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Detection of Barrels that contain Low-level Radioactive Waste in Farallon Island Radioactive Waste Dumpsite Using Side-scan Sonar and Underwater-Optical Systems -- Preliminary Interpretation of Barrel Distribution --

by

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INTRODUCTION

Between 1946 and 1970 approximately 47,800 barrels (55-gallon drums), concrete blocks and other containers of low-level radioactive waste were dumped on the continental shelf and slope adjacent to the Farallon Islands offshore of San Francisco Bay (Noshkin et al., 1978). Three specific sites were chosen for disposal of the drums (Fig. 1). Approximately 150 drums were deposited at the shallow (90 m water depth) site, 3600 at the mid-depth (900 m) site, and 44000 at the deep (1800 m) site. Owing to inclement weather and navigational uncertainties, many of the drums were not disposed of at the specific sites and it is more likely that the drums litter a 1400 km^2 area of sea floor, the Farallon Island Radioactive Waste Dump (FIRWD), defined by the irregular polygon shown in Figure 1 (Noshkin et al., 1978). Consequently, the true location and distribution of the drums on the sea floor is unknown. Not knowing the distribution of the drums has impeded attempts to sample the sediment and biota around concentrations of the drums and to retrieve individual drums for study. An unmanned submersible was used to explore the 900-m site in 1974 and three clusters of drums were located (Appendix I); a barrel was retrieved from this site in 1977 with a manned submersible (Dyer, 1976; Columbo and Kendig, 1990). In order to use submersibles efficiently and to design good experiments to sample from surface vessels and submersibles in the FIRWD, it is necessary to have a map of the distribution of the drums.

Much of the FIRWD now lies within the boundaries of the Gulf of the Farallones National Marine Sanctuary (GFNMS) (Fig. 1). In summer 1990 the National Oceanic and Atmospheric Administration (NOAA) provided funds for the U.S. Geological Survey

(USGS) to survey part of the FIRWD with a sidescan sonar system as part of a major multi-federal agency multi-purpose research cruise (Karl et al., 1990). The purpose of the search was to determine whether the drums could be be detected with sidescan sonar and, if so, to locate clusters of drums and plot their distribution. Other sidescan sonar surveys have been conducted by USGS in the FIRWD, but the purpose of these was not to detect drums. Although these other surveys are mentioned in this report for completeness, only the two surveys conducted in cooperation with NOAA are described in detail.

DATA COLLECTION

Sidescan Sonar

The principal sidescan sonar surveys designed specifically to detect the barrels of low-level radioactive waste were conducted during cruise F7-90-NC in July 1990 (Karl et al., 1990). These sidescan data were collected with the SeaMARC 1A, operated by Williamson & Associates under contract to USGS. SeaMARC 1A is a deep-towed sidescan-sonar system that operates at a frequency of 27 to 30 kHz and that can be towed at speeds up to 5 knots, although speeds of 1.5-3.5 knots are more typical. The USGS supplied the winch, armored conducting cable, and shipboard data acquisition and computer processing equipment for the SeaMARC 1A. The USGS research vessel, FARNELLA, was used for the survey.

Data were collected in a 70 km^2 area around the shallow (90 m) radiation waste site on the continental shelf and in a 120 km^2 around the 900 m site on the continental slope (Fig. 2). The SeaMARC 1A can be set to ensonify swaths of sea floor that are 5, 2, 1, and 0.5 km wide. Narrower swath widths provide greater resolution. The 90 m site was surveyed using a swath of 0.5 km and the 900 m site using a swath of 1 km. Tracks in both areas were spaced so that adjacent swaths overlapped by 10-20% to obtain a continuous sonographic image of each survey area (Fig. 2). Typically the tow vehicle is kept a distance that is 10% of the total swath width above the sea floor for optimum data quality and processing results. Both areas were surveyed in about two days and approximately 15% of the FIRWD was surveyed at these swaths.

SeaMARC 1A was used for two other surveys as part of the multi-federal agency cruise (Karl et al., 1990) (Fig. 2). A survey was done for the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE) over a large part (3300 km^2) of the continental slope with the system set to ensonify a 5-km swath (Fig. 3). This survey incidentally included approximately 60% of the FIRWD. Another survey (200 km^2) was done for the U.S. Navy (USN) with the system set at a 2-km swath that incidentally covered about 10% of the FIRWD immediately north of the 1800-m site (Fig. 2). The 120 km^2 NOAA and 200 km^2 USN surveys are within the boundaries of the 3300 km^2 USEPA survey (Fig. 3).

The USGS collected another set of sidescan data on the shelf and upper slope that included about 5% of the FIRWD with an AMS-120 sidescan sonar, a 120 kHz system, in 1989 (Fig. 3). The 30 kHz and 120 kHz surveys combined mapped approximiately 65-70% of the FIRWD.

The analog signal from the sidescan tow vehicle (both the SeaMARC 1A and AMS-120) was acquired with and stored on a QMIPS data acquisition system manufactured by Triton Technologies, Inc. The data were transferred from the QMIPS to a Masscomp computer for processing (see Danforth et al., 1991 for a description of processing techniques). All geometric and radiometric corrections were done in realtime at sea and a hardcopy record of the processed imagery produced on a Raytheon 850 thermal printer. A true plan-view digital mosaic of each survey area was constructed while at sea (Figs. 4 and 5). Identical features in the zone of overlap on adjacent sonographic swaths were matched and the hardcopy from the thermal printer fixed to a stable base thereby progressively building the mosaic of the sea floor.

Ancillary Geophysical Data

Three types of acoustic-reflection data were collected as part of the SeaMARC 1A survey. Bathymetric data were collected with a 10 kHz acoustic reflection system simultaneously with the SeaMARC 1A data. These data were recorded graphically in analog form on a wet-paper recorder at scan rates of 2 seconds (s). The SeaMARC 1A tow vehicle includes a 4.5 kHz subbottom profiler allowing the simultaneous collection of 4.5 kHz profiles with the sidescan data. Additional subbottom data were collected with a 3.5 kHz seismic-reflection profiler along selected tracks; these data were not collected simultaneously with the sidescan data. Both the 3.5 kHz and 4.5 kHz data were collected at scan rates of 1 s and displayed graphically in analog form on line scanning recorders.

Optical Data

Optical images of the sea floor were obtained along a transect on the continental slope with a remotely operated camera/video system (Fig. 6). The camera system was towed for 4 hours along 4 transects each about 1-hr in duration. The transects were parallel with the isobaths and at a nominal depth of 1000 m. The system consists of a 35 mm still-camera that can be programmed to take photographs at a fixed-interval and a video camera programmed to operate through a VCR. The system is powered by batteries and can operate for up to 5 hours and is towed at speeds of 1-1.5 knots. The system does not provide realtime images of the sea floor.

Navigation

Four systems were used to navigate the ship: (1) Global Positioning System (GPS); (2) LORAN-C, either hyperbolic or rho-rho; (3) shore-based, line-of-sight transponder net (Del Norte system); and (4) long baseline bottom transponder net. The primary system used for real-time positioning was chosen either manually by the navigator or automatically by the computer. Steering of the ship was aided by a trackline-following program displayed on a CRT screen both at the helm and at the navigation station. Positional accuracy of navigation tracks varied between a few meters when within range of the Del Norte or long baseline system to as much as 100 m of the preplotted tracks when using LORAN-C and GPS. The long baseline system was used to navigate only during a small part of the 5-km swath survey.

The navigation coordinates entered into the SeaMARC 1A data acquisition/processing computers were those of the ship's position and not the position of the tow vehicle. The position of the tow vehicle relative to the ship is a function of the length of cable deployed and the speed of the ship. Since we could not range acoustically on the tow vehicle owing to acoustic interference (ship noise), it was necessary to estimate the position of the tow vehicle with respect to the ship. This difference between ship and tow vehicle is called "layback". The shallower the water, the less the layback difference. The positional difference between the ship and the tow vehicle at the 90 m survey site is on the order of 100 m or less, whereas at the 900 m site the difference is on the order of 0.5-1 km. Because of the necessity to estimate layback, specific features on the sonographic mosaics are probably offset from their true geographic position. The amount of offset at the shallow site is within the accuracy of the navigation system used to position the ship (from a few to 100 m). The positional offset of features on the 900 m site mosaic is potentially as large as 1 km. However, we estimate that offsets of 200-300 m are more probable.

SURFICIAL GEOLOGIC SETTING OF THE SURVEYED SITES

The shallow dumpsite is located on a flat (0.2°) area of the continental shelf just east of the shelf break (Figs. 1, 4, and 7)). According to our navigation and bathymetric charts, the site is situated in a water depth of about 105 m. The area around the site is featureless except for a low ridge of outcropping rock to the north (Fig. 4). Based on two grab samples collected near the site, the substrate consists of a uniform blanket of fine and medium sand (Maher et al., 1991).

In contrast, the mid-depth site is located at a depth of about 975 m on the rugged and steep (regional slope of 6° with slopes as steep as 17° locally) upper continental slope (Figs. 1, 5, and 7). The specific location of the site is on the side of a submarine canyon (Fig. 5). Except for the small triangular area on the continental shelf, most of the FIRWD encompasses a rugged terrain that consists of a series of ridges and canyons (Figs. 1, 5, 7, and 8). No cores have been collected immediately adjacent to the 900 m site. The substrate at similar depths (about 1000 m) to the south of the site consists generally of coarse silt (Booth et al., 1989; Karl et al., 1990). Although the slopes are steep in the area of the 900-m site, very little evidence of downslope mass movement of sediment has been detected on the sidescan sonar images and high-resolution seismic-reflection profiles.

DISCUSSION OF RESULTS

Interpretation of Sidescan Sonar Mosaics

The sidescan-sonar mosaics described herein are acoustic images of the sea floor; acoustic energy transmitted from the sidescan tow vehicle is backscattered from the sea floor. These acoustic data have been computer processed so that the mosaics represent a true plan view of the sea floor. That is features on the sea floor seen on the mosaic are in their correct spatial position and their true geometric shape. The shades of gray ranging from black to white that define the features of the sea floor on the mosaic represent varying energy levels of acoustic backscatter. The darker shades correspond to high backscatter levels. Many complex factors determine how sound is backscattered and reflected from the sea floor. Steep slopes and rough bottom are just two elements that backscatter more acoustic energy. We assume that the sidescan sonar is imaging only the surface of the sea bed. This is probably true for the high-frequency systems. However, sound transmitted by the mid- and low-frequency systems is capable of penetrating below the surface of the sea bed under certain conditions. Therefore, some features seen on the mid-range (30 kHz) mosaic may not represent features on the sea floor, but may represent features buried at an unknown depth (typically a few meters) beneath the surface. Consequently, interpretation of the acoustic mosaic is not as straightforward as viewing and interpreting an aerial photograph or satellite image (see Johnson and Helferty, 1990 for a discussion of sidescan sonar). Interpretation of sonograph images is an art as well as a science. Other data sets must be used to supplement and complement the sonar data so that the sonar images can be interpreted as accurately as possible. By so doing, the sonar image can be verified or "ground-truthed". For that reason other data such as high-resolution seismic-reflection profiles, bottom photographs, and sediment samples must be collected in the sidescan sonar survey area.

Resolution, the ability to distinguish closely spaced or small objects on the sea floor, of a sidescan sonar system is a complex function of several variables that include but that are not limited to pulse length, frequency, and pixel size (see summary in Johnson and Helferty, 1990). Fifty-five -gallon drums are very small objects (about 0.6x0.7 m) and theoretically beyond the resolution of a 30 kHz system even at the narrowest swath setting of 0.5 km. However, eventhough a feature is smaller than the theoretical resolution of the sidescan sonar system, the object still can be "detected" with that system and make a visible record on the sidescan sonar image (Johnson and Helferty, 1990). In general, in order for an object to be recorded or recognized as a target on the sonograph, the ambient background level of backscattered acoustic energy should be low and uniform and the acoustic energy backscattered from the object must be sufficiently high so that the object contrasts with the sea floor (see summary in Johnson and Helferty, 1990). When surveying over flat, uniform sea floor, Williamson & Associates have detected 55-gallon drums on numerous occasions with the SeaMARC 1A system (oral communication, M.Williamson, 1990). The acoustic energy from the SeaMARC 1A system excites the modal resonances of many targets which are barrel sized and smaller (oral communication, A. Wright, 1991).

The interpretations in this report are based on visual inspection of the hardcopy sonographic mosaics. Because objects as small as 55-gallon drums are "detected" and not "resolved" with the 30 kHz system, the visible record produced on the hardcopy image is often subtle and indistinct especially in areas of high relief, hard substrate, and coarse-grained or rippled sediment. In many cases it is difficult to differentiate the visible record of the small non-geologic targets not only from small geologic features, such as boulders, but also from noise (acoustic artifacts on the images) on the hardcopy records. The interpretation of the images is as much an art, a culmination of skill through experience, as a science. For example, patterns of objects provide a great deal of information. Consider the following: drums would be either dumped at a fixed location while the vessel is stationary or dumped over a variable straight-line distance as the vessel is transiting. Consequently, the drums would accumulate on the sea floor either in isolated clusters or in linear trends depending upon whether the vessel was stationary or transiting, respectively. Patterns such as these are characteristic of a process and, thus, aid in differentiating among noise, geologic and non-geologic objects. Examples of these patterns are illustrated on Figures 10 and 12.

When the sidescan data are displayed on a CRT monitor, it is much easier to differentiate between targets (real objects on the sea floor) and noise not only visually but also by using several techniques of image enhancement and analysis. With the aid of notes taken while observing the CRT monitor in realtime during the sidescan survey, we have identified several areas on the mosaics that we confidently believe represent clusters of 55-gallon drums (Appendix I; Figs. 9 and 10). Indeed, as discussed below, we verified our interpretation of one area by observing drums on the sea floor with an underwater camera system.

500-m Mosaic

Sea floor conditions are excellent to detect drums at the shallow site. The sea bed is a monotonously flat and featureless blanket of uniform fine and medium sand. Numerous small targets are visible on the sonograph (Fig. 9), many of which we have interpreted as non-geologic. Only 150 drums were reported to have been dumped at this site. The area immediately surrounding the specific dumpsite is devoid of targets. This site is located within a ship transit lane and, undoubtedly, much of the debris on the sea floor represents material thrown overboard from passing ships. Because of this possibility, we did not invest any shiptime to identify targets at this site and do not know if any represent drums of radioactive waste.

Part of this area was surveyed by USGS with an AMS-120 kHz sidescan sonar system in August 1989. The AMS-120 data and SeaMARC 1A data overlap in a 15 km^2 area. USGS provided Williamson & Associates with processed imagery to compare the two sidescan systems with respect to non-geologic target detection. A. Wright (Williamson & Associates) has analyzed the coincident AMS-120 and SeaMARC 1A images for barrel-size targets using modal resonance as a detection and classification aid when inspecting the hard copy sonographs and the images on a CRT monitor. Using this technique, barrel-size non-geologic targets are easily discerned by a skilled operator on the 30 kHz images; many of these targets are poorly discerned or not discerned at all on the 120 kHz records (Wright, 1991). None of these targets were visually verified with underwater camera systems.

1-km Mosaic

Small objects are much more difficult to detect on the rugged continental slope. Ambient levels of backscattered acoustic energy are relatively high and sound paths complex owing to the intricate morphology and steep slopes. Unless a strong signal is received from an object, it may not make a visible record on the sonar image. Even under these non-optimum conditions, numerous small targets were detected on the sonographs (Fig. 10; Appendix I). Many of these are interpreted as 55-gallon drums. This interpretation, however, has been verified at only one location (Fig. 11). This location, a small canyon just to the south of the 900-m dumpsite, was chosen for three reasons: (1)

numerous small objects occur over the area, (2) some of the objects are arranged in a linear pattern, and (3) the sea floor relief is sufficiently subdued so that risk to the underwater camera system is minimal. Five 55-gallon drums were observed with the underwater video/camera system (Figs. 11 and 12). The drums are in various states of deterioration. One of the drums observed on the video tape has imploded in the center. Four of the drums are clustered within a very short distance (100-200 m) of each other. The video system images an area of about 4 m^2. The fact that the camera randomly captured 5 drums in so small a field of view suggests that many more drums were grouped in the area. In fact, a cluster of 28 drums was found in a 30x60 m area during the 1974 survey sponsored by USEPA (Noshkin et al., 1978). Because we could not view the images in realtime, we could not do a detailed search in the vicinity of the 5 drums. The characteristics of the drums observed on the video tape and 35 mm film are consistent with the descriptions of the drums containing radioactive waste reported in the literature (see eg., Columbo and Kendig, 1990) and prove that they are part of the consignment of 47,800 containers of low-level radioactive waste.

As at the shallow site, no large concentration of targets was detected in the immediate vicinity of the specific dumpsite; targets are distributed over the entire 120 km^2 area of the sonograph (Fig. 10). The targets are not distributed uniformly over the area but concentrations of drums are clustered in discrete areas. Most of the visible targets are in canyon floors and on gently sloping plains. Targets likely litter the steep ridge slopes but probably were not detected owing to the high levels of acoustic energy backscattered from the slopes. Many targets were observed in realtime on the waterfall display on the CRT monitor that are not visible on the hardcopy sonographs. For example, an extremely high concentration of targets that cannot be seen on Figure 10 was observed on the CRT monitor in Area 4, a zone of very high acoustic backscatter. Owing to the combination of steep slopes and limited shiptime, we did not attempt to identify these targets with the underwater camera system.

2- and 5-km Mosaics

Most of the 1-km survey overlapped the 5-km survey conducted for the USEPA and the USACE. Although numerous targets are visible on the 1-km mosaic, no targets are visible on the 5-km mosaic in the zone of overlap. Moreover, no targets unequivocally interpreted as 55-gallon drums were observed on the CRT monitor during the 5-km swath survey. Large non-geologic objects were identified on the 5-km mosaic. One target is the SS Puerto Rican and another 270 m long target is possibly the USS Independence scuttled in 1951 or a dry-dock scuttled in 1985 (locations marked with "x" on Fig. 1).

Some large non-geologic (?) targets are visible on the USN 2-km mosaic, but we did not interpret any targets as drums. Apparently, the SeaMARC 1A is not capable of resolving or detecting objects as small as 55-gallon drums when operated at swaths greater than 1 km. More conclusive computer analyses of the data are necessary to verify this conclusion.

CONCLUSIONS

Drums containing low-level radioactive waste that litter the sea floor in the GFNMS are detectable with a deep-towed 30 kHz sidescan sonar system. The surveys of the 90-m and 900-m dumpsites show that the 55-gallon drums are not concentrated at the designated dumpsites, but that the drums and other containers are scattered over a wide area. In order to adequately map the distribution of the drums over the entire FIRWD, it is necessary to survey the entire area with the 30 kHz sidescan operated at a swath width of 1-km or less.

We have verified our interpretation of the sonograph with an underwater camera system at one location. Camera surveys need to be done at other sites not only to verify the sidescan interpretation but also to establish the condition of the drums. These surveys are necessary prior to extensive collection of sediment, water, and biota samples in order to design efficient and rigorous sampling schemes to evaluate confidently the impact the drums of radioactive waste have on the environment.

ACKNOWLEDGEMENTS

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APPENDIX I

Locations (1-6) of probable concentrations of 55-gallon drums of low-level radioactive waste based on interpretation of 1-km swath side-scan sonar mosaic around 900-m dumpsite. Geographic cooridnates are the center point of probable areas of drum concentrations shown on Figure 9. A and B are the locations of clusters of drums observed in 1974 during USEPA sponsored submersible operations (coordinates from Noshkin et al., 1978).

Area number on mosaic	Lat	Lon	
1a	37° 37.33' N	123° 07.18' W	
1b	37° 37.38' N	123° 08.24' W	
2	37° 39.94' N	123° 12.56' W	
3	37° 41.33' N	123° 14.24' W	
4	37° 40.53' N	123° 12.35' W	
5	37° 39.14' N	123° 11.40' W	
6	37° 38.31' N	123° 11.52' W	
A	37°37'57.2" N	123°08'00.8" W	(2 clusters)
B	37°38'02.4" N	123°07'32.9" W	(1 cluster)

FIGURES

Figure 1. Map showing location of the 90-, 900-, and 1700-m dumpsites, the area of the Farallon Island Radioactive Waste Dump (FIRWD), and the boundary of the Gulf of the Farallones National Marine Sanctuary.

Figure 2. Map showing tracks of the four side-scan sonar surveys for NOAA, USEPA, and USN and track of high-resolution profile shown in Figure 8. The NOAA surveys, a 0.5 km swath survey at the 90-m site and a 1-km swath survey at the 900-m site, were designed to search for drums of low-level radioactive waste.

Figure 3. Location of 30 kHz 0.5-km swath mosaic (black lines) and AMS-120 mosaic (gray lines) showing area of overlapping coverage.

Figure 4. Digital sonographic mosaic (0.5-km swath) of the 90-m dumpsite.

Figure 5. Digital sonographic mosaic (1-km swath) of the 900-m dumpsite.

Figure 6. Location of camera transect on continental shelf in vicinity of 900-m dumpsite and high-resolution seismic-reflection (3.5 kHz) profile shown in Figure 8.

Figure 7. Shaded-relief diagram produced using SeaBeam bathymetric data collected by NOAA.

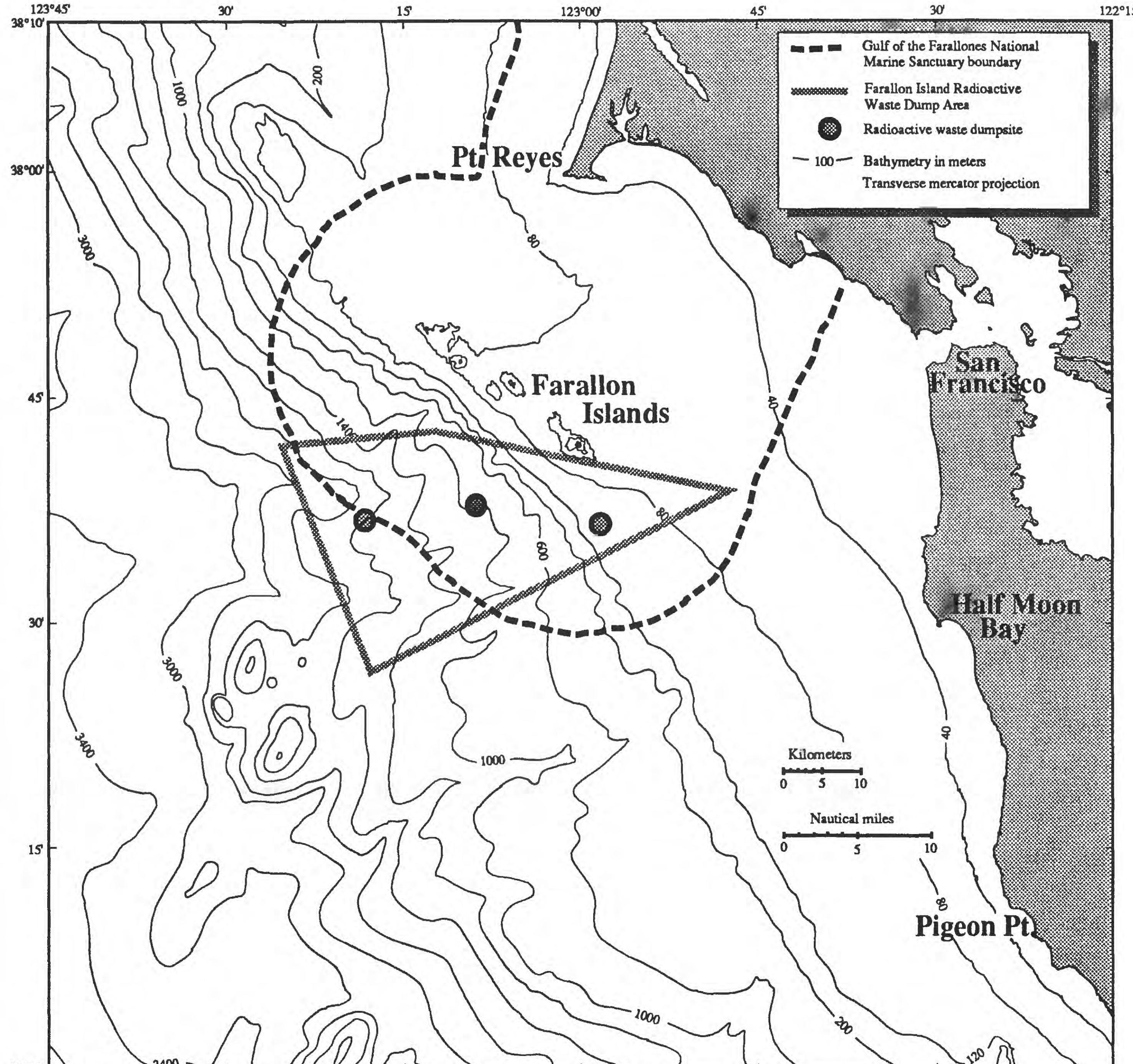
Figure 8. High-resolution seismic-reflection profile illustrating rugged canyon and ridge topography typical of a large part of the FIRWD.

Figure 9. Preliminary interpretation of digital mosaic of 90-m dumpsite area. Solid lines outline areas of coarse sediment or outcropping bedrock; dashed lines outline non-geologic targets that could be barrels. It is not known whether these represent part of the consignment of low-level radioactive waste.

Figure 10. Preliminary interpretation of digital mosaic of 900-m dumpsite area. Numerals identify locations of non-geologic targets interpreted as barrels; letters mark locations of barrels identified by USEPA during previous studies (see text and appendix). Examples of ridges and canyons are shown by dashed and solid lines, respectively.

Figure 11. Location of camera transect superposed on digital mosaic of 900-m dumpsite area. Circles define specific area designated as the 900-m disposal site.

Figure 12. Part of sidescan sonar mosaic obtained on the continental slope adjacent to the mid-depth radioactive waste dumpsite. Small dots within the circled area are 55-gallon drums. The black line from the photograph points to a particularly prominent cluster of barrels. The barrel illustrated is one of the barrels within the circled area, but it is not possible to attribute the photograph to a specific target (barrel) on the sonograph.



123°45'
30'
15'
123°00'
45'
30'
122°15'
38°10'
38°00'
45'
30'
15'
37°00'
Gulf of the Farallones National Marine Sanctuary boundary
Farallon Island Radioactive Waste Dump Area
Radioactive waste dumpsite
100 Bathymetry in meters
Transverse mercator projection
Pt. Reyes
Farallon Islands
San Francisco
Half Moon Bay
Pigeon Pt.
Kilometers
0 5 10
Nautical miles
0 5 10
40
80
120
140
200
600
1000
3000
3400

Figure 1

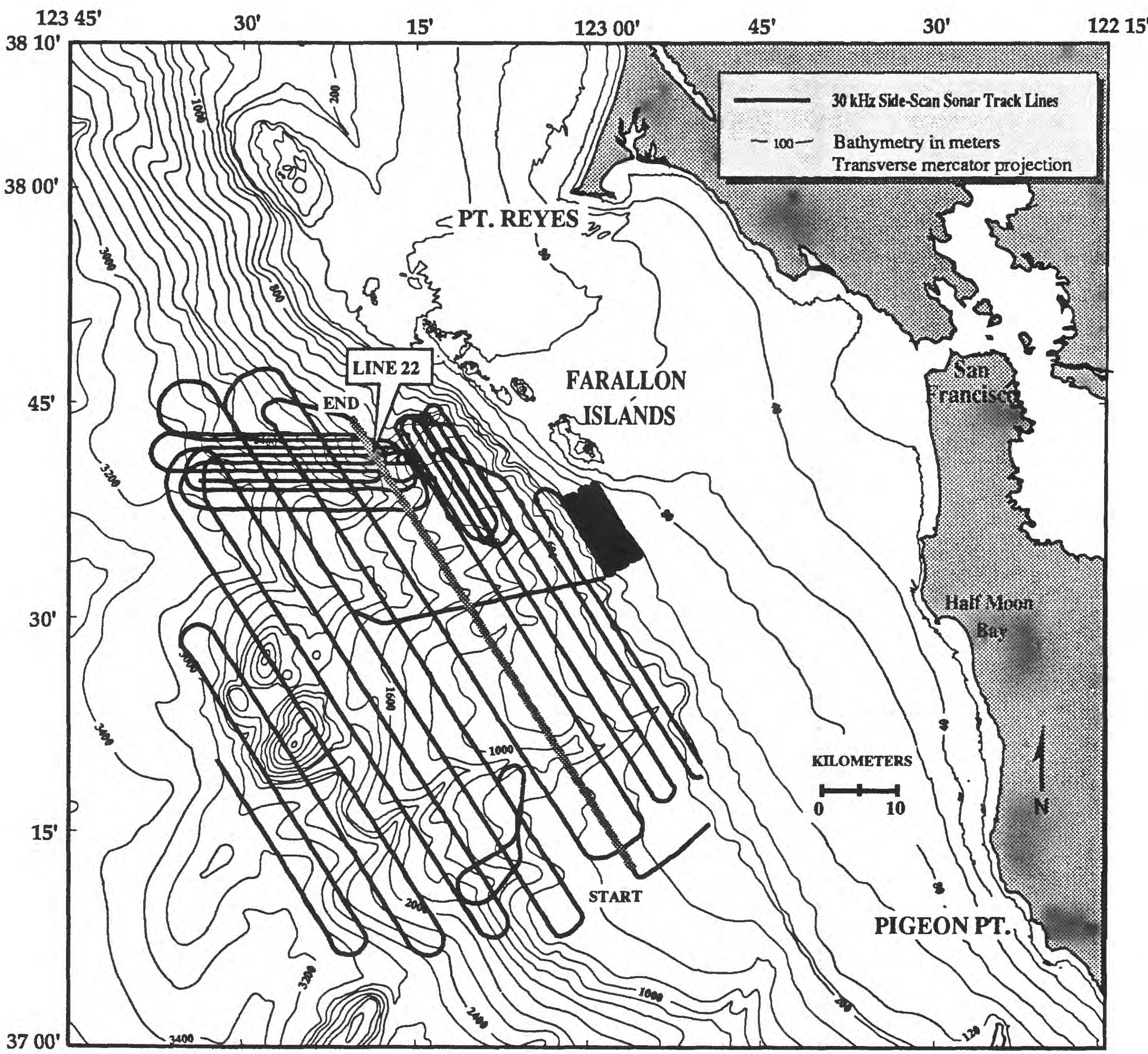

123 45'
30'
15'
123 00'
45'
30'
122 15'
38 10'
38 00'
45'
30'
15'
37 00'
30 kHz Side-Scan Sonar Track Lines
100 Bathymetry in meters
Transverse mercator projection
PT. REYES
LINE 22
END
FARALLON ISLANDS
San Francisco
Half Moon Bay
KILOMETERS
0
10
N
START
PIGEON PT.

Figure 2

Figure 3

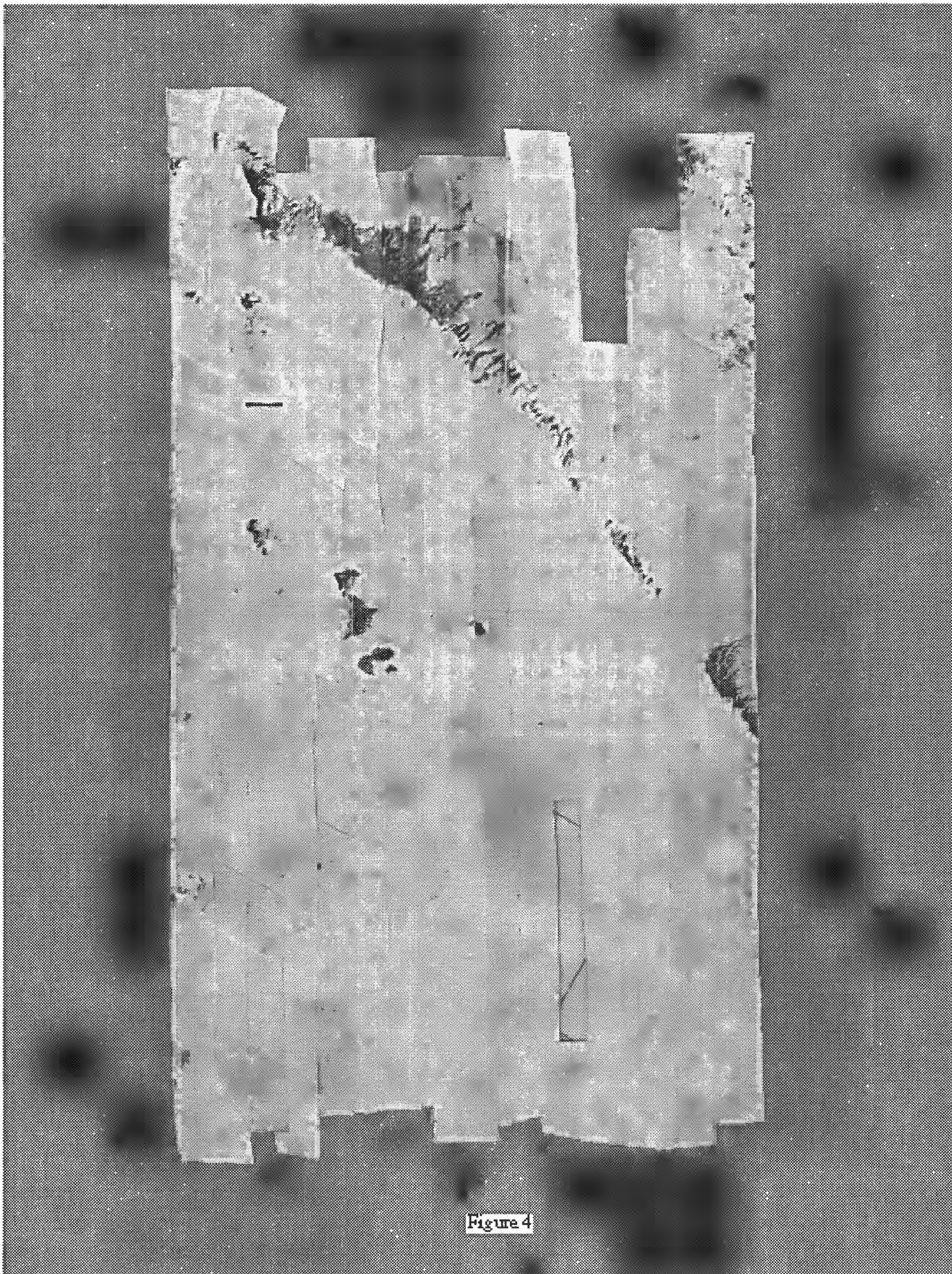


Figure 4

Figure 5

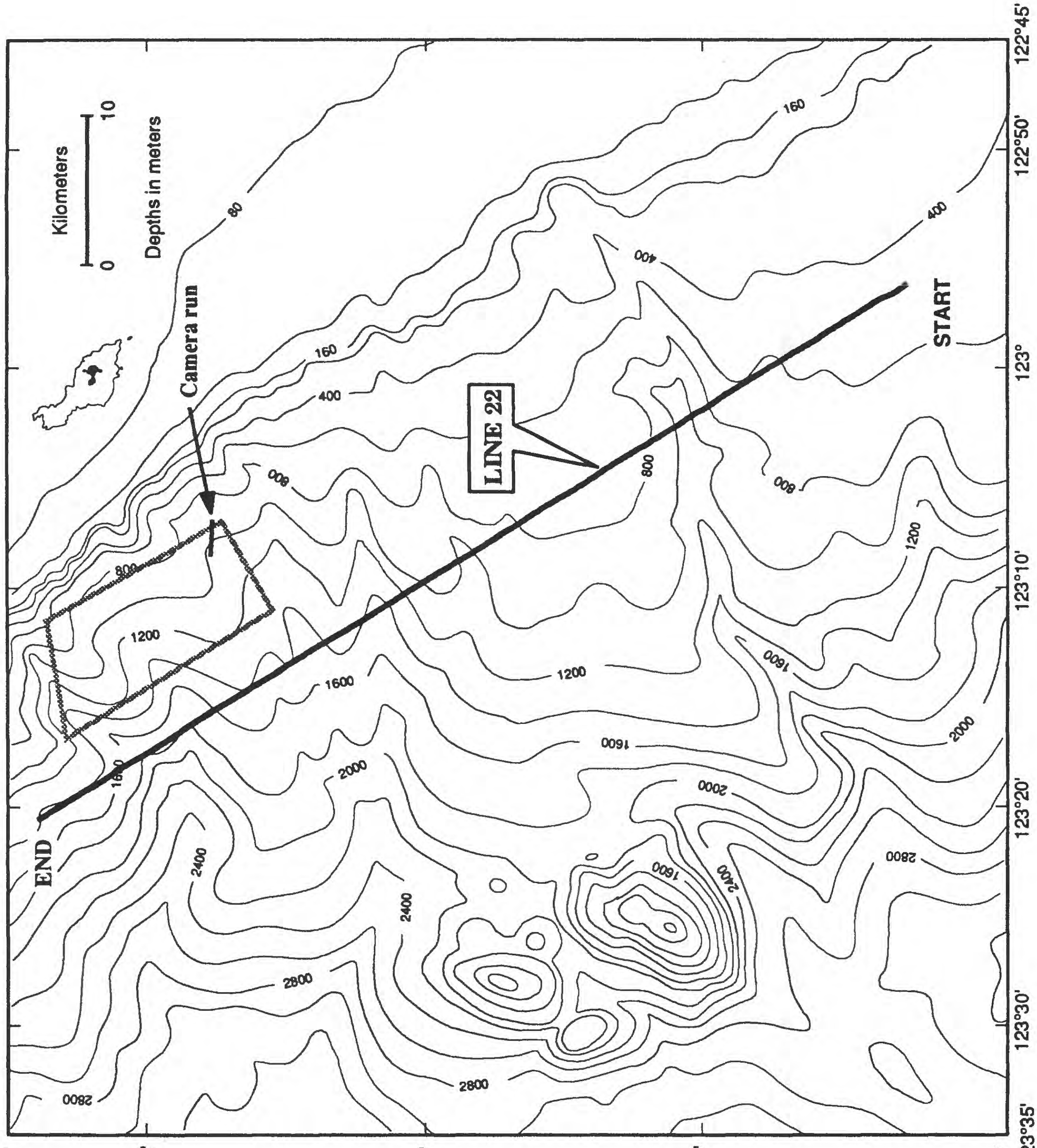

Kilometers
0
10
Depths in meters
Camera run
LINE 22
START
END
80
160
400
800
1200
1600
2000
2400
2800
37°45'
37°40'
37°30'
37°20'
37°9'
123°35'
123°30'
123°20'
123°10'
123°
122°50'
122°45'

Figure 6

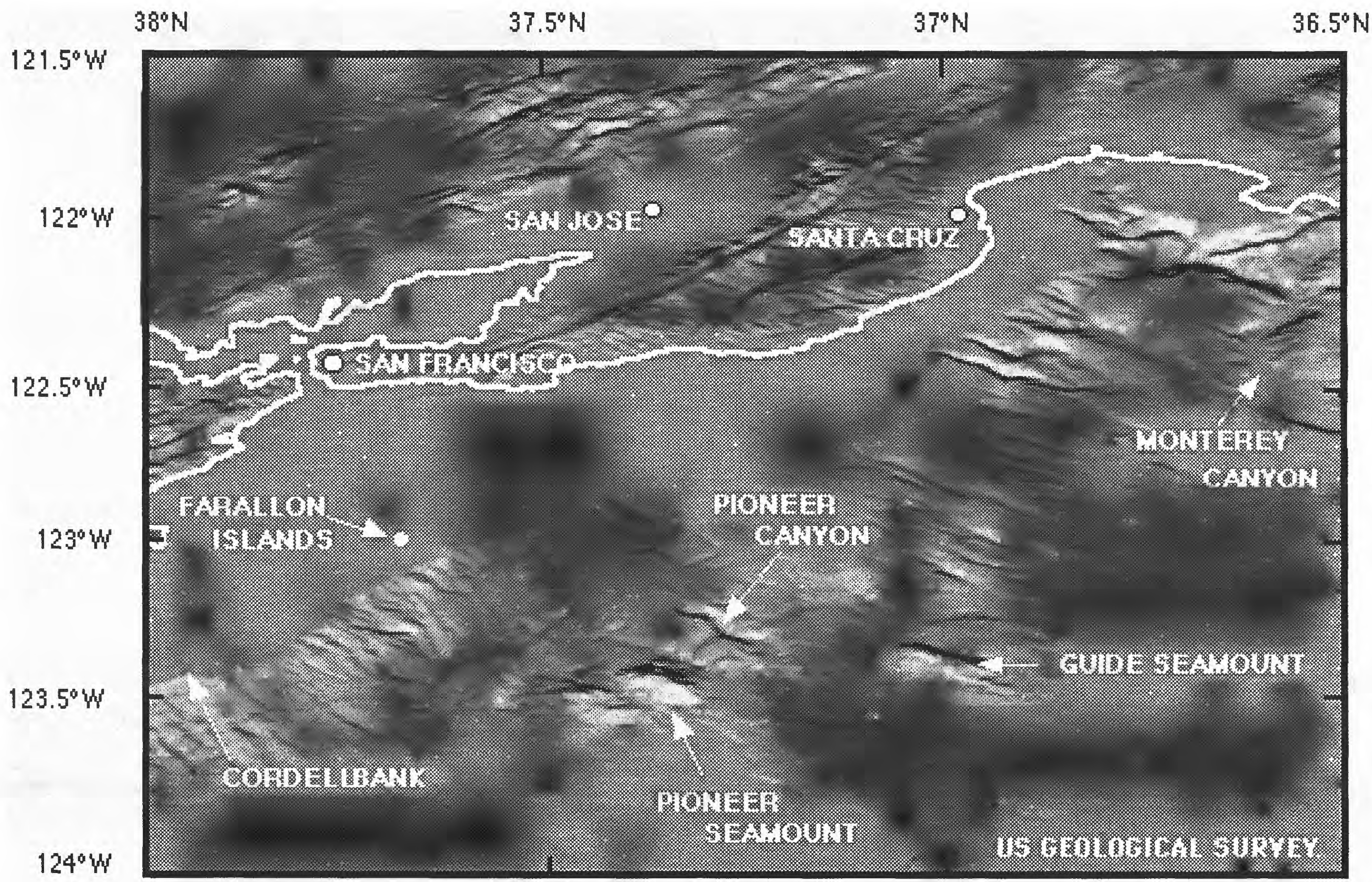

38°N
37.5°N
37°N
36.5°N
121.5°W
122°W
122.5°W
123°W
123.5°W
124°W
SAN JOSE
SANTA CRUZ
SAN FRANCISCO
MONTEREY
CANYON
FARALLON
ISLANDS
PIONEER
CANYON
GUIDE SEAMOUNT
CORDELLBANK
PIONEER
SEAMOUNT
US GEOLOGICAL SURVEY

Figure 7

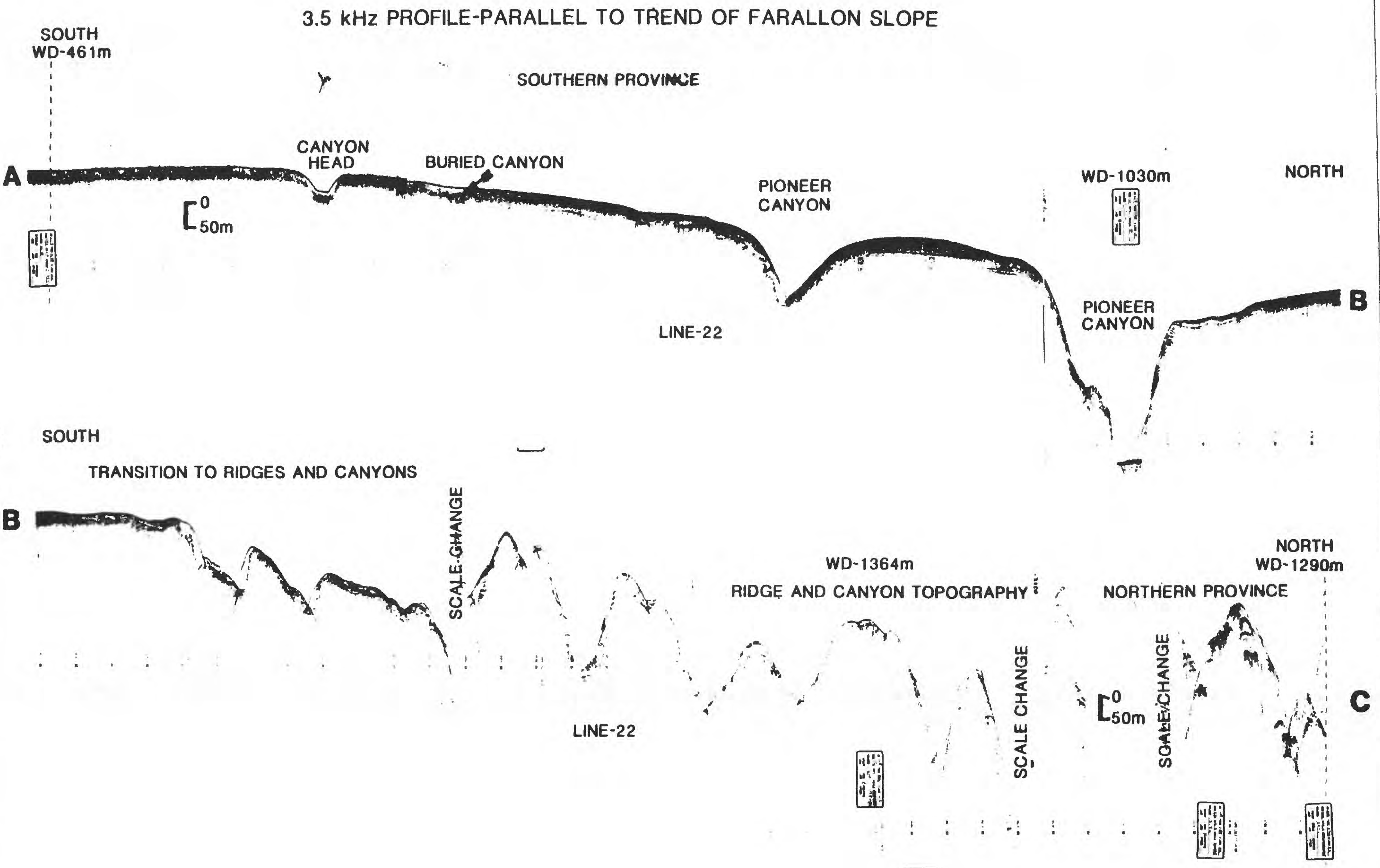

3.5 kHz PROFILE-PARALLEL TO TREND OF FARALLON SLOPE
SOUTH
WD-461m
SOUTHERN PROVINCE
CANYON
HEAD
BURIED CANYON
PIONEER
CANYON
WD-1030m
NORTH
A
B
0
50m
PIONEER
CANYON
LINE-22
SOUTH
TRANSITION TO RIDGES AND CANYONS
B
SCALE CHANGE
WD-1364m
RIDGE AND CANYON TOPOGRAPHY
NORTHERN PROVINCE
NORTH
WD-1290m
SCALE CHANGE
SCALE CHANGE
0
50m
C
LINE-22

Figure 8

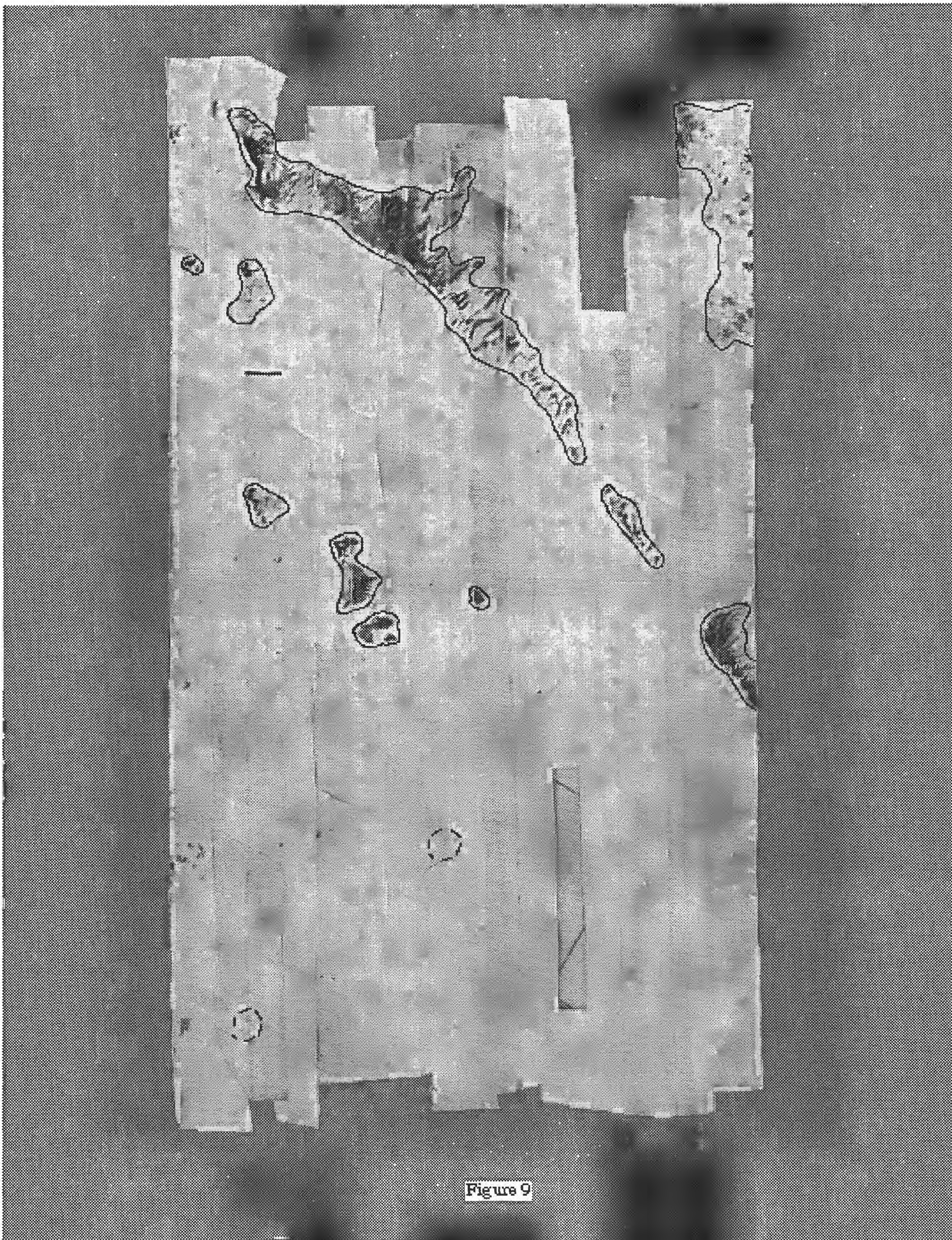


Figure 9

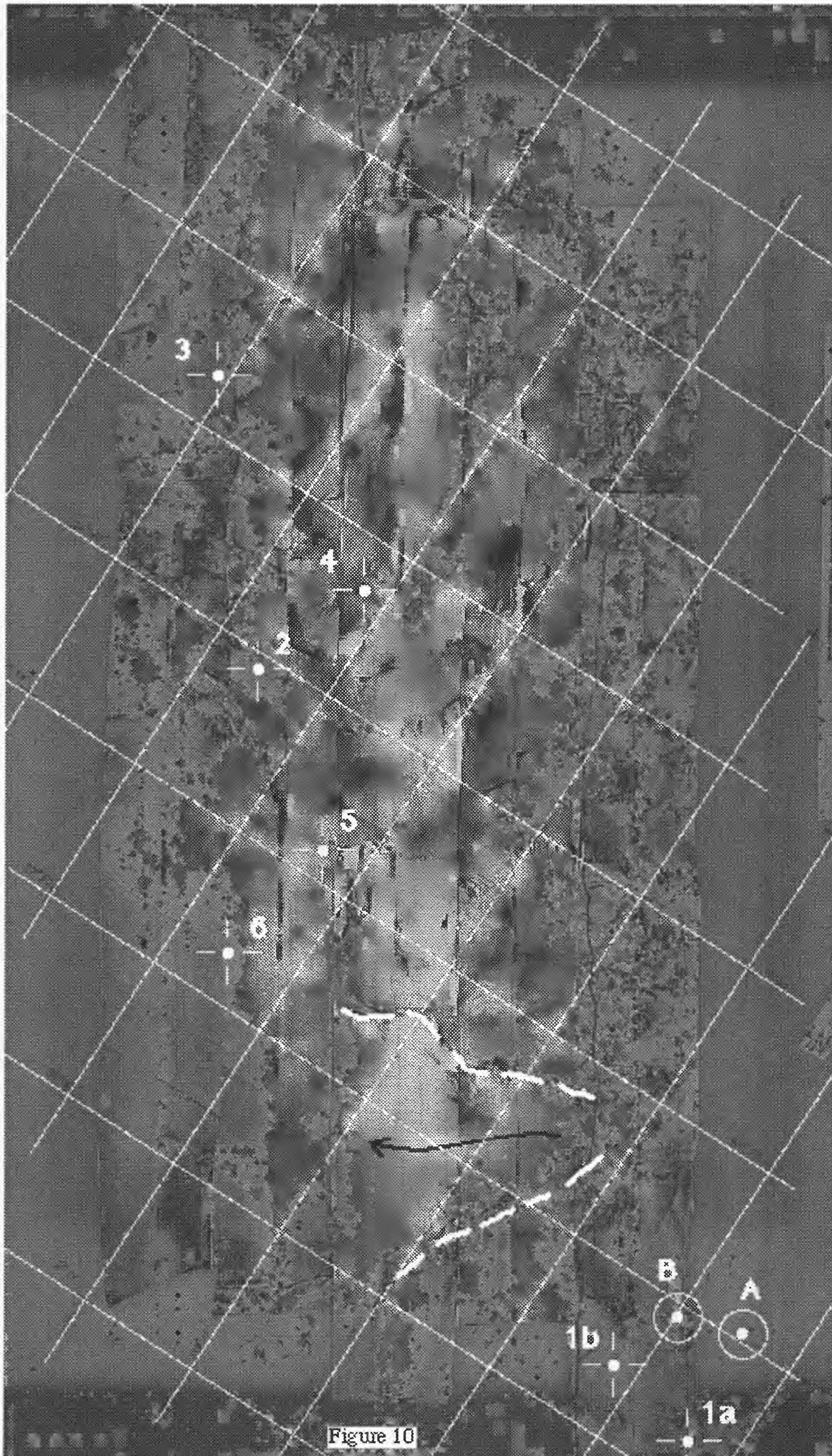

3
4
2
5
6
B
A
1b
1a
Figure 10

Figure 11

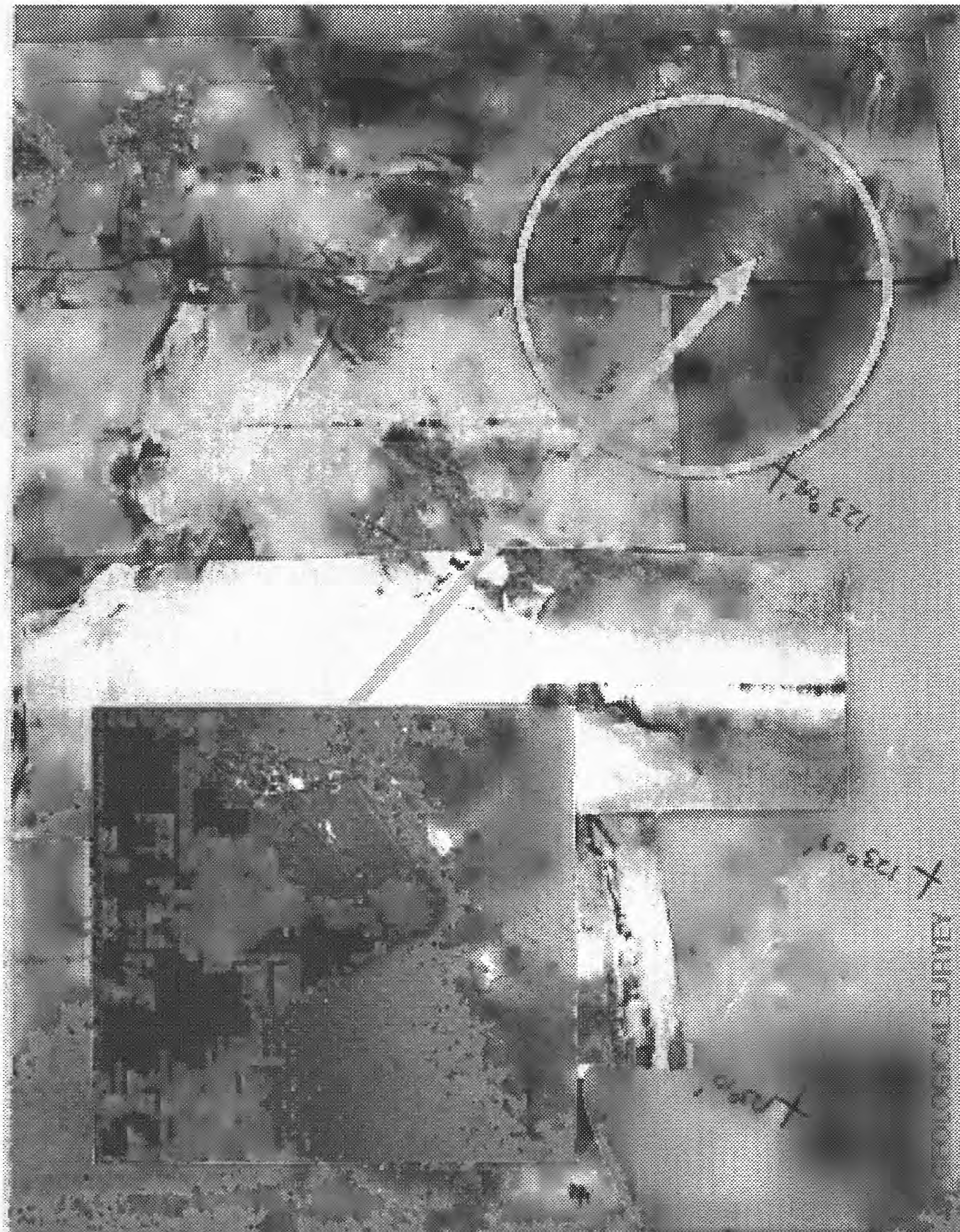


Figure 12