DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

GLORIA study of the Exclusive Economic Zone off Alaska -- southern Bering Sea: Initial report for cruise F4-86-BS

3 September to 30 September 1986

by

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This report is preliminary and has not been reviewed for conformity with Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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THE EEZ-SCAN 86 PROGRAM

EEZ-SCAN is a cooperative research program between the United States Geological Survey (USGS) and the British Institute of Oceanographic Sciences (IOS). The major aim of the EEZ-SCAN program is a reconnaissance of the entire United States exclusive zone using the long-range side-scan sonar, GLORIA. The area covered during 1986 on four successive cruises included a small part of the northeastern Gulf of Alaska (Leg 1) and most of the Bering Sea (Legs 2-4), seaward of the continental shelf edge.

The cruises were conducted aboard the MV FARNELLA with a complement of both U.S. and U.K. scientists and technical support staff. In addition to GLORIA data, 160-cu-in air-gun two-channel seismic-reflection profiles, gravity, magnetic gradiometer, and 3.5-kHz and 10-kHz high-resolution seismic measurements were continuously collected during the program.

Leg 4, the subject of this report, covered the southern Bering Sea between the Bering continental shelf, south of Pribilof Canyon, and Bowers Ridge (Figure 1). The cruise was highly successful and more than 9000 km of GLORIA and geophysical data were collected during the 26 working days at sea.

CRUISE NARRATIVE

Ongoing crew arrived in Dutch Harbor Sept 1. USGS crew consisted of Alan Cooper, Andy Stevenson, Brian Edwards, Guy Cochrane, and Jim Nicholson. IOS crew consisted of Neil Kenyon, Derek Bishop, John Cherriman, Colin Jacobs, Roger Gowlett, Graham Lake, and Martin Beney.

Conversations with the departing crew indicated that all equipment aboard was operating well and no repairs were necessary prior to sailing. The leg 3 crew left the ship in excellent condition and ready for operations to resume. The only inport configuration change was an attempt to switch the Masscomp over to the "clean" 110 power. This failed when the ship's electrician was unable to attach the dummy load received in Dutch to the generator. Masscomp, therefore, was configured as it was for leg 3. Gravity land base-ties to each of the previous dockside locations of the ship were made with an Lacoste and Romberg land gravity meter. Departing crew left Sept 2. Ship left the OSI fuel pier at the south end of Captains Bay for the operations area at 9:30 am ADT Sept 3.

After a short transit along the north side of the Aleutian Arc, GLORIA operations commenced at 2:00 pm ADT Sept 3. All systems fired up without problems and data collection began along the north flank of the Aleutian Ridge. After making several passes parallel to the ridge, we reverted to the NW-SE pattern parallel to the southern Bering margin established by legs 2 and 3, and proceeded to fill in the southern basin area. The survey was continued westward to the east flank of Bowers Ridge.

Track spacing was designed to give an overlap on GLORIA sonographs. Consequently, in shallow water areas near the easternmost end of the survey area, tracklines were spaced more closely that in deep water areas of the abyssal basin. In general, tracklines were kept as long as possible for greater efficiency of GLORIA coverage. Figure 2 shows the location of tracklines for leg 4.

Weather during the first week of the cruise was marginal for good quality data collection with winds in excess of 20 kts. and seas greater than 8 feet. This pattern continued throughout the cruise with the exception of a five day calm period mid-cruise. On two occasions, trackline directions had to be modified to prevent GLORIA from pitching into the seas.

Underway operations were terminated at 1:20 pm ADT on September 28 for the transit to Dutch Harbor. The ship arrived in Dutch at 8:00 am ADT on September 30, and all USGS and IOS crew, except Martin Beney departed Dutch Harbor on September 30.

EQUIPMENT SYSTEMS

GLORIA side-scan sonar

The GLORIA system continued to function without major problems throughout the entire cruise. Minor problems encountered were:

1. Data dropouts on individual traces occurred in bad and sometimes calm weather caused by yawing of the fish when the ship was running with the seas (SE tracks) and occasionally when the ship was pitching into the seas.

2. Inability to read two consecutive magnetic tapes (gliches) nearly necessitated resurveying 12 hours of previous trackline. Problem was overcome with new software to read these tapes.

3. Two power failures, occuring during testing of the ship's electrical system, shut down GLORIA for up to 20 minutes. One gap was resurveyed and the other was not.

During a majority of the cruise, GLORIA produced spectacular images in all water depths and all sea conditions.

Navigation

Navigation was controlled by GPS satellite, transit satellite, and Loran C (hyperbolic). GPS coverage was about 12 hours per day, although problems with locking onto sufficient satellites were frequently encountered. Principal locations were controlled by satellite fixes and the Northstar Loran system. Ship's speed and heading were used for intervening DR positions. Loran C rho-rho mode was not used because the high-price leased Cesium clock could not be fed into the Loran receiver because receivers with the necessary modifications had been taken off the ship for use elsewhere. Comparisons of Loran and GPS positions indicated continuous navigational accuracy of better than 1/4 NM. No major problems were encountered by the navigation system. The onboard computer logging and plotting system was in continuous use providing navigation and data plots for all phases of field and interpretive work -- an outstanding tool!

Seismic-reflection profiling

The dual-channel seismic profiling system with 160 cu. in. airgun worked well during this leg with only minor problems in the digitizing module. Good results were obtained using a 10 sec fire and 6 sec sweep rate and three duplicate traces (original and two repeats). The use of three traces produces a blocky look to the profiles on steep slopes which is a minor annoyance. The airgun worked well, and only two solenoid (gun timing) problems and a leaking air hose were encountered. Routine airgun maintenance and minor airgun problems resulted in loss of only four hours of seismic data during the 26 days of operations.

The MASSCOMP suffered four undiagnosed crashes, one of which necessitated a cold boot to clear the system. In all cases, the system was restarted with minimal data loss. The installation of the DAFE system on the MASSCOMP is marginal. Data can be entered into the database with no apparent problems, but no editing, searching, or other file manipulations can be attempted without risking a crash of the seisdata program. The crashes are not predictable, as the same operation does not always provoke a crash. Occasional unexplained problems occurred with the crt screen buffer. Trace amplitude would increase substantially and the screen would fail to clear, resulting in traces overwriting and a white screen. Only a "newline" command would recover the system.

Bathymetry

The IOS 3.5 kHz and 10 kHz systems performed excellently throughout leg 4 producing very high quality records in all sea conditions. The IOS designed and built correlator for the 3.5 is an excellent unit and far surpasses the performance of commercial systems. No down time was encountered on either system.

Magnetics

The Geometrics 801 gradiometer system functioned continuously throughout the cruise. Minor difficulties were encountered initially with the logging system because starting and stopping of the tape recorder could not be controlled. This problem is unsolved and continues to make start-up a time consuming operation. The cable was inspected following initial deployment and several small gashes in the cable, between the reel and the slave sensor, were found. The gashes were repaired and the noise level decreased slightly. Water in the cable is the likely explanation for the noise. The spare gradiometer cable required a great deal of work in replacing the missing master sensor because of improperly machined parts supplied to us by Geometrics. The spare cable was never deployed.

Gravity

The Lacoste and Romberg meter S-53 functioned well for most of the cruise. Several problems were:

1. A power failure, immediately prior to sailing, disrupted the gravity meter. The harbor pilot's schedule necessitated departure of the ship before the meter settled down again. Although a base tie was not made for the time after the power failure, a tie was made prior to the failure.

2. Spikes followed by exponential decay occurred in the spring tension causing the gravity values to have spurious 'bumps'. The problem was believed to be a bad servo amplifier or bad socket; however, the problem disappeared before it could be resolved. Gravity data during the 24 hour period can probably be recovered from readings between spikes.

3. A mid-cruise power failure, caused by inopportune testing of the ship's electrical system, caused large periodic variations in total correction. The problem was traced to a "trashed" amplifier. The effect on the gravity data is unknown.

A gravity tie was successfully made at the end of the cruise.

Expendable bathythermograph - XBT

Several XBT's were recorded at scattered locations throughout the survey area. Results were disappointing because temperature-depth readings could not be attained below about 250 meters. The location of the possible XBT launching sites, amidships and directly aft, caused the XBT wire to get tangled in the streaming gear and thereby break the wire prior to maximum deployment. Model T7 XBTs, with 2000 m depth range, were attempted but abandoned for model T10 XBTs (250 meter depth) because of this problem. During the transit to Dutch Harbor, one Mode T7 XBT was successfully deployed to its maximum depth range ; however, the computer program provided with the XBT system would not record data for deployment depths greater than 900 m. Automatic transmission of XBT data to NOAA via satellite apparently was not occurring, although all shipboard systems appeared to be functioning normally.

PRELIMINARY SCIENTIFIC RESULTS

During the cruise, several phases of initial compilation and analysis of the GLORIA and geophysical data were accomplished. Our successes in these endeavours can be directly attributed to the excellent IOS staff and shipboard facilities! The initial compilations included:

- two mosaics of GLORIA images covering the Leg 4 survey area
- preliminary interpretation of geomorphic and sedimentary features on GLORIA mosaics
- preliminary isopach map of total sedimentary thickness in the survey area
- preliminary structural contour map on basement for the survey area
- preliminary magnetic anomaly map for areas surveyed by Legs 2,3, and 4
- preliminary map of surface and subsurface structural features in the Leg 4 survey area

- preliminary line drawings of select seismic-reflection profiles

- final plots of navigation, bathymetry, and magnetic anomaly data for the Leg 4 survey area at several different scales

- Leg 4 cruise report

The Leg 4 survey area covered the southern and southeastern parts of the Aleutian Basin in the Bering Sea. This area encompasses the southeastern part of the Bering continental slope, the north flank of the Aleutian Ridge, Umnak Plateau, the southern part of the Aleutian abyssal plain, and the eastern flank of Bowers Ridge (Figure 1).

Bering continental slope

The Bering continental slope in the Leg 4 area is underlain by up to 8 km of sedimentary rock filling structural troughs that parallel the shelf edge. GLORIA images over the slope and Pribilof Canyon region show impressive evidence for mass wasting of the continental slope by debris flows, surface faulting and slumping, and canyon cutting by submarine currents(?). Most of the slope is unstable and is actively being eroded. Sediment is being carried downslope into Bristol and Bering Canyons. Canyons with a tributary pattern of branches and up to fourth order gullies, are prevalent on most slopes. However, canyoned slopes are not found east of Pribilof Canyon where the upper slope dips less than about 5 degrees.

Bristol and Bering Canyons incise the base of the slope, bathymetrically isolating Umnak Plateau. These broad, steep-walled, and flat-floored canyons are impressive features that extend several hundred kilometers from near the Aleutian Ridge to the Aleutian Basin (Figure 1). Their previously unknown morphology can clearly be seen on the new GLORIA data (Figure 3). Seismic and GLORIA data indicate that the location of the canyons is probably structurally controlled and that extensive sediment has been carried by these canyons into the abyssal basin.

Aleutian Ridge

The north flank of the Aleutian Ridge is marked by numerous dendritic and, in their upper reaches, radial canyon systems that either extend directly into the abyssal Aleutian Basin (western survey area) or run into Umnak Canyon. Umnak Canyon, which forms the southern boundary of Umnak Plateau, is another major sinuous canyon (Figure 4) that has probably carried extensive sediment from the ridge flanks into the abyssal basin. The sinuous canyon lies in a structural depression at the base of the ridge and has probably been active, to some degree, throughout at least late Cenozoic time. GLORIA data clearly show the active erosional processes in the canyons and the sediment dispersal patterns at the mouths of these canyons in the abyssal basin (see section on Aleutian Basin).

Bogoslof Island, an active volcanic island, lies north of the Aleutian Ridge and is clearly visible on GLORIA data as an isolated symmetrical volcanic cone (Figure 5). Erosion of this young feature appears to contribute significant quantities of sediment into the Umnak Canyon system. Although island-arcs have not been considered major suppliers of sediment, examples at Bogoslof Island and elsewhere along the Aleutian Ridge in the new GLORIA data indicate that older ideas may be incorrect.

Umnak Plateau

Umnak Plateau is a triangular-shaped bathymetric high bordered on its NE and S sides by steep-walled canyons and on its W side by a sediment-draped and diapirically-intruded slope. The outline of the plateau, which is clearly visible on GLORIA images, is structurally controlled by basement faults, intrusive structures, and basement warps. The top of the plateau, unlike surrounding areas, is bathymetrically smooth and has a uniform acoustic backscatter character on GLORIA images except near the edges of the plateau. Major sediment failure and erosional features characterize the edges of the plateau. One such feature, a likely slump-debris flow nearly 15 miles across by 30 miles long, lies on the western edge of the plateau (Figure 6). This feature is associated with underlying large diapir-like structures that lie near the edges of the flow. Shallow sediment deformation above these basement structures suggests recent uplift and likely association of sediment failures and slumps with relatively recent tectonic activity. The distinct circular shape of the diapir-like basement highs can be seen in a GLORIA image (Figure 7) across the edge of the plateau south of the major slump-debris flow. A smaller debris flow appears to be associated with the diapirs that crop out at the seafloor.

Aleutian Basin

The Aleutian Basin abyssal plain is a nearly flat, bathymetrically-featureless area that is underlain by more than 4 km of flat-lying sedimentary strata overlying igneous oceanic crust. In areas near the Aleutian Ridge, seismic-reflection data indicate that acoustically opaque, coarse-grained(?) sediment fills the basin. This sediment becomes internally more reflective in the central parts of the basin. GLORIA data reveal a spectacular and previously unknown pattern of sediment dispersal similar to braided channels of surface outwash areas (Figure 8), and in one case, a channel appears to terminate in a pattern similar to crevasse splays.

At least two major dispersal systems emanating from Umnak and Bering Canyon systems cross the basin from NE to SW. Other smaller systems, originating from the Aleutian Ridge, enter the abyssal basin and cut across or merge with the major systems. The patterns at the ends of the dispersal systems are in an area of very low relief and show up as strongly reflective areas on the GLORIA records, perhaps due to small-scale bed roughness or coarse sediment. The features have a dynamic shape. Darker areas appear to be narrow channels branching down the transport paths. They separate broad sheets that are highly reflective on the sonographs and correspond in many cases to lense-shaped surface layers up to 6 meters thick that are internally, acoustically transparent on the 3.5 khz bathymetry record.

Geophysical data indicate that the areas underlying most of the southern Aleutian Basin have nearly flat-lying igneous crust. This is in contrast to the central Aleutian Basin, where basement ridge systems occur, and to the area around Umnak Plateau, where basement horsts or intrusions are common. Magnetic anomaly data from the 1986 GLORIA survey confirm the initial hypothesis that the Aleutian Basin is characterized by a suite of north-south trending magnetic anomalies. These anomalies are probably the result of seafloor spreading (outside of the Bering Sea and before the development of the

Aleutian Ridge).

Bowers Ridge

Bowers Ridge is a large arcuate bathymetric ridge that is probably an inactive volcanic arc. The steep eastern flank appears to have little sediment cover and is incised by narrow and steep canyons that empty onto the abyssal plain. Many of these canyons head into structural half-grabens that lie near the axial parts of the ridge. These features have a general NE-SW trend (near the southern part of the ridge) and show clearly on GLORIA data. High-amplitude magnetic anomalies and high reflectivity GLORIA images along the ridge flank suggest basement rocks crop out or lie at shallow depth.

SUMMARY

GLORIA and geophysical survey operations on leg 4 were highly successful with data collection occupying 93%, transit 6%, and deployment/down time less than 1% of available time. Reasonably good weather conditions prevailed, and only a few tracklines had to be modified for bad sea conditions. In addition to voluminous data collection, several preliminary geological and geophysical maps and compilations were completed during the cruise.

Spectacular GLORIA sonographs of the continental slopes and ridge flanks surrounding the southern Bering Sea clearly show that large sediment bodies are actively being eroded by slumps, debris flows, submarine slides, and bottom currents. These sediments are being carried to the abyssal basin through major submarine canyon systems that are structurally controlled by late Cenozoic and possibly older tectonic activity. Sediment dispersal across the Aleutian basin is by widespread sheet flow.

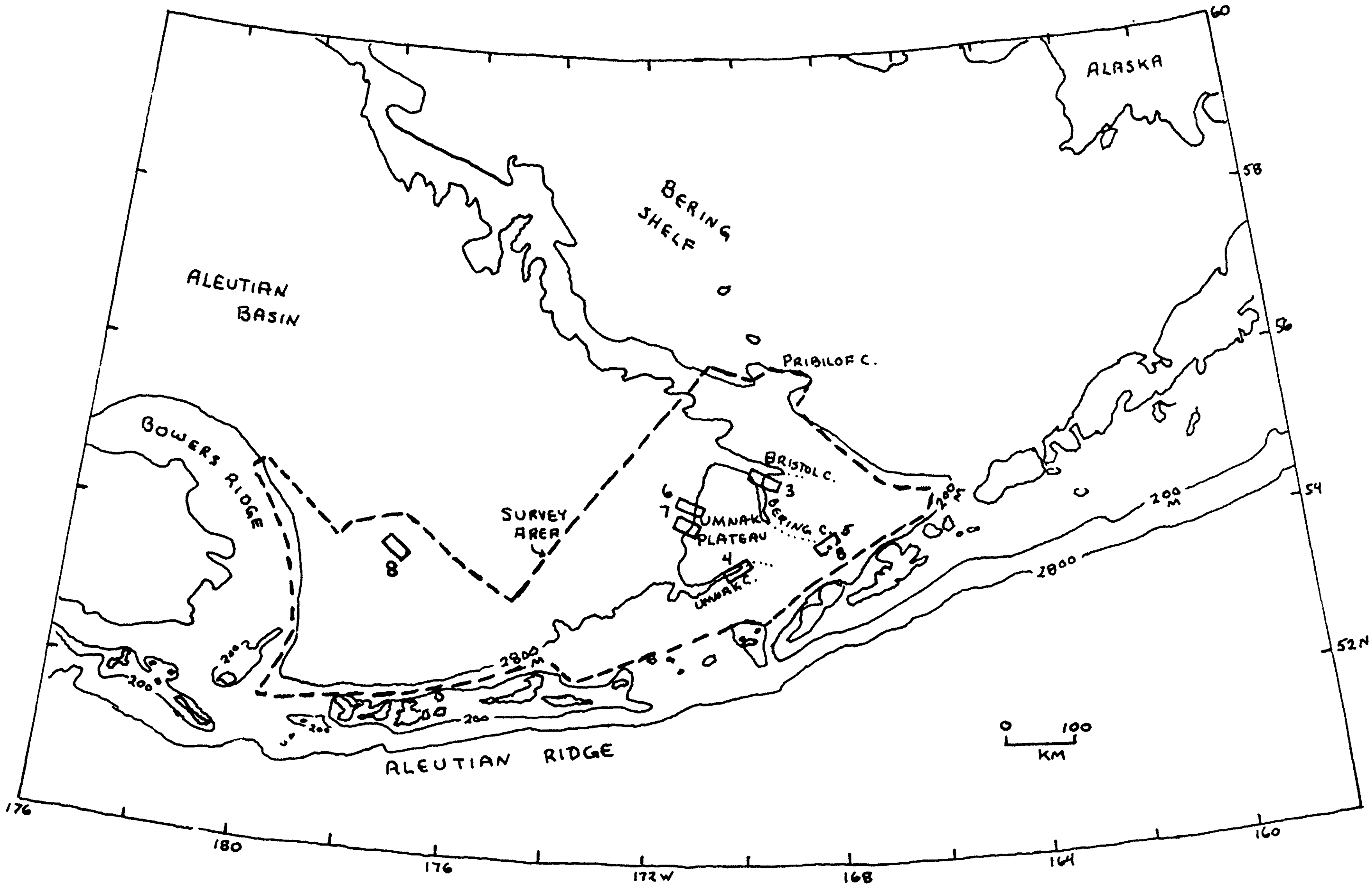

Figure 1: Index map of the southern Bering Sea showing location of survey area for Leg 4 (F4-86-BS).

"B" is Bogoslof Island. Numbers refer to figures discussed in text.

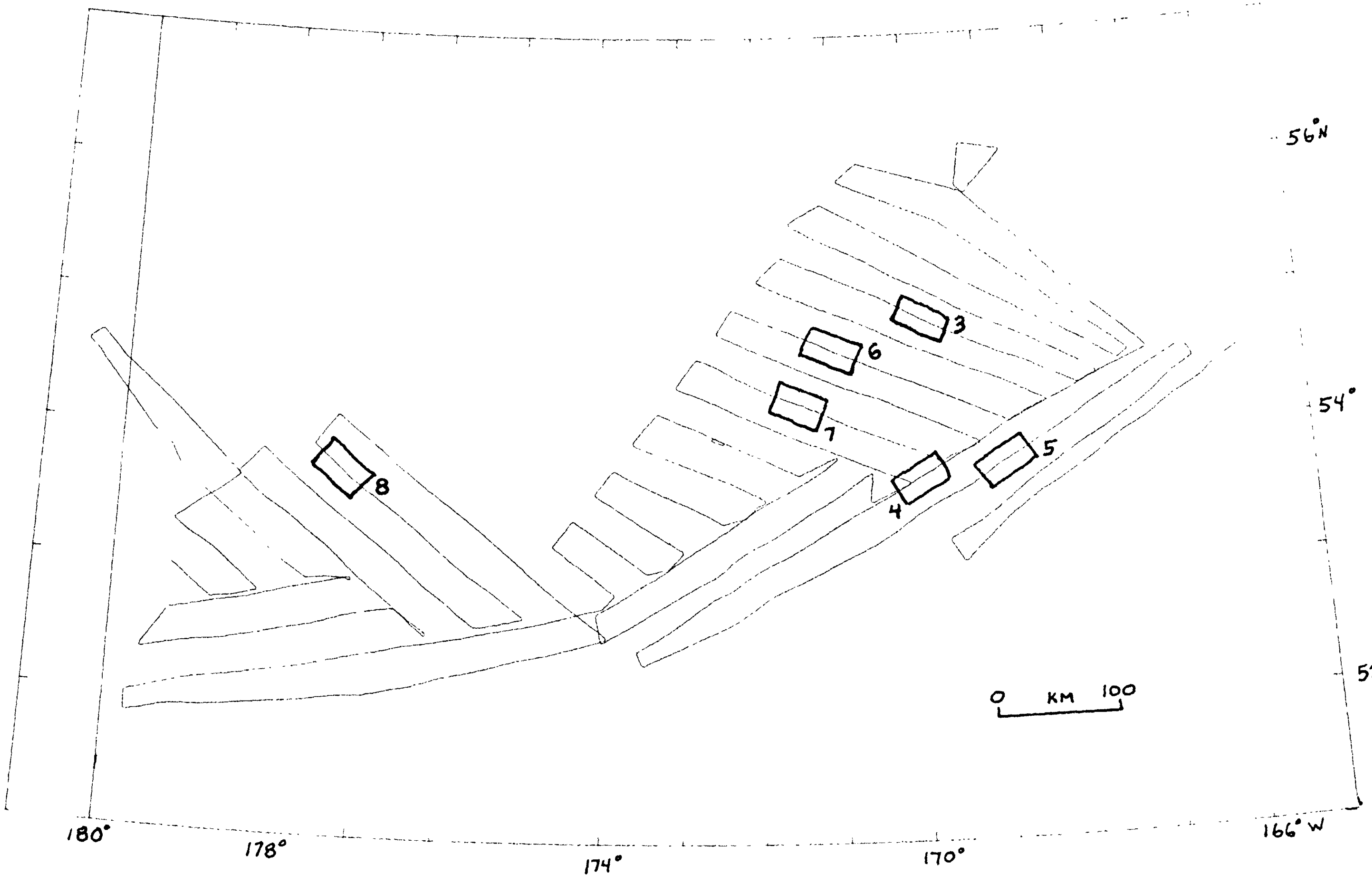

Figure 2: Map showing location of tracklines for Leg 4. See Figure 1 for location.

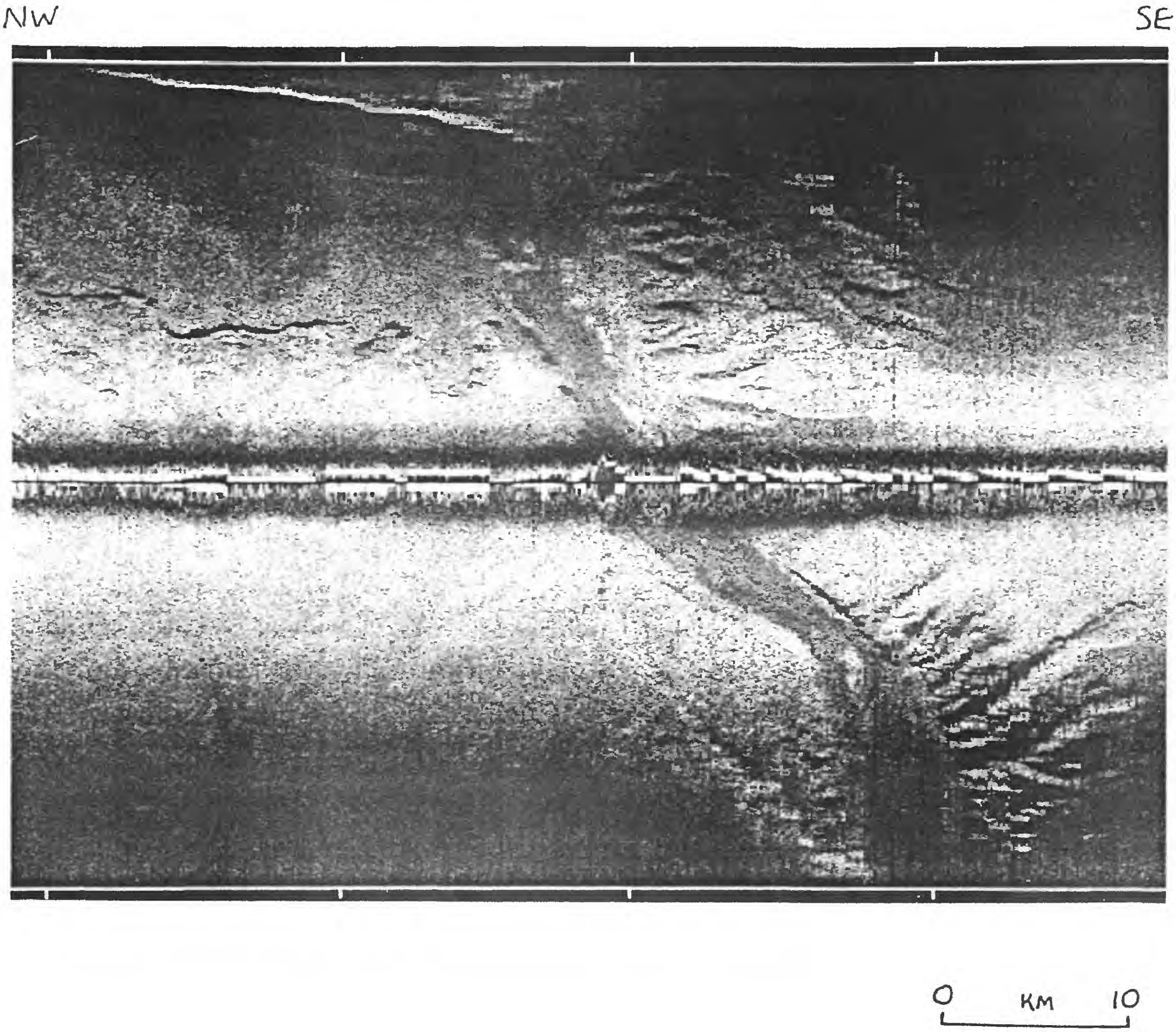

Figure 3: GLORIA sonograph (pass no. 35) along NW-SE trackline showing confluence of Bering (bottom) and Bristol (top) canyons. Seaward of the confluence, the narrow canyons become a broad channel floor (top). Numerous side canyons lead into the major canyon systems. White line in middle of sonograph is ship track. White areas are those with high reflectivity and dark areas have low reflectivity. See Figures 1 and 2 for location.

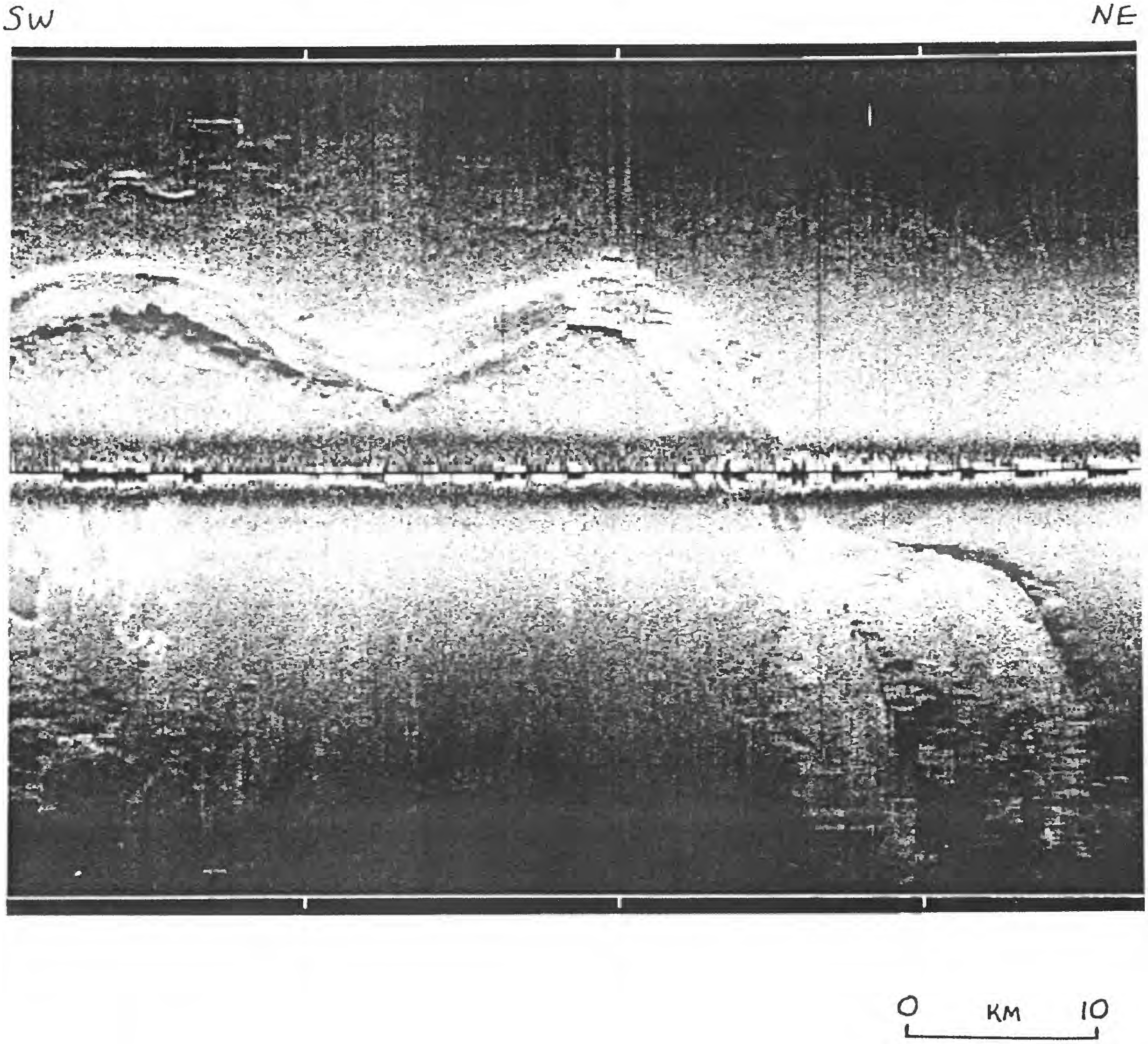

Figure 4: GLORIA sonograph (pass no. 17) along trackline parallel to the Aleutian Ridge showing Umnak Canyon, which separates Umnak Plateau (upper) from north flank of Aleutian Ridge (lower). Sediment failure scars can be seen along edge of the steep-sided plateau. Two large channels can be seen flowing into Umnak Canyon from the ridge flank. See Figures 1 and 2 for location.

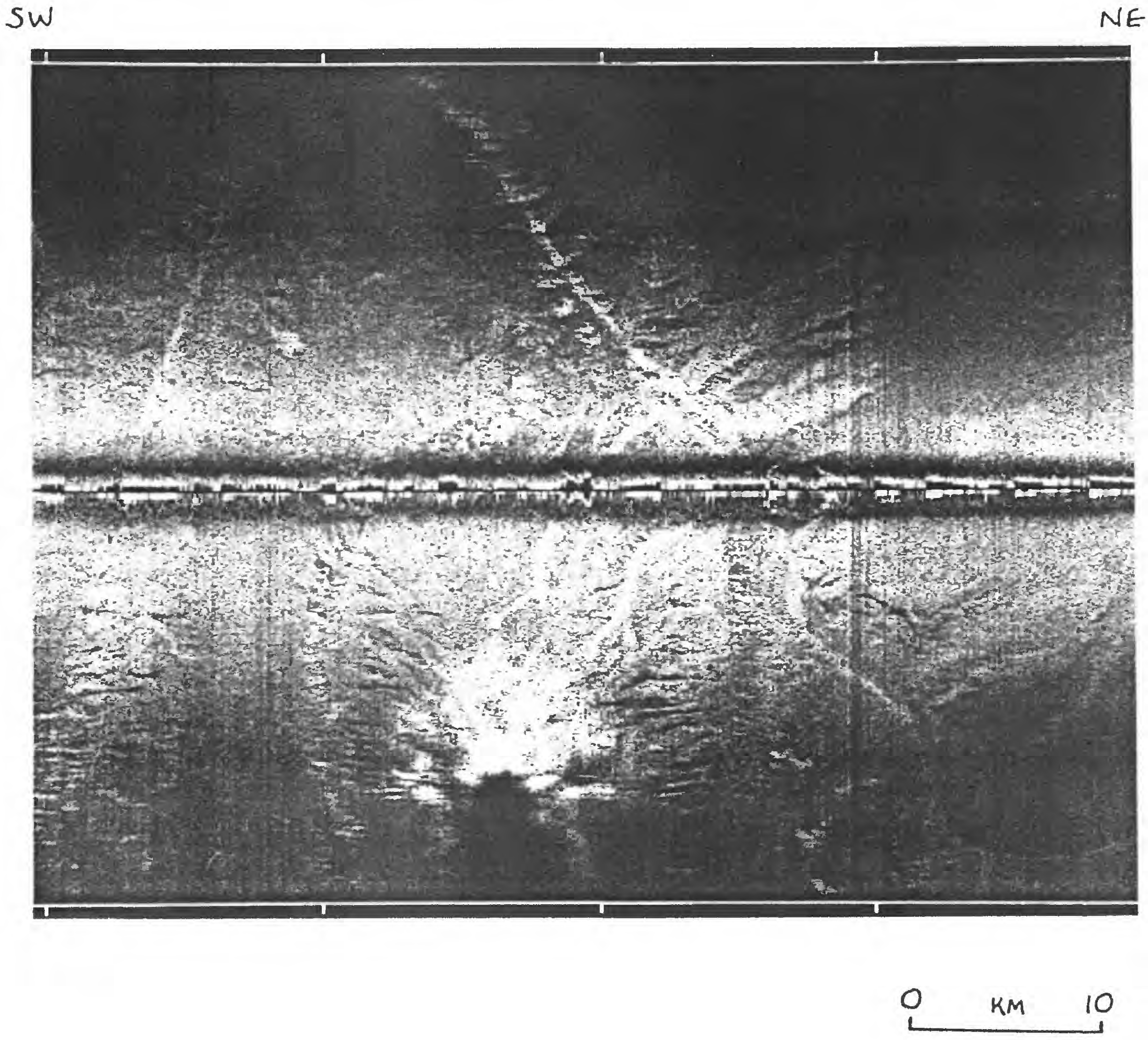

Figure 5: GLORIA sonograph (pass no. 9) along trackline parallel to the Aleutian Ridge showing north side of Bogoslof Island, an active, conical, volcano that intrudes the north flank of the Aleutian Ridge. Large channels can be seen flowing northward down the flank of the volcano and into the upper reaches of Bering Canyon (upper right). Another channel flows into Bering Canyon around the west side of the volcano. See Figures 1 and 2 for location.

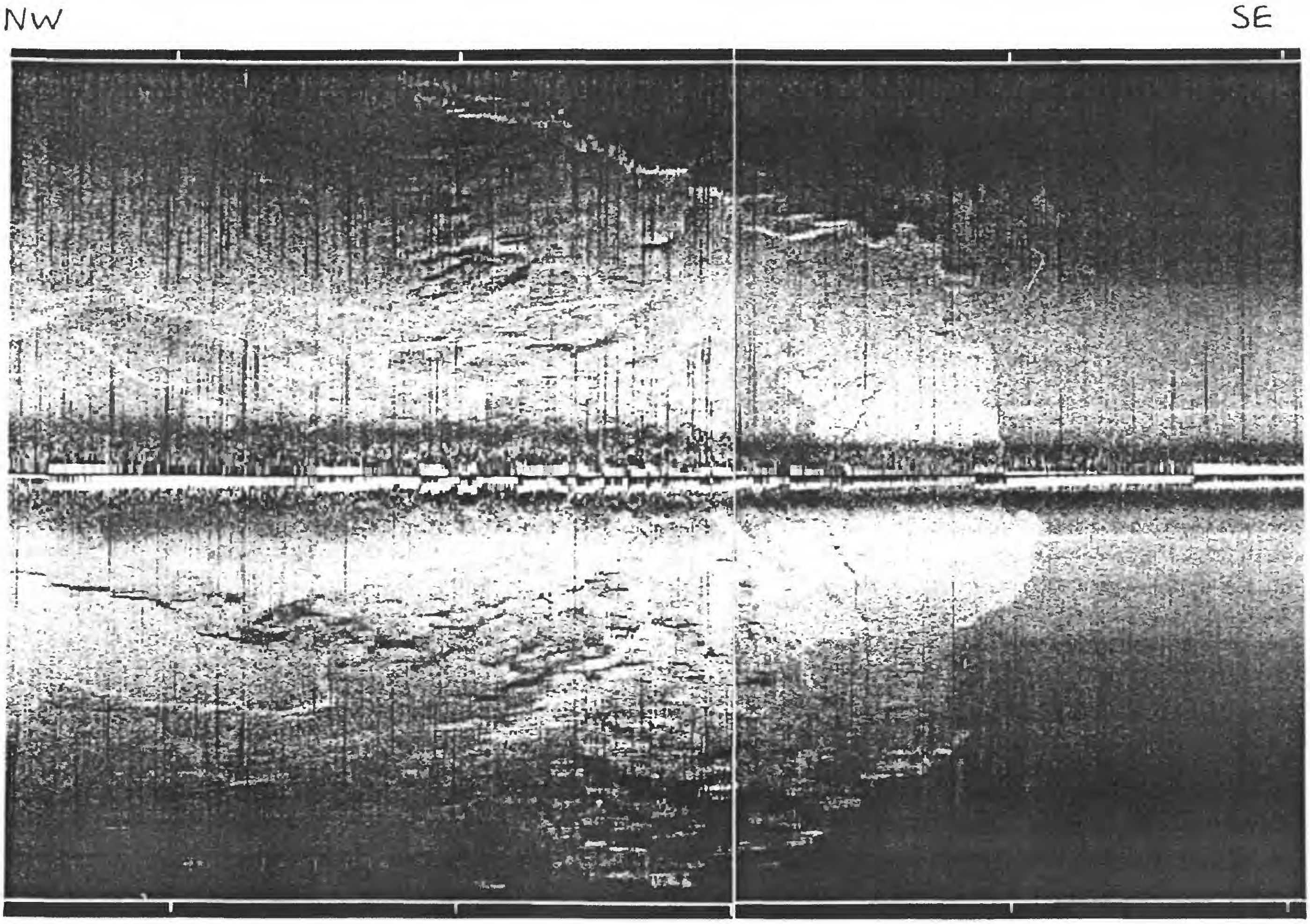

Figure 6: GLORIA sonograph (pass nos. 44 and 45) along NW-SE trackline showing a major slump/debris flow emanating from the west face of Umnak Plateau. Long, concentric, semicircular failure-scarps are visible at the head of the slump. Large diapir-like basement features occur (but are not visible in GLORIA) beneath the SW (lower) part of the debris tongue and may be related to initiation of the failure. See Figures 1 and 2 for location.

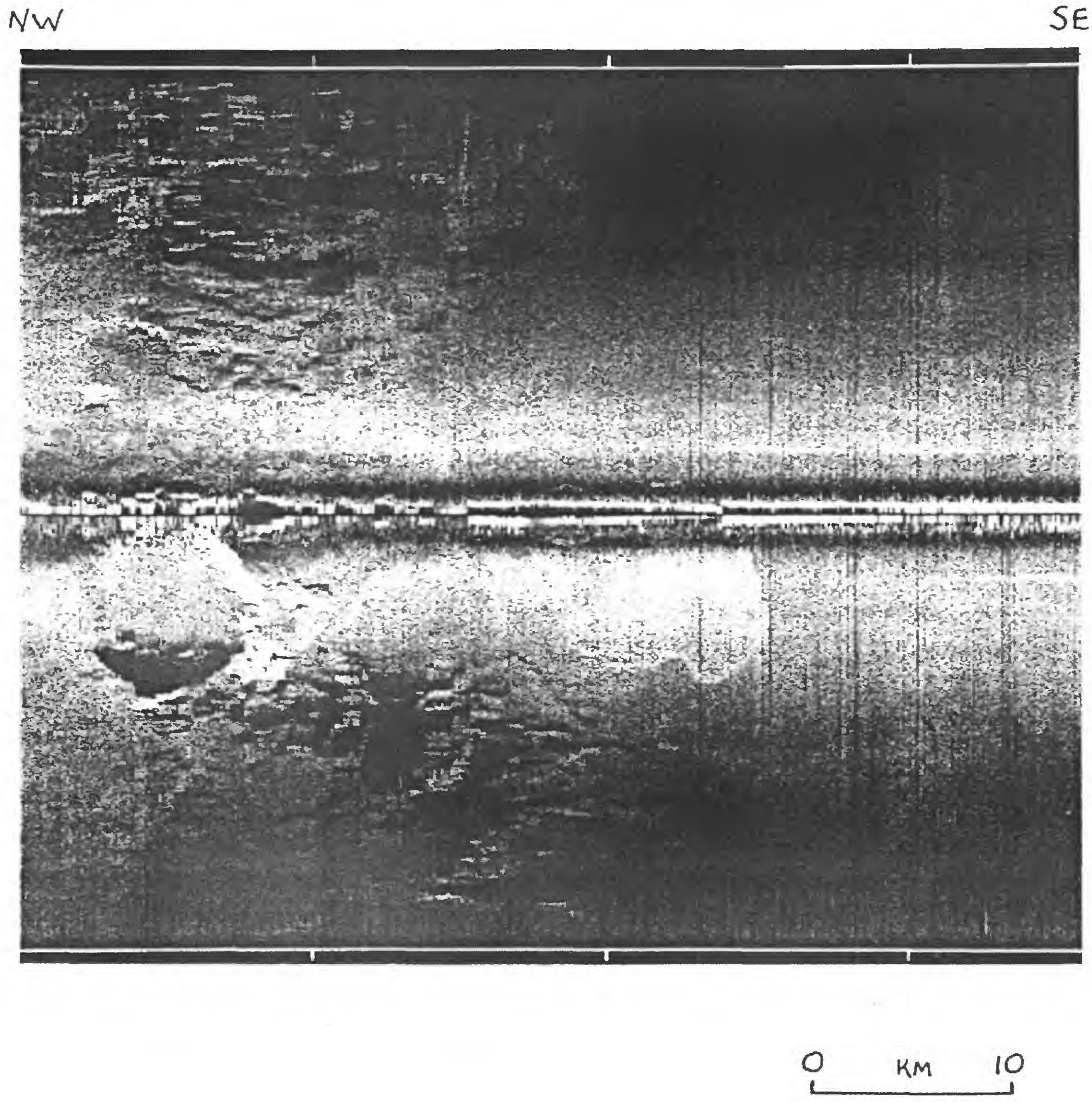

Figure 7: GLORIA sonograph (pass no. 47) along NW-SE trackline showing two circular domes at the west face of Umnak Plateau. The seafloor domes are sediment-covered, diapir-like basement structures, with magnetic anomalies, that indicate late Cenozoic deformation. Sediment failures, channels, and a brightly reflecting slide surface are also visible at the edge of the plateau. See Figures 1 and 2 for location.

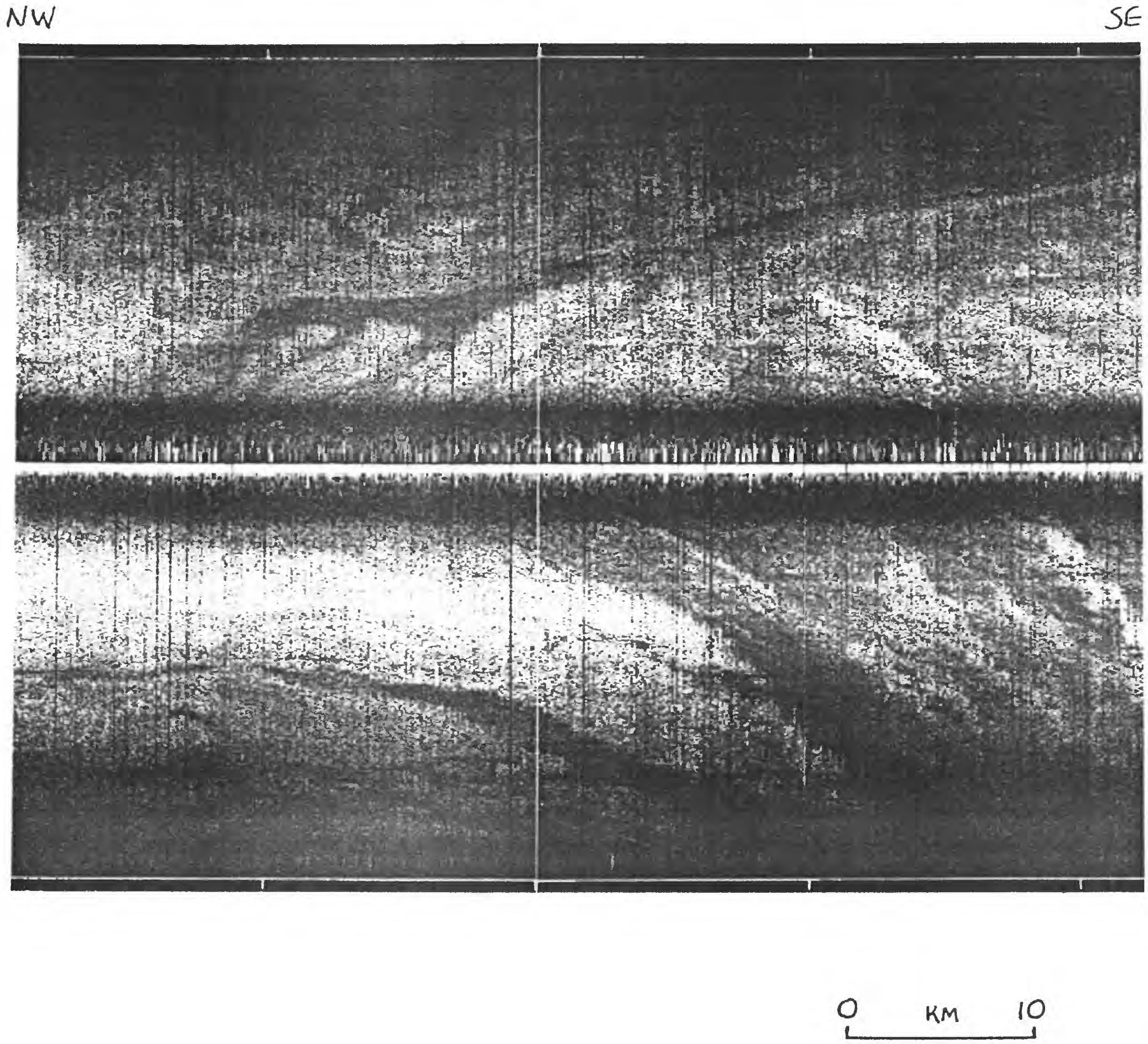

Figure 8: GLORIA sonograph (pass no. 80) along NW-SE trackline showing part of the sediment-distribution system found in the abyssal Aleutian Basin. Strongly reflective (light toned) areas are similar in appearance to braid bars separated by branching channel-like features (dark toned). Deposits that have come westward through the Umnak Canyon (upper) merge with deposits that have come northward from the central Aleutian Ridge (lower). See Figures 1 and 2 for location.