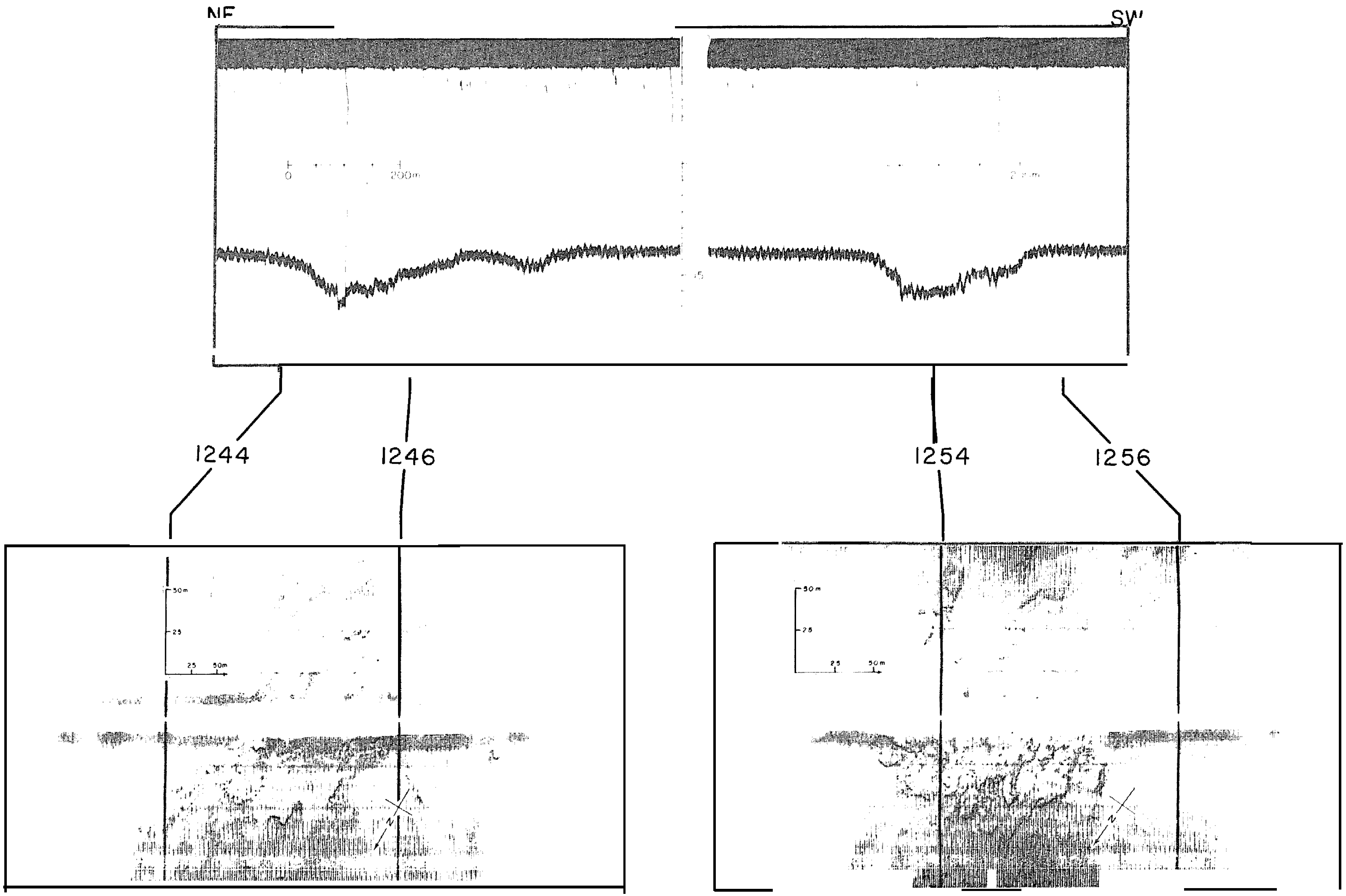


Fig. 18. Depth profile (top) and sonographs (bottom) of probable sand waves from the trough between Prince of Wales Shoal and the shoreline. Line 1, time: 1243-1257.

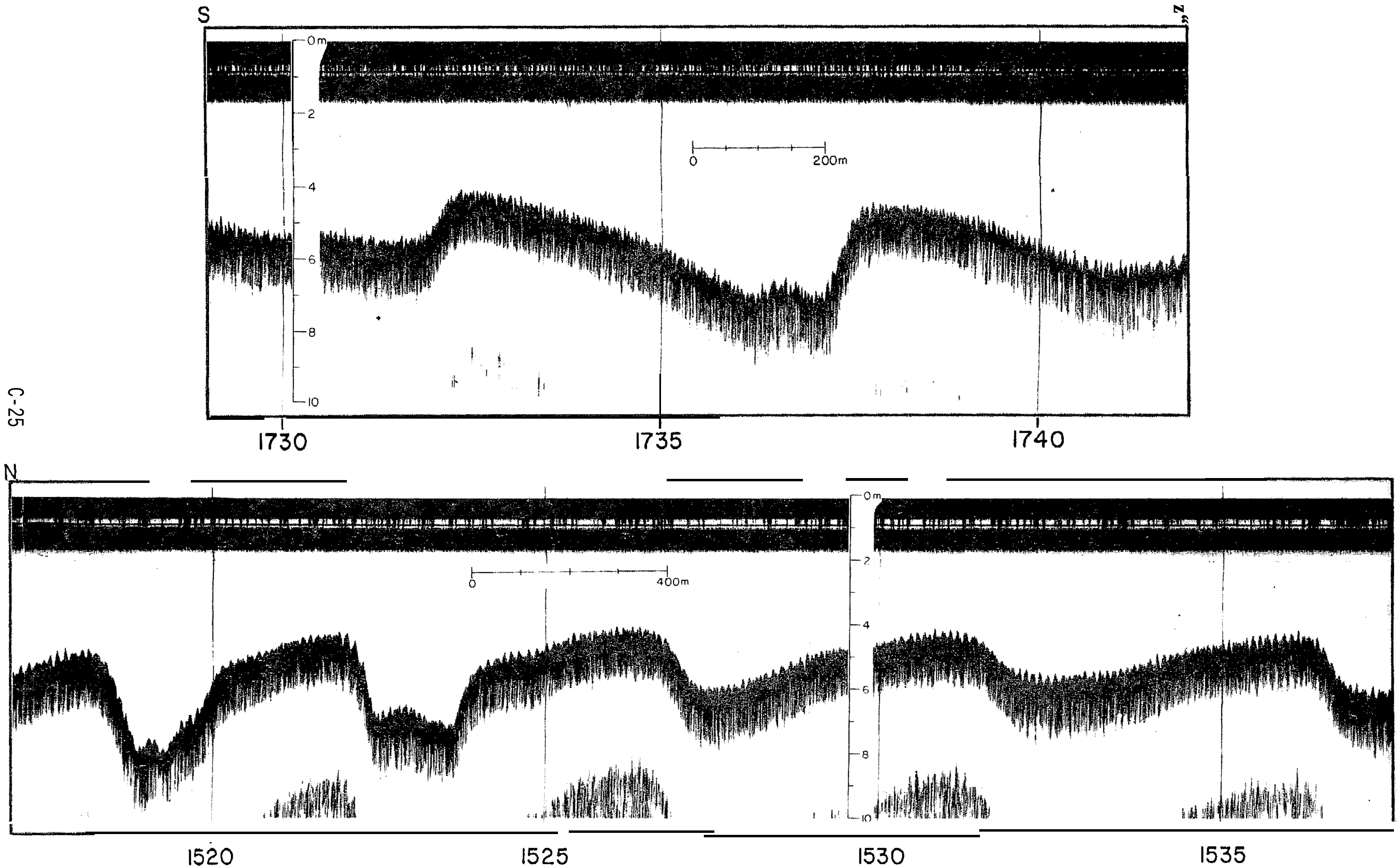


Fig. 19. Depth profiles of sandwaves from nearshore shelf just north of Cape Prince of Wales. Top: line 2, time: 1729-1742; bottom: line 1, time: 1517-1537.

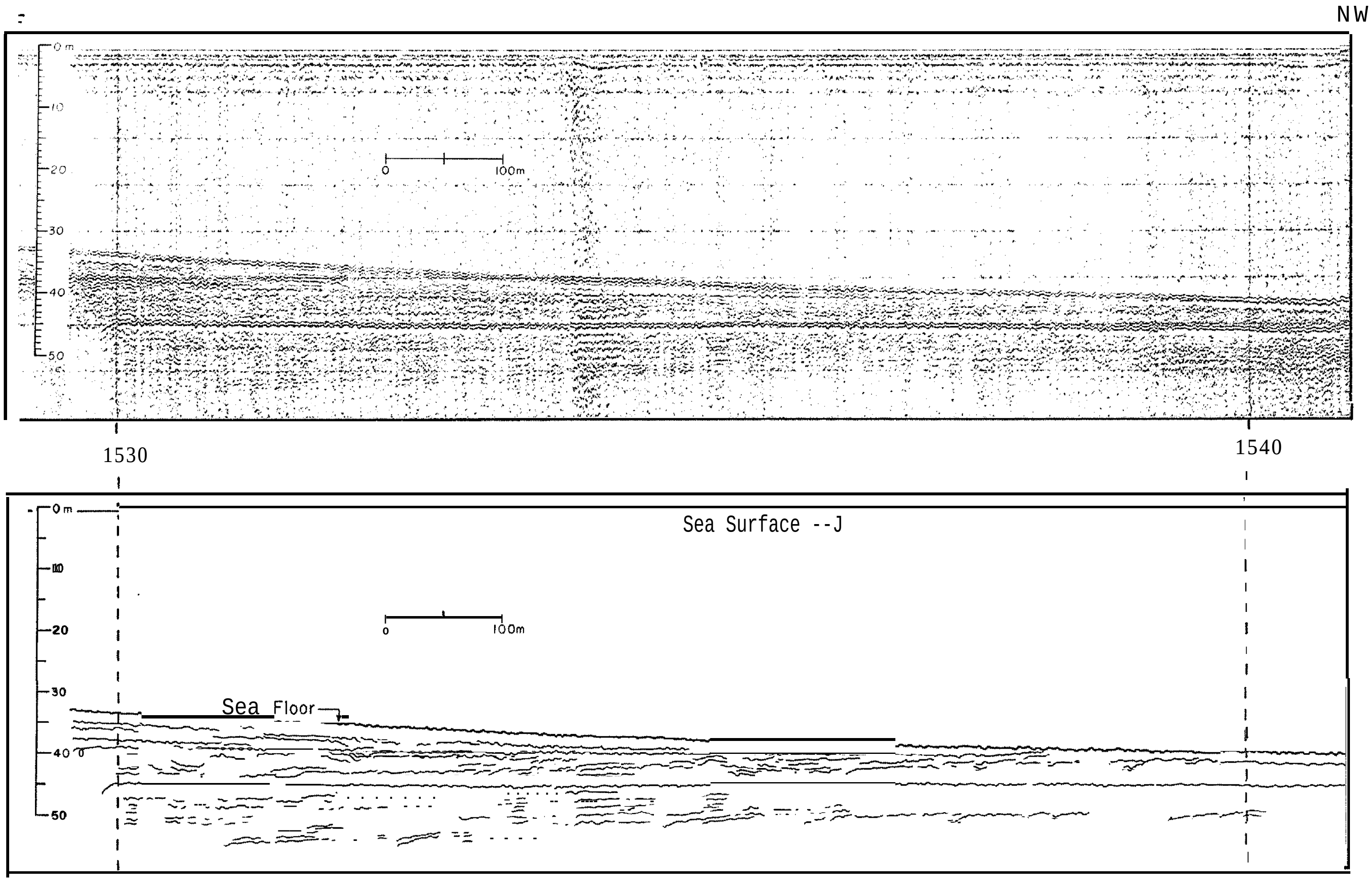


Fig. 20. Uniboom record (top) and interpretive drawing (bottom) of western slope of Prince of Wales shoal. Line 4, time: 1529-1540.

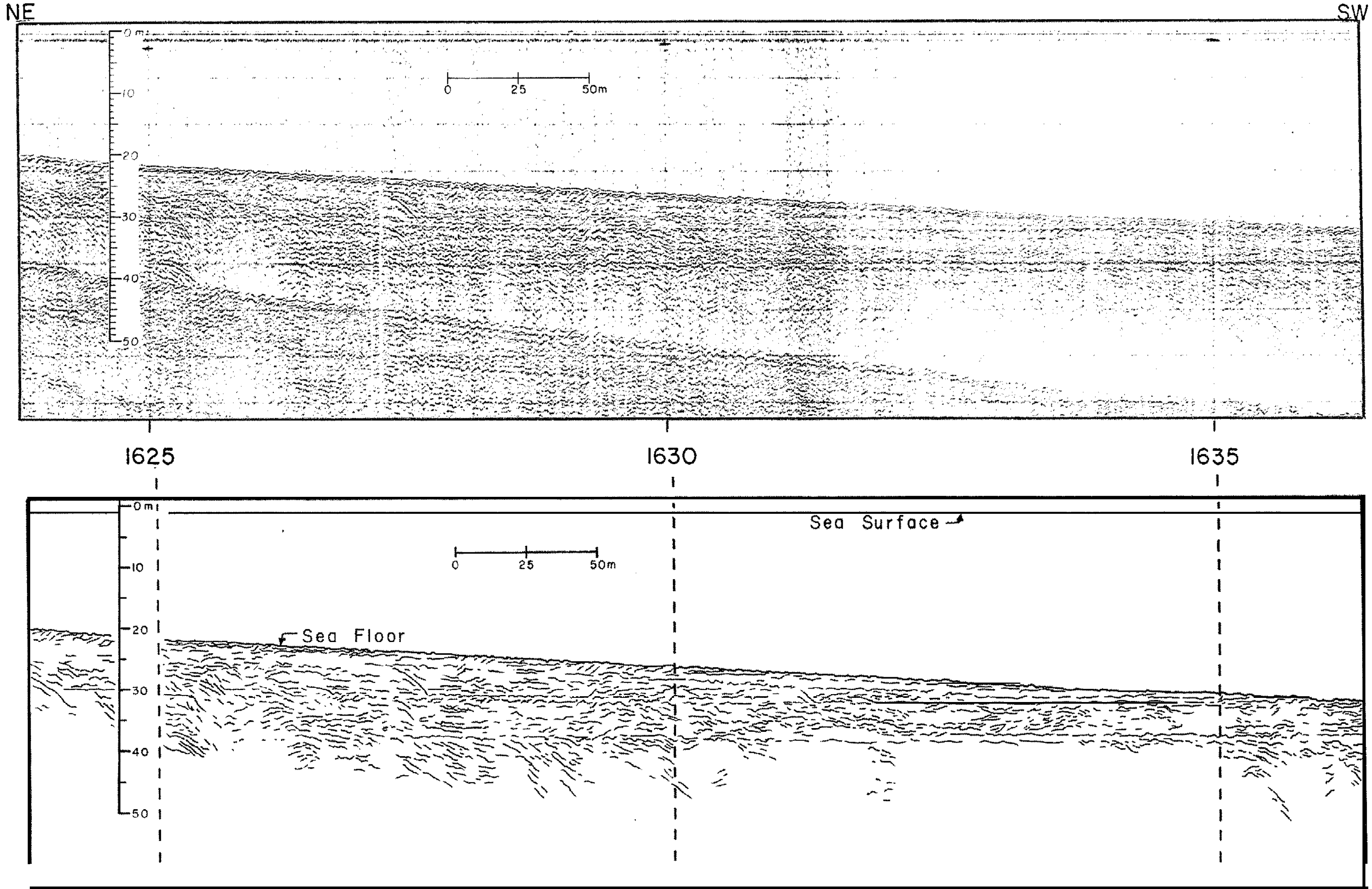


Fig. 21. Uniboom record (top) and interpretive drawing (bottom) of slope just north of Cape Prince of Wales. Line 1, time: 1625-35.