UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Preliminary Presentation and Interpretation
of ARGO/SeaMARC 1B Reconnaissance Investigation
of Mohns Ridge, Norwegian Sea

by

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This report is preliminary and has not been reviewed for conformity with U.S. 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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RESEARCH CRUISE REPORT

SHIP NAME: R/V KNORR, Cruise 130-1
OPERATING INSTITUTION: Woods Hole Oceanographic Institution (WHOI)
CLEARANCE COUNTRIES: Norway, Denmark, Iceland
DATES: August 2 - August 20, 1987
PROJECT TITLE: Mid-Ocean Ridge Research
SPONSORING AGENCY: Office of Naval Research, Contract Number N00014-C-870810
PORT CALLS: Bodo, Norway to Reykjavik, Iceland
SENIOR SCIENTIST: Dr. William C. Schwab
SHIP'S CAPTAIN: Richard Bowen
FOREIGN PARTICIPANTS: None
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Josef R. Labermeyer	U.S. Navy	Sonar Technician

DESCRIPTION OF SCIENTIFIC PROGRAM

Cruise 130-1 took place from August 2 to August 20, 1987, onboard the R/V KNORR; from Bodo, Norway to Reykjavik, Iceland. The primary objectives of this cruise were: 1) to investigate the Mohn's Ridge segment of the Mid-Atlantic Ridge, Norwegian Sea, to determine if any hydrothermal activity is present; and 2) if a high-temperature hydrothermal vent (black smoker) were located, to undertake detailed measurements of all the technical parameters (thermal, physical, chemical, and geological) surrounding the vent area by placing an instrument package on an active vent. The search for hydrothermal activity was conducted using the SeaMARC 1B sidescan-sonar system and the photographic and video images recorded by the ARGO system. SeaMARC 1B is a deep-towed (200 to 300 m elevation above the sea floor) sidescan-sonar system which generates rectilinear plan-view acoustic images of the sea floor in swaths up to 5 km wide (Chayes, 1983). The acoustic sensors of SeaMARC 1B consist of a 27 kHz port and 30 kHz starboard sidescan transducers with a 1.7^0 horizontal beam. The system also contains a 4.5 kHz down looking subbottom profiler. ARGO (Harris and Ballard, 1986) carries three silicon-intensified target cameras having a 12-mm down looking lens, a 24-mm foward looking lens and a 24- to 80-mm down looking zoom lens. ARGO also contains a 35-mm still camera that is capable of collecting 800 high-resolution color photographs, a high-resolution charge-couple device (CCD) electronic still camera, and a thermistor capable of detecting temperature fluctuations of 0.1^0 C. Navigation of the systems was performed using an integrated Loran C - Global Positioning System - transit satellite - bottom transponder system.

Although no black smokers were found, other evidence (including temperature anomalies, sediment thought to be of hydrothermal origin, sediment elutriation features (blow-outs), and a density plume in the water column) suggests that there is ongoing hydrothermal activity in one (Area 1) of the three areas searched (Fig. 1). The ARGO and SeaMARC 1B systems provided sufficient bathymetric, sidescan sonar, and video data to map geologically two areas of the median rift valley (neovolcanic zone) of Mohn's Ridge (Fig. 1, Areas 1 and 3). In this report, we present preliminary ship-tracklines (based on Loran C only) and preliminary interpretation of the video data. Detailed geologic mapping will be conducted in the future (following computer processing of the navigation and sidescan data) by merging the observations made from the video data with the SeaMARC 1B sidescan imagery and bathymetric data.

The strategy used for locating vents was based on current understanding of mid-ocean ridge processes. Since hydrothermal activity is related to the cooling of magma chambers, the search strategy revolved around locating areas of recent volcanic activity and mapping them. Studies of the crestal zone of mid-ocean ridges have noted that segments between transform faults display a series of regional topographic highs (e.g., Lonsdale, 1977; Ballard and Francheteau, 1982; MacDonald, 1982). These topographic highs are thought to be magma injection points: They display abundant volcanic sheet flows of fluid lava, they lack fissures and faults, and they are sites of active hydrothermal processes. The principal sites of investigation during this cruise were two out of seven regional topographic highs within the median rift valley of Mohn's Ridge (Areas 1 and 3), and on an area (Area 2) 47 km north of the Jan Mayen Fracture Zone, that was thought to be a site of recent rifting.

PRELIMINARY OBSERVATIONS

Area 1

Area 1 is located within the median valley of Mohn's Ridge between longitudes $1^{0}05'$W. and $0^{0}05'$E. (Fig. 1). It was mapped using a SeaMARC 1B on-bottom time of about 30.6 hrs, covering about 395 km^2. A detailed search of this area was conducted using ARGO for 106 hrs, covering approximately 108 km of sea floor. The volcanic rock units observed (Fig. 2) from the ARGO video, ship tracklines, and SeaMARC 1B coverage are presented on Plates 1 and 2. We used the percentage of sediment cover to estimate the relative age of the underlying basalt. Sedimentation rates in the study area are approximately 1 to 2 cm/100 yrs (Thiede and others, 1986), thus volcanic rocks which have a negligible sediment cover may be less than 500 years old; if there is no redistribution of the sediment by bottom currents.

The most extensive volcanic rock unit mapped in Area 1 is pillow basalt, analogous to subaerial tube-fed pahoehoe flows (Fig. 3). It has been found that in areas of active volcanism and hydrothermal activity, pillow lavas are less dominant than volcanic sheet flows, analogous to subaerial surface-fed pahoehoe flows (Fig. 4) (Ballard and Francheteau, 1983; ARGO RISE Group, 1987). Therefore, our detailed investigation centered on areas of sheet flows and pillow terranes devoid of sediment. Two other types of volcanic rock units found in Area 1 were rubble lava, similar in appearance to subaerial aa flow (Fig. 5), and volcanic talus (Fig.

6). Rubble lava is composed of blocks of broken pillows of varying size and shape, while talus is composed of blocks being more uniform in shape (round to subrounded) and size.

There are many indicators that Area 1 is an area of waning activity including only minor temperature anomalies, the presence of large colonies of sponges (Fig. 7), sheet flows, sediment that appears to be hydrothermal in origin (Fig. 8) and fresh but not glassy pillow basalts. In addition, a density plume in the water column was identified on the SeaMARC 1B 4.5 kHz subbottom profile (Fig. 9) and a series of possible sediment elutriation structures (Fig. 10) were also observed. A hydrothermal plume is the only reasonable explanation for the water-column density anomaly even though a frustrating ARGO search of the area (Fig. 11) did not reveal the source. The sediment elutriation structures were found in areas with a sediment cover greater than 1 m thick. In these areas, fissures in the underlying bedrock are exposed at the floor of linear depressions in the sediment. It is proposed that these sedimentary structures were caused by hydrothermal seepage coming from the fissures at a flow of sufficient velocity to either blow sediment away from the fissures, or retard sediment accumulation along the fissure. In some cases, the removed sediment was observed to be covering the rippled, bioturbated sediment on either side of the fissure. In other cases, hydrothermal staining surrounded the fissure.

The 35-mm color still-photos collected by ARGO were disappointing, particularly in the areas of suspect hydrothermal deposits. These deposits are typically identified by subtle color differences. Although taken from an altitude of 7 m above the sea floor, a majority of the 35-mm photos were underexposed. The suspected hydrothermal sediment (Fig. 11) was initially recognized by its texture (Fig. 8). This was verified by a yellow staining identified on the 35 mm still-photos, indicating precipitation of sulfur. However, these photographs are too dark for high-resolution reproduction. In addition to the yellow-stained hydrothermal deposit, black sediment was common (Fig. 12). Although this sediment may be an erosional product of the surrounding volcanic rocks, an alternative possibility is that this black sediment is rich in sulfides, another hydrothermal product.

Area 2

Area 2 is located at the SW terminus of Mohn's Ridge at longitude $5^{0}23'$W. (Fig. 1). This study area was abandoned after 5.5 hrs of ARGO on-bottom time in which a 7 km long reconnaissance line was run (Fig. 13).

The area has a bioturbated, rippled sediment cover of 100 percent.

Area 3

The final area investigated, Area 3, is located between longitudes $3^{0}40$'W. and $3^{0}00$'W. in the median rift valley of Mohn's Ridge (Fig. 1) and was mapped using a SeaMARC 1B on-bottom time of approximately 29 hrs, covering about 275 km^2. A detailed search of this area was conducted using ARGO for 56.2 hrs, along about 87 km of sea floor, and an additional 222 km of bathymetric data was also collected. Ship tracklines, volcanic rock units, and SeaMARC 1B coverage are presented on Plate 3.

The volcanic terrane of Area 3 appears extremely similar to that of Area 1, including pillows, sheet flows, large sponge colonies, and fissures void of sediment. The general lack of temperature anomalies, suspect hydrothermal sediment, and greater amount of fissures and faults in the youngest volcanic flows suggest that this area is volcanically and hydrothermally less active than Area 1.

PRELIMINARY CONCLUSIONS

Mohn's Ridge is an area of sea floor spreading and associated volcanic activity (Vogt and others, 1982). As with other mid-ocean ridge systems, the recent or fresh volcanic activity along Mohn's Ridge is discontinuous, both temporally and spatially. The question that remains is, what are the odds of finding a high-temperature hydrothermal vent on Mohn's Ridge? The findings of this cruise suggest that hydrothermal activity has taken place on Mohn's Ridge. The presence of temperature anomalies, sediment elutriation structures in rippled, bioturbated sediment, and a water-column density plume suggest that Area 1 was hydrothermally active at the time of this investigation. Although the evidence suggests hydrothermal activity, the existence of a black smoker on Mohn's Ridge is not guaranteed by the findings of this cruise.

The most debilitating factor affecting this investigation (and future investigations) was the lack of high-quality reconnaissance data. Bathymetry of the study area proved to be incorrect, with an overall variance of 200 m. In order to continue with this investigation, it would be advisable first to identify areas of potential hydrothermal/volcanic activity by means of a regional reconnaissance prior to conducting a detailed search. Although both Seabeam bathymetry and SeaMARC 1B sidescan-sonar surveys would be desirable, a more economical strategy would be to conduct a GLORIA sidescan-sonar survey of the Mohn's Ridge neovolcanic zone. Due to its wide swath-width (approximately 30 km) and relatively fast survey speed (approximately 10 knots), most of the neovolcanic zone could be imaged in a single 30-day cruise. Allowing approximately three months for data processing, sites having a high potential for hydrothermal activity could then be identified from the GLORIA data, thus eliminating the potential of conducting detailed surveys in areas of limited probability.

ACKNOWLEDGMENTS

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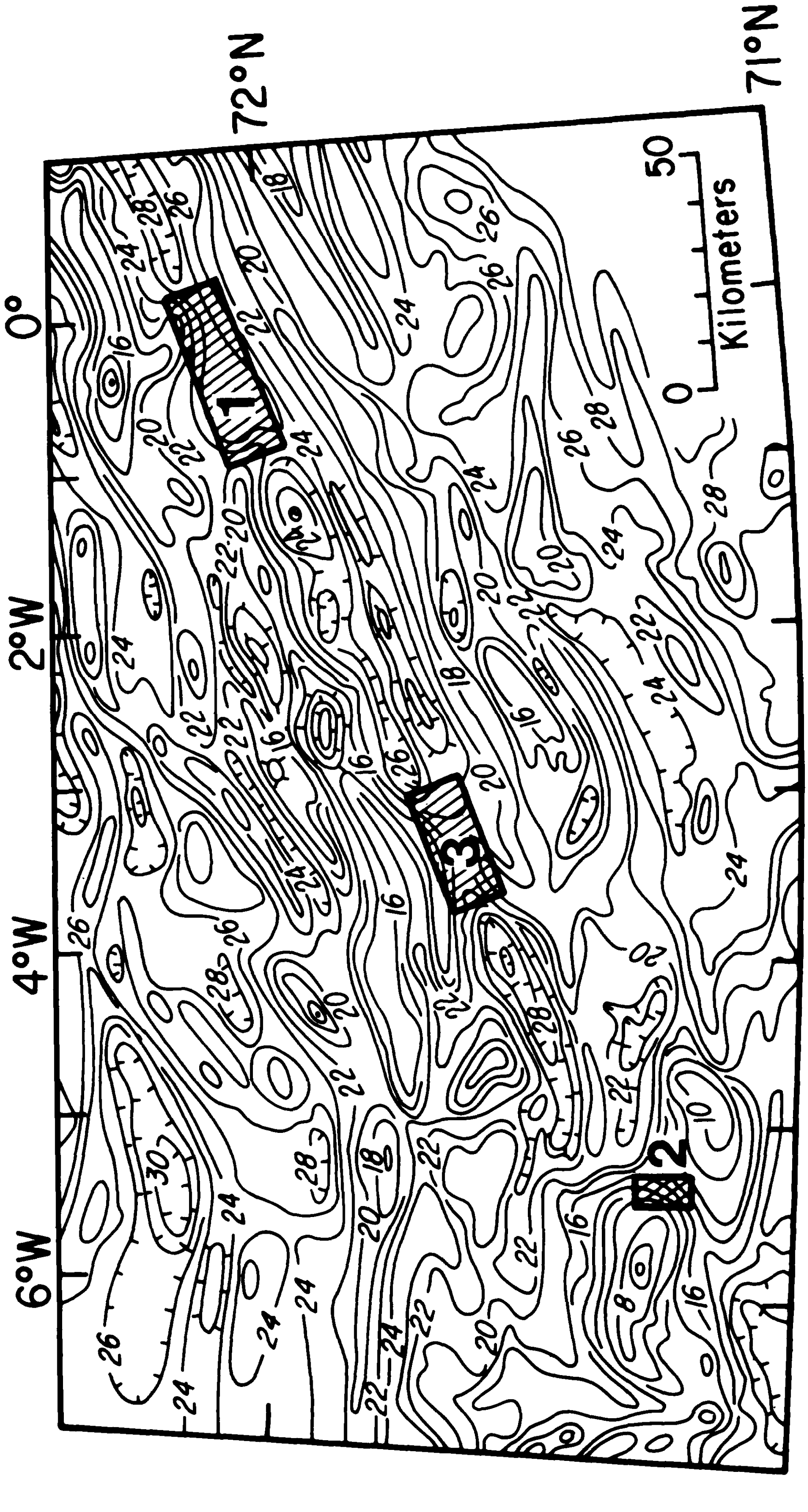

Figure 1. Location map of the three study areas.

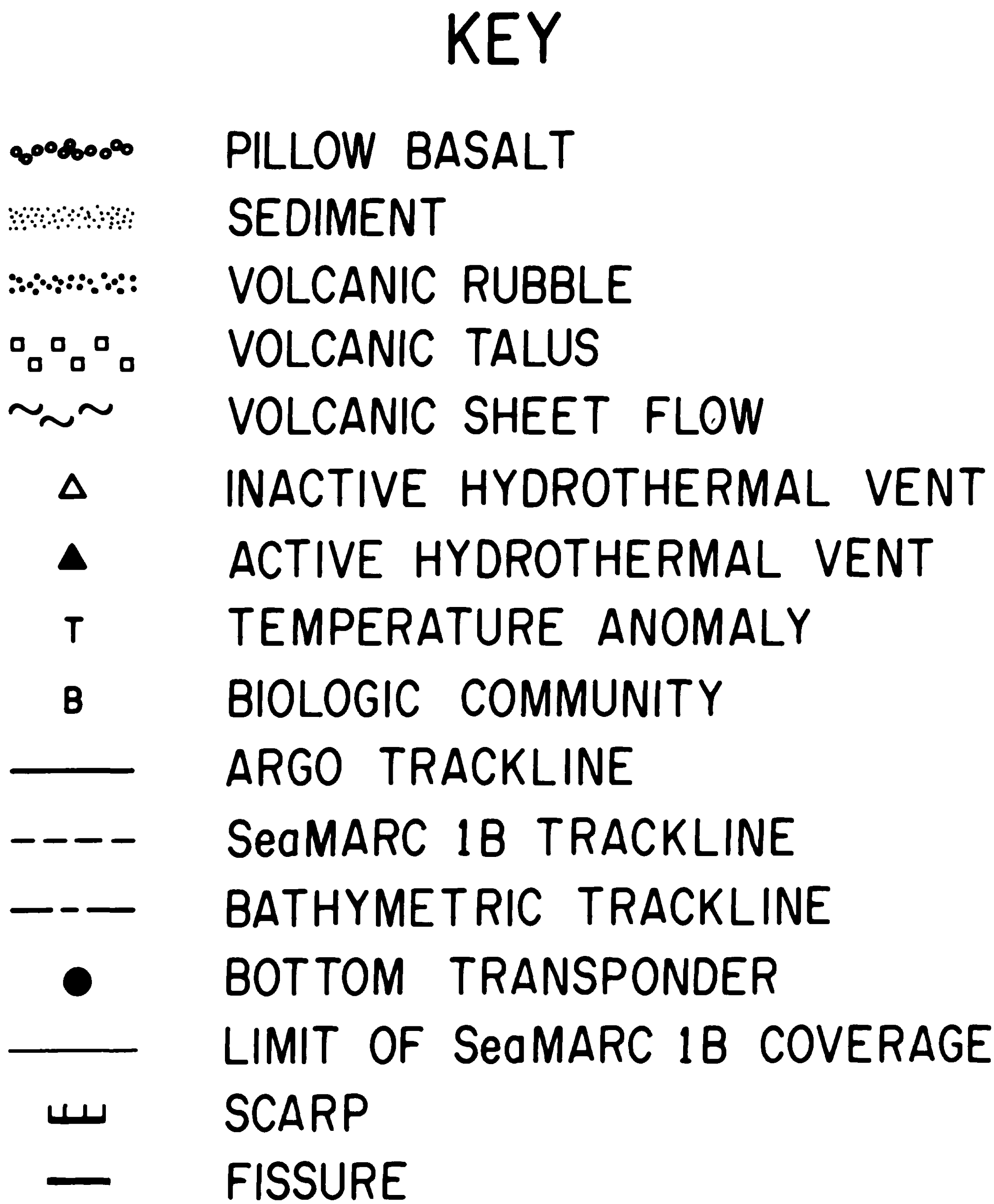

Figure 2. Symbols used in the maps of the study area.

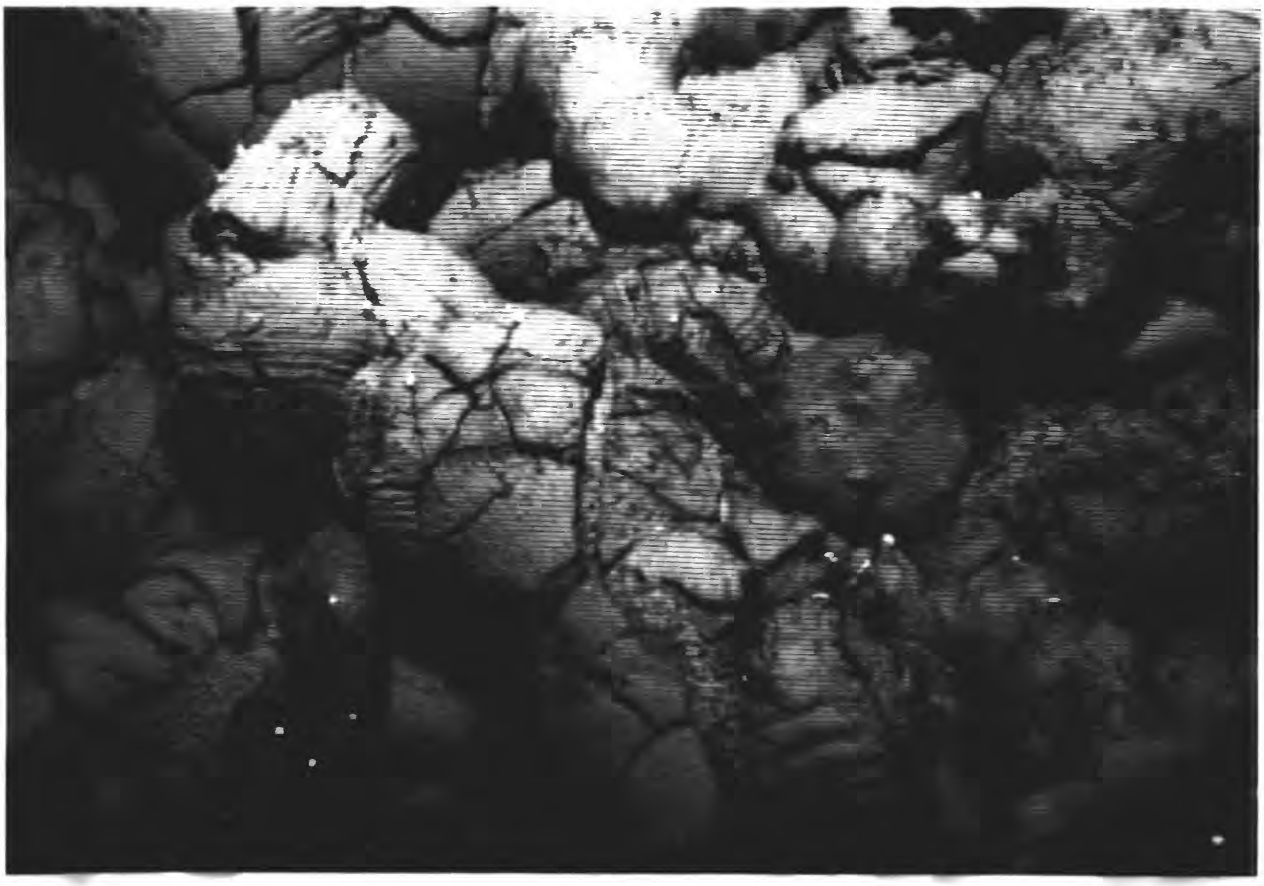

Figure 3. A CCD image of a relatively young pillow basalt. The distance across the image is approximately 17 m.

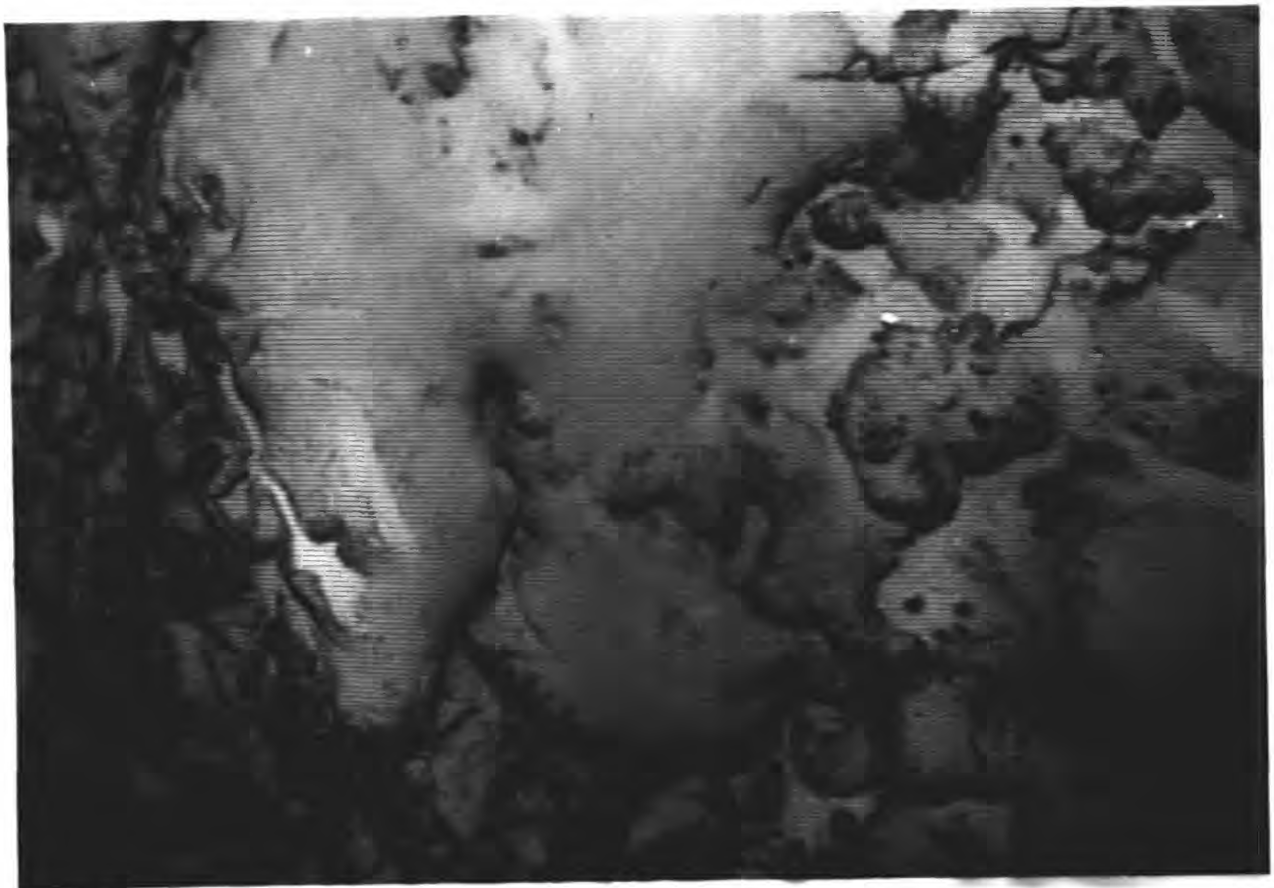

Figure 4. A CCD image of a lobate sheet flow overlapping a rubbly sheet flow. The distance across the image is approximately 17 m.

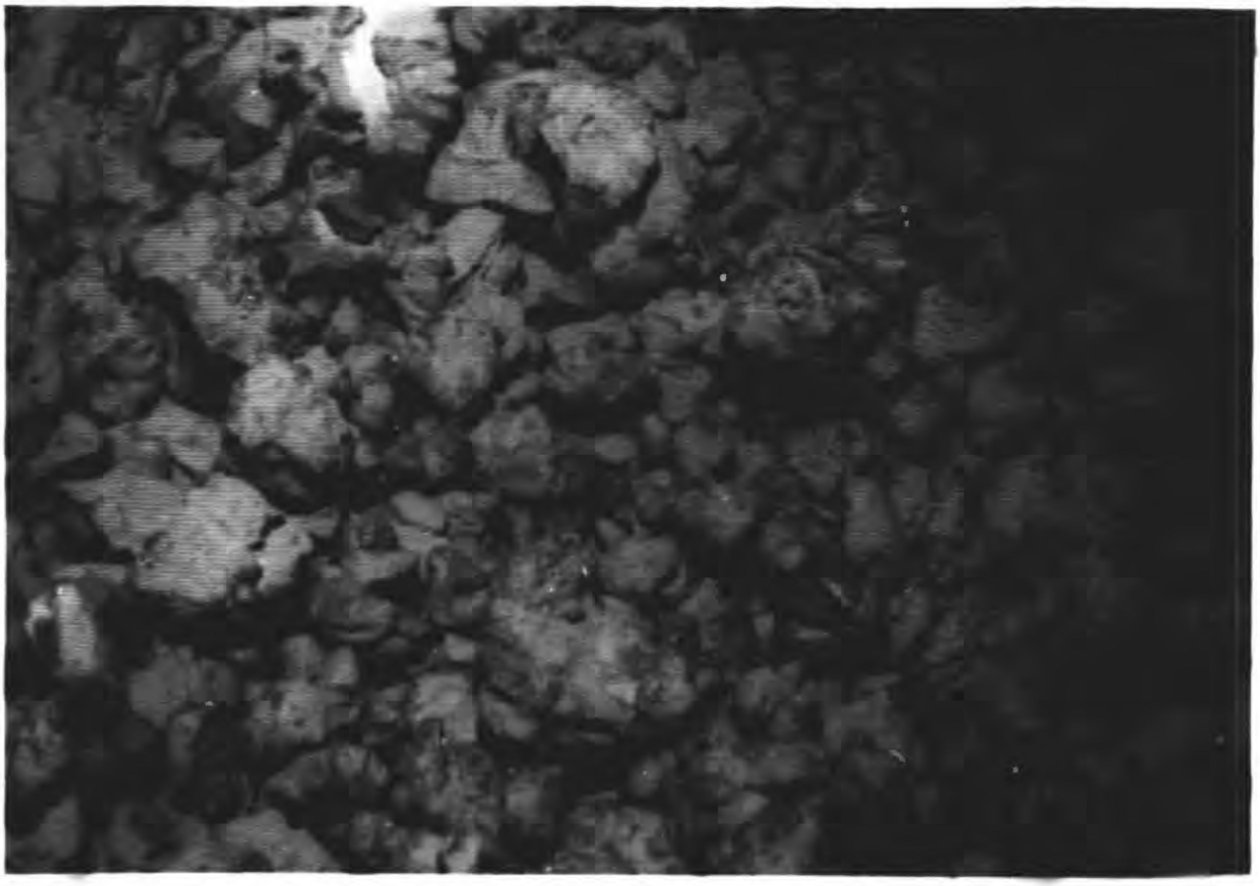

Figure 5. A CCD image of volcanic rubble. The distance across the image is approximately 17 m.

Figure 6. A CCD image of volcanic talus. The distance across the image is approximately 17 m.

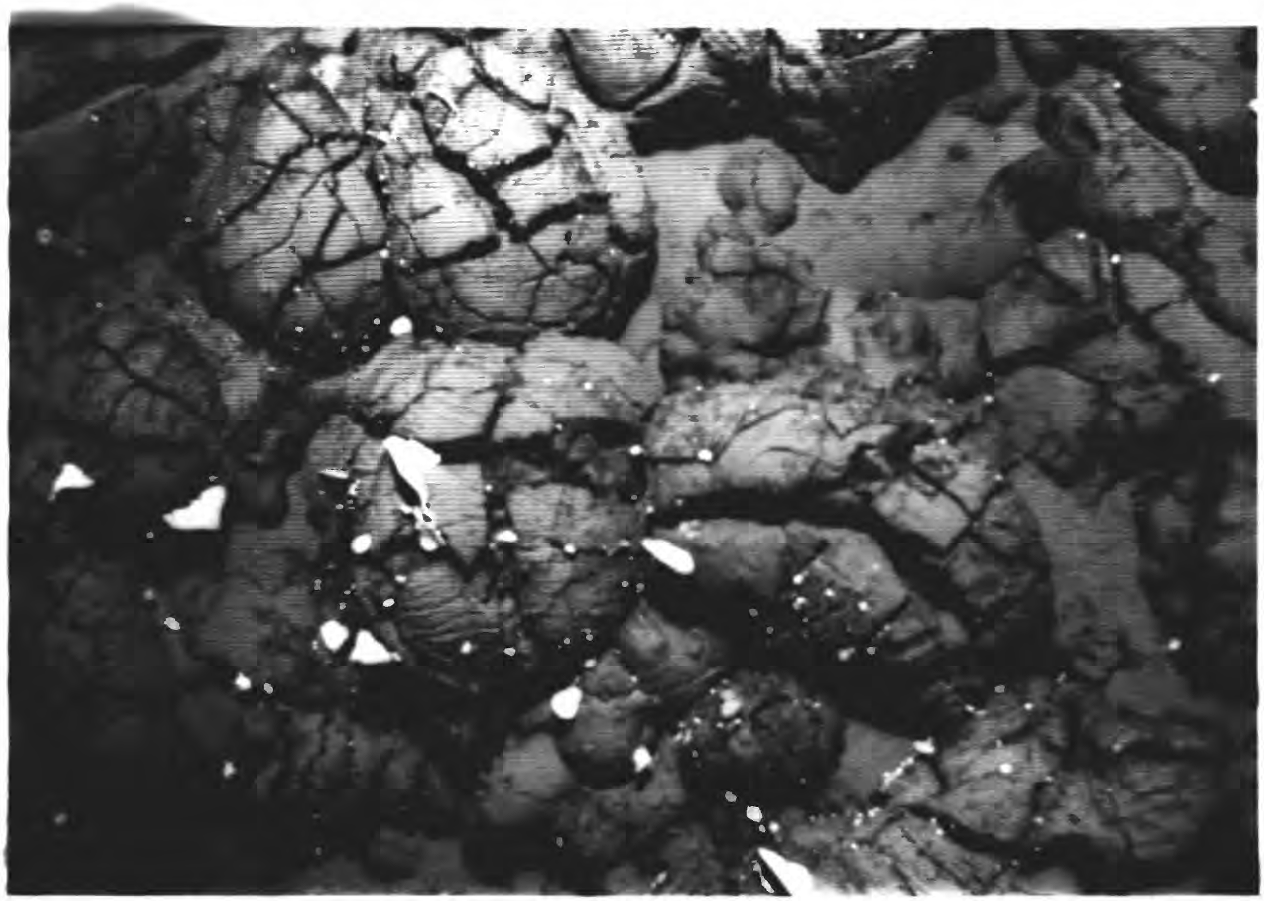

Figure 7. A CCD image of a colony of sponges on pillow basalt. The distance across the image is approximately 17 m.

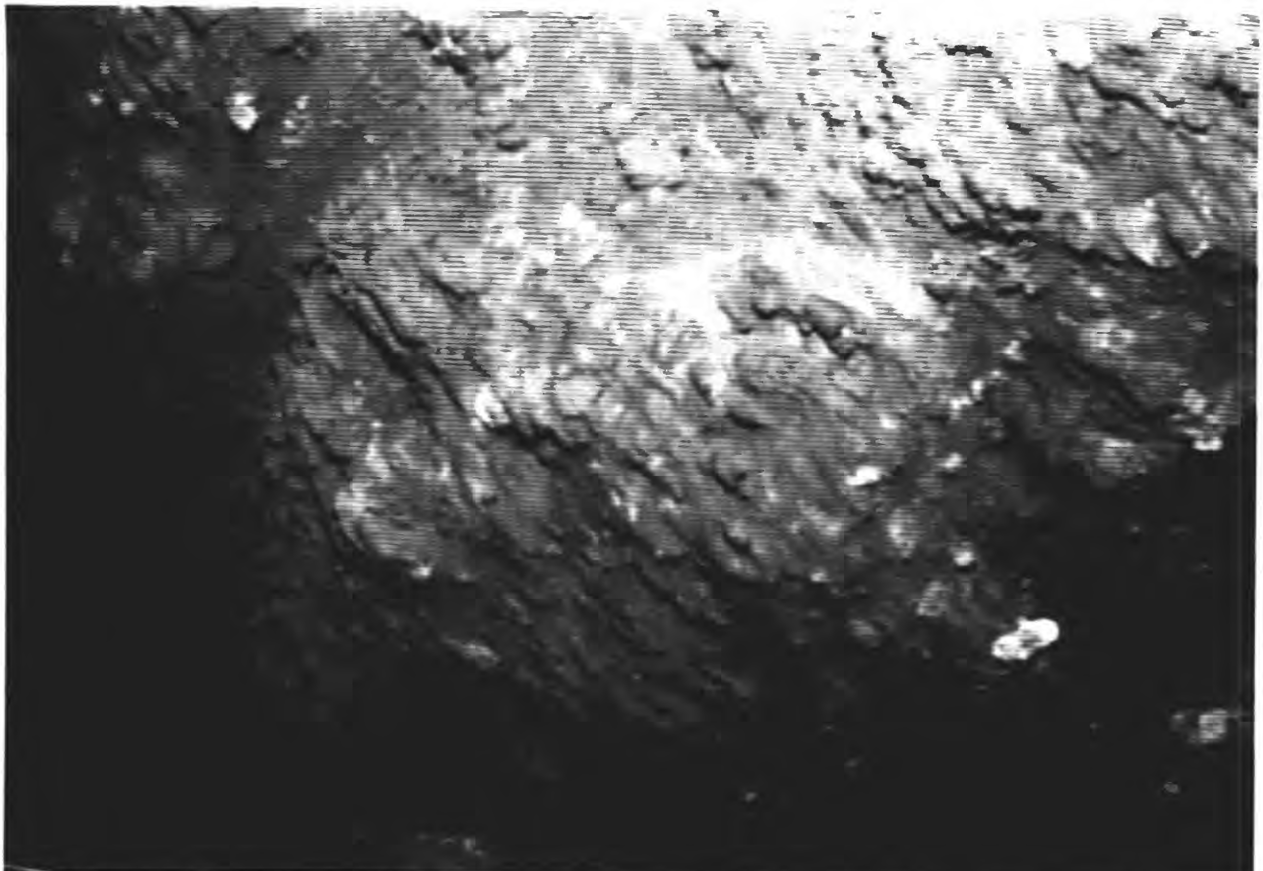

Figure 8. A CCD image of suspect hydrothermal sediment. The distance across the image is approximately 17 m.

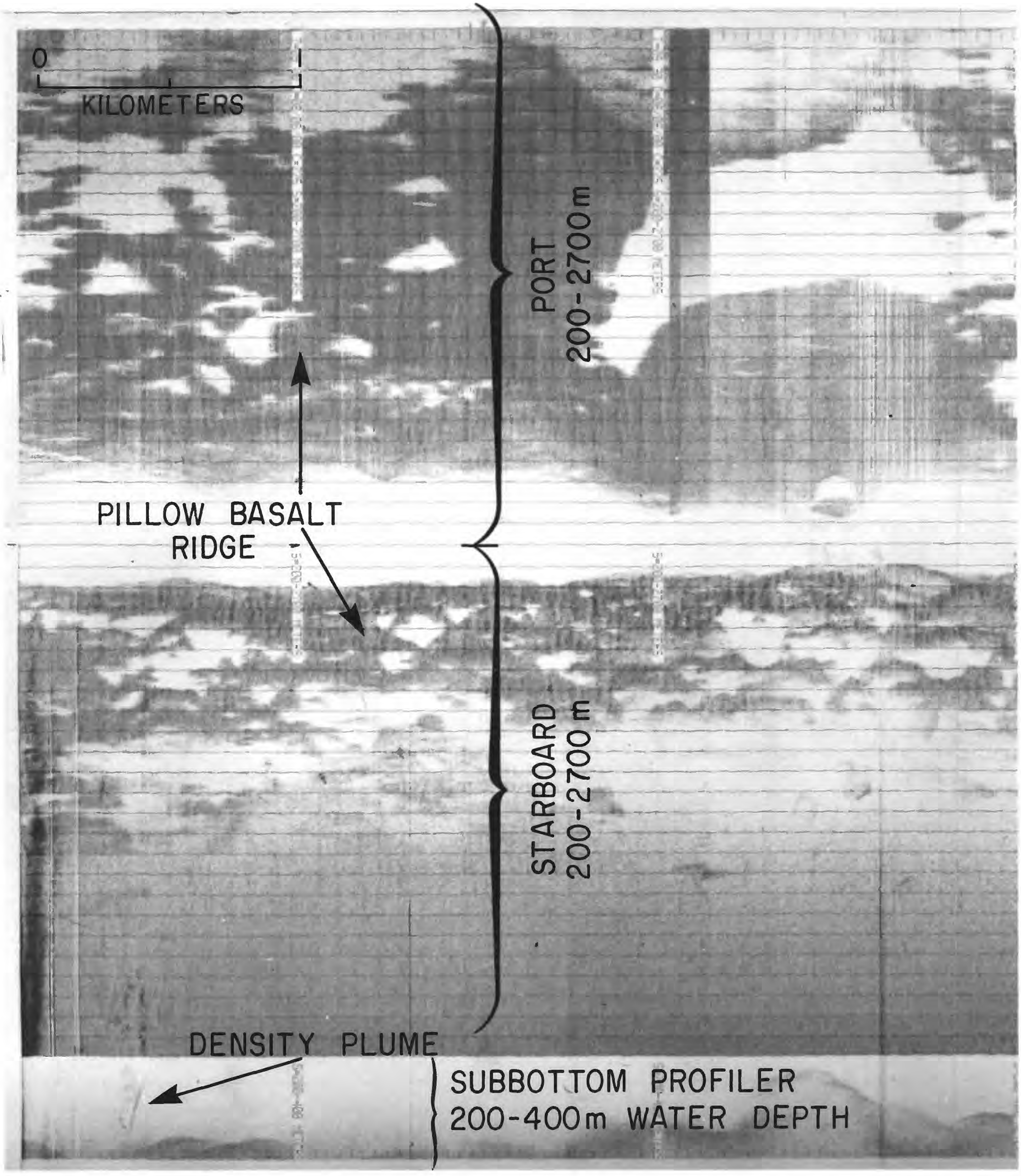

Figure 9. A) SeaMARC 1B sonograph and 4.5 kHz subbottom profile in Area 1. The location of the water-column density plume is shown on Figure 3 (labeled as an active hydrothermal vent).

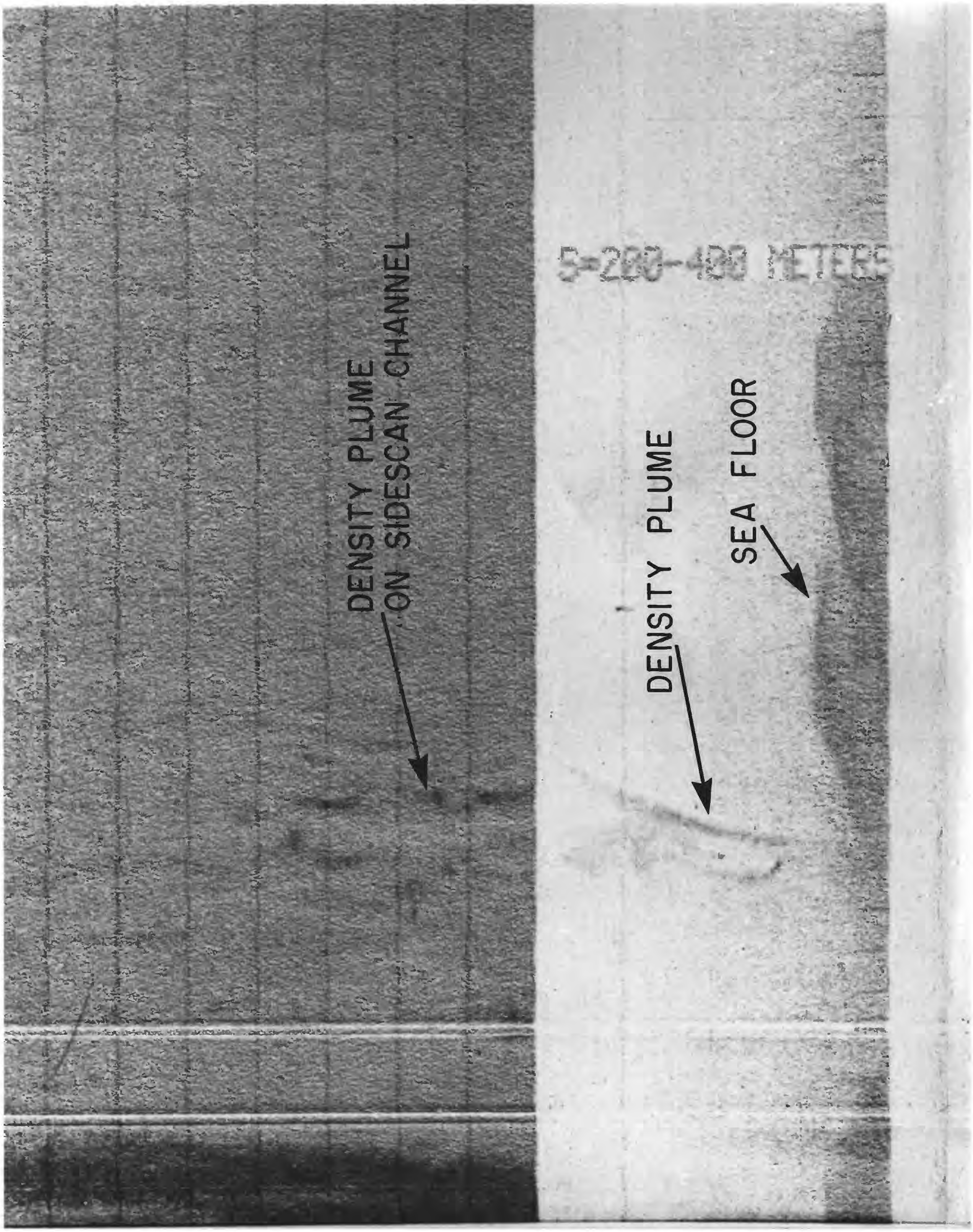

Figure 9. B) Sea MARC 1B sonograph showing a close-up of the water-column density plume.

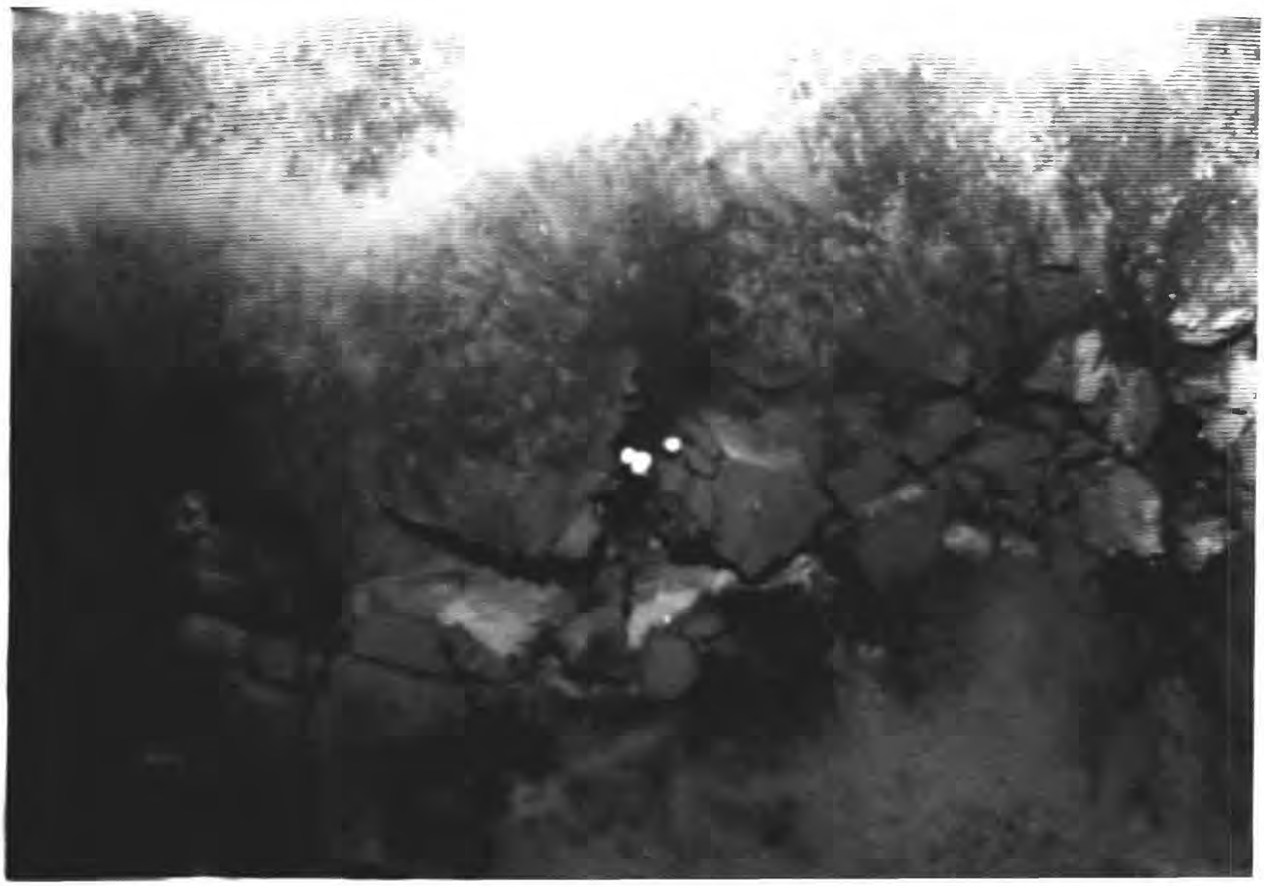

Figure 10. A CCD image of a sediment-elutriation structure. The distance across the image is approximately 17 m.

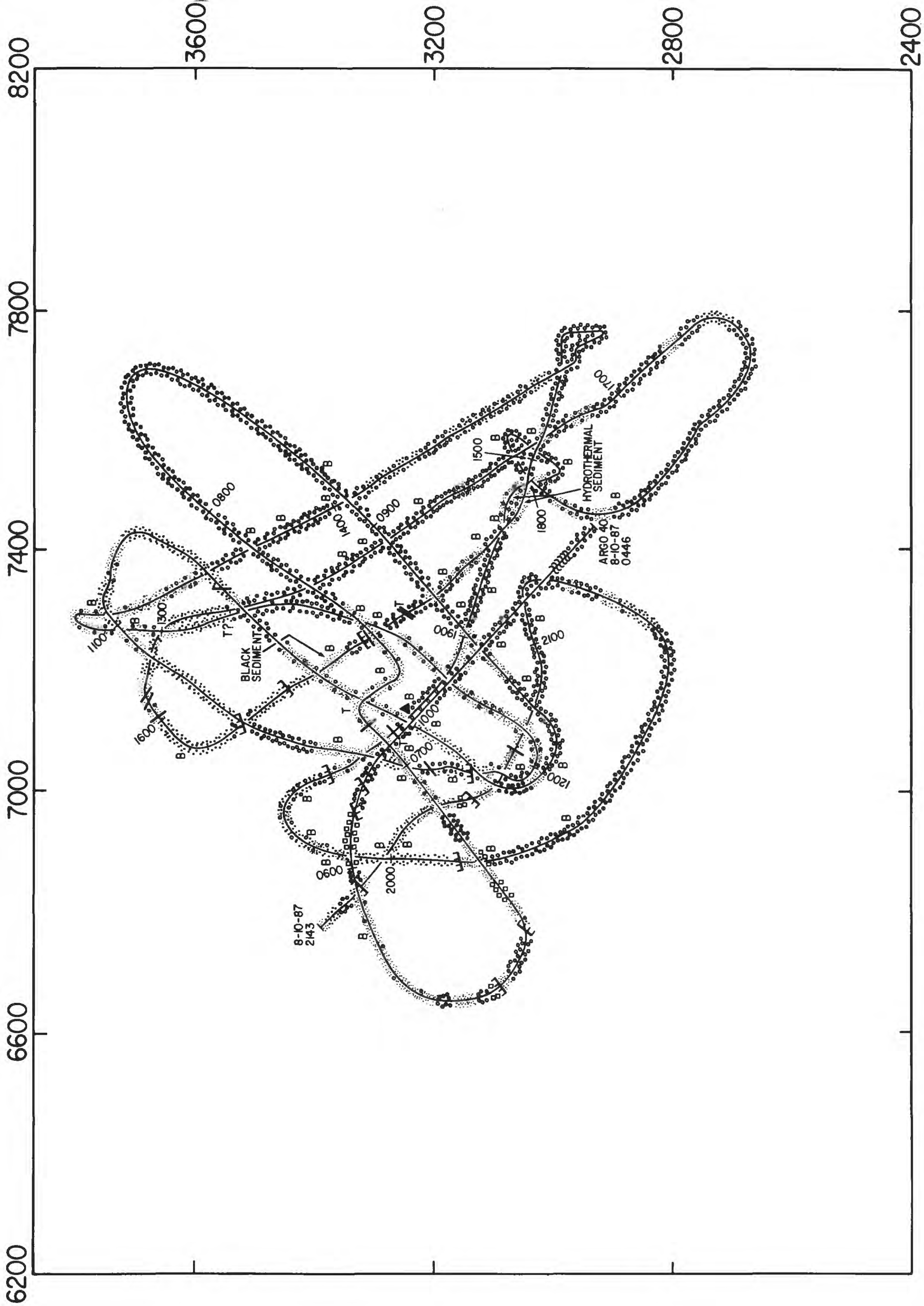

Figure 11. Trackline map of the ARGO vehicle during a detailed search for the cause of the water column anomaly (Fig. 10) in Area 1. An x-y coordinate system in meters is used with x=5000 m and y=5000 m at transponder A (Fig. 3).

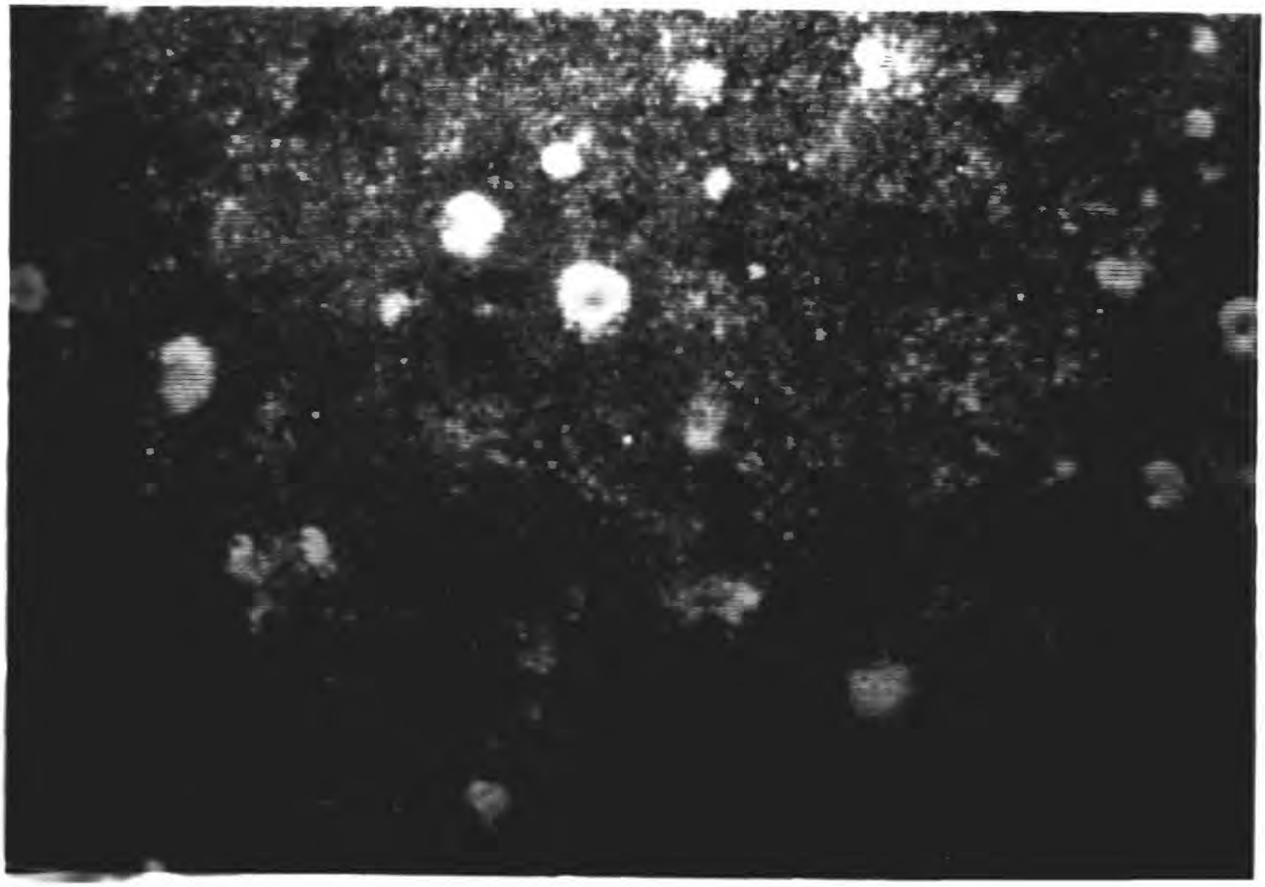

Figure 12. A CCD image of black bioturbated sediment suspected as being hydrothermal in origin. The distance across the image is approximately 15 m.

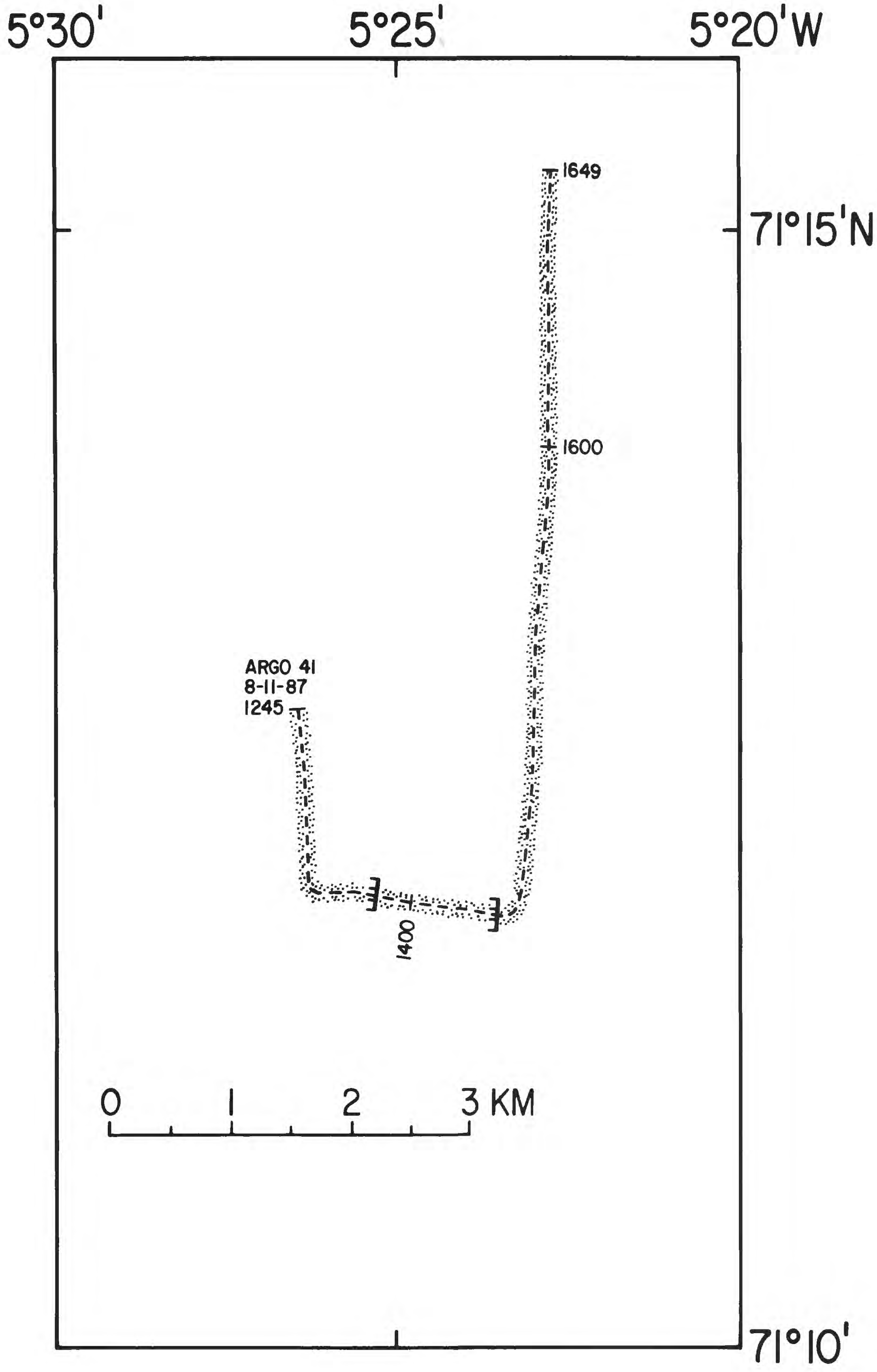

Figure 13. Ship tracklines and preliminary geologic interpretation in Area 2.