Search for Containers of Radioactive Waste on the Sea Floor

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Summary and Introduction

Between 1946 and 1970, approximately 47,800 large containers of low-level radioactive waste were dumped in the Pacific Ocean west of San Francisco. These containers, mostly 55-gallon (208 liter) drums, were to be dumped at three designated sites in the Gulf of the Farallones, but many were not dropped on target, probably because of inclement weather and navigational uncertainties. The drums actually litter a 1,400-km^2 (540 mi^2) area of sea floor, much of it in what is now the Gulf of the Farallones National Marine Sanctuary, which was established by Congress in 1981 (fig 1).

The area of the sea floor where the drums lie is commonly referred to as the "Farallon Islands Radioactive Waste Dump" (FIRWD). Because the actual distribution of the drums on the sea floor was unknown, assessing any potential environmental hazard from radiation or contamination has been nearly impossible. Such assessment requires retrieving individual drums for study, sampling sediment and living things around the drums, and directly measuring radiation levels.

In 1974, an unmanned submersible was used to explore a small area in FIRWD, but only three small clusters of drums were located. Two years later, a single drum was retrieved from this site by a manned submersible. However, use of submersibles in this type of operation is highly inefficient and very expensive without a reliable map to direct them.

In 1990, the U.S. Geological Survey (USGS) and the Gulf of the Farallones National Marine Sanctuary began a cooperative survey of part of the waste dump using sidescan-sonar—a technique that uses sound waves to create images of large areas of the ocean floor. Because of limited time and funding, the survey only covered about 200 km^2 (80 mi^2), or 15 percent of the waste dump area.

Expert skills are required to distinguish waste drums and other man-made objects from natural geologic features or acoustic noise on ordinary sidescan-sonar images produced onboard ship. USGS scientists developed new techniques for enhancing the sidescan-sonar data from FIRWD to detect waste drums more easily and to distinguish them from other targets with a high level of confidence. Using these techniques, it was also possible to differentiate real targets (drums) from acoustic noise.

The enhanced images from the survey showed the locations of many objects that the scientists interpreted to be radioactive waste containers. In 1994, the USGS, the Marine Sanctuary, and the U.S. Navy used the Navy's DSV (Deep Submergence Vehicle) *Sea Cliff* and unmanned Advanced Tethered Vehicle (ATV) to verify these interpretations by direct observation of the sea bottom. The previous attempts in the mid-1970's to locate waste drums in the Gulf of the Farallones using submersibles had been like trying to find a needle in a haystack and had little success.

Using the enhanced sidescan-sonar images as guides, *Sea Cliff* and ATV were able to "drive" directly from one suspected drum site to the next. In every instance, waste containers and other physical features were found where the enhanced images showed them to be, and no containers were found where they were not indicated.

This was the first successful test of locating barrels by regional mapping and, in that regard, represents a breakthrough. By using the new USGS maps to detect suspected barrel sites and U.S. Navy technology to directly view the sea floor, many barrels and other containers were

found during just a single 24-hour ATV deployment, and each DSV *Sea Cliff* and ATV dive verified the predicted absence or presence of barrels. Visual observations revealed that the condition of the barrels ranged from completely intact to completely deteriorated.

This work proved that enhanced sidescan-sonar images are a cost-effective and time-efficient method for locating relatively small objects on the sea floor and could be used to locate containers of hazardous waste in other ocean areas, such as Boston Harbor in Massachusetts and the Kara Sea in the Arctic Ocean north of Russia.

Besides being the site of a marine sanctuary, the Gulf of the Farallones supports a major commercial fishery. In the past, fear of radiation contamination from leaking drums in FIRWD has adversely affected the market for fish caught in the gulf. In 1998, the actual impact of the drums on the marine ecosystem began to be evaluated. Preliminary results suggest that it is much less than feared (see chapter on Measuring Radioactivity from Waste Drums on the Sea Floor).

Background

Between 1946 and 1970, approximately 150 containers of radioactive waste were supposedly deposited at a shallow site (depth about 90 m [295 ft]), 3,600 at an intermediate-depth site (depth about 900 m [2,950 ft]), and 44,400 at a deeper site (depth about 1,800 m [5,900 ft]). Although these sites are referred to as the 90-m, the 900-m, and the 1,800-m sites, the actual water depths at and around each site vary from these values.

In 1974, an unmanned submersible was used to explore the 900-m site, but only three small clusters of drums were located. Two years later, a single barrel was retrieved from this site by a manned submersible (Columbo and Kendig, 1970; Dyer, 1976). However, use of submersibles in this type of operation is highly inefficient and very expensive without a reliable map to direct them.

In 1981, Congress established the Gulf of the Farallones National Marine Sanctuary (GFNMS), and much of FIRWD lies within its boundaries (fig. 1). In the summer of 1990, the U.S. Geological Survey (USGS) and the GFNMS entered into a cooperative agreement to survey part of FIRWD using sidescan-sonar—a technique that uses sound waves to create images of the ocean floor. This survey was part of a major research cruise in 1991 involving several Federal agencies and was designed to address multiple questions (Karl and others, 1992, 1994). One purpose of the USGS survey was to determine whether sidescan-sonar could successfully detect waste drums on the sea bottom and, if so, to map their locations.

Survey Results

Because of limited time and funding, the search for waste drums was focused on one site, the 900-m site. This site is located at a depth of about 975 m (3,200 ft) on the rugged and steep upper part of the Continental Slope (fig. 2); The steepness of the slope in the area is generally 6° but locally can be as much as 17°. The specific location of the 900-m site is on the side of a submarine canyon. Except for a small triangular area on the Continental Shelf, most of the FIRWD encompasses rugged sea-floor terrain that consists of a series of ridges and canyons (fig. 2). This terrain contrasts markedly with the sea floor to the southeast, which is characterized by a gently sloping, relatively smooth plain (fig. 2). The rugged terrain not only makes it difficult to locate the barrels but also to collect samples and to retrieve individual barrels.

Some of the 3,600 drums of radioactive waste at the 900-m site were dumped one by one from barges and others were dumped as bound 12-drum clusters (Noshkin and others, 1978). On enhanced sidescan-sonar images, fewer than 75 targets (distinctive features) were interpreted as possible 55-gallon drums, but individual drums could not be distinguished from 12-drum clusters. Thus, discrete targets on the images may represent more than one 55-gallon barrel. This interpretation was verified at one site by using an underwater video system (fig. 3). Camera surveys also allow assessment of the condition of the drums to determine whether they are leaking. Five 55-gallon drums were observed with the underwater video system (fig. 4). The drums were in various states of deterioration (fig. 5), and the video tape showed that one of them had imploded in the center (fig. 4).

Expert skills are required to distinguish barrels and other nongeologic targets from geologic features on nonenhanced sidescan-sonar images produced onboard ship. USGS scientists developed new techniques for enhancing the sidescan-sonar data from FIRWD to detect barrels more easily and to distinguish barrels from other targets with a high level of confidence (Chavez and others, 1995). Using these techniques, it was also possible to differentiate real targets (barrels) from acoustic noise (fig. 6). From the enhanced data, USGS scientists have plotted the locations of probable 55-gallon containers over an area of 125 km^2 (50 mi^2) (fig. 7).

As part of the ongoing effort to find barrels of radioactive waste in FIRWD, the U.S. Navy, USGS, and GFNMS pooled their expertise and resources to verify the effectiveness of the new computer techniques developed for enhancing sidescan-sonar images. This interagency partnership used existing U.S. Navy equipment to accomplish new environmental applications. In 1994, a test cruise was conducted using the U.S. Navy deep submergence vehicle (DSV) *Sea Cliff* (fig. 8) and the unmanned Advanced Tethered Vehicle (ATV) to dive to locations of probable 55-gallon containers determined from sidescan-sonar images (fig. 1). The DSV *Sea Cliff* is capable of taking three people (a scientific observer and the pilot and copilot) to water depths as great as 10,000 m (33,000 ft), and the remotely operated ATV is capable of deep-ocean deployments that last as long as 48 hours. Both vehicles have search sonars and video and still cameras.

The combined use of manned and unmanned vehicles contributed to the overall success of the 1994 cruise and verified USGS interpretations of sidescan-sonar imagery from FIRWD. Barrels and other physical features were found without fail where enhanced images had indicated they would be found. This was the first successful test of locating barrels by regional mapping and, in that regard, represents a breakthrough. Without sidescan-sonar "maps" as guides to probable barrel sites, previous attempts to locate the barrels by using submersibles had been unsuccessful. By using the new USGS maps to detect suspected barrel sites and U.S. Navy technology to directly view the sea floor, many barrels and other containers were found during just a single 24-hour ATV deployment, and each DSV *Sea Cliff* and ATV dive verified the predicted absence or presence of barrels. Visual observations revealed that the condition of the barrels ranged from completely intact to seriously deteriorated (figs. 4, 5).

Implications and Conclusions

Besides being the site of a national marine sanctuary, the Gulf of the Farallones study area supports a major commercial fishery. Fear of radiation contamination from barrels in FIRWD has adversely affected the commercial-fisheries market in the past. The actual impact of the barrels

on the marine ecosystem is only beginning to be evaluated; however, it appears to be much less than feared (see chapter on Measuring Radioactivity from Waste Drums on the Sea Floor).

The interagency cooperation among the U.S. Navy, USGS, and GFNMS has provided the technological, scientific, and practical expertise to develop a cost-effective and time-efficient method to locate barrels of radioactive waste on the sea floor. This method has universal application for locating containers of hazardous waste over a regional scale in other ocean areas, such as Boston Harbor in Massachusetts and the Kara Sea in the Arctic Ocean north of Russia. This successful application of military and civilian expertise and technology has provided scientific information that can help formulate policy decisions that affect the environmental management and quality of the ocean.

Further Reading

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Colombo, P., and Kendig, M.W., 1990, Analysis and evaluation of a radioactive waste package retrieved from the Farallon Islands 900-meter disposal site: Environmental Protection Agency Report 520/1–90–014, 65 p.

Dyer, R.S., 1976, Environmental surveys of two deep-sea radioactive waste disposal sites using submersibles, *in* International Symposium on the Management of Radioactive Wastes from the Nuclear Fuel Cycle, Vienna, Austria, 1976, Proceedings: International Atomic Energy Agency Report IAEA–Su/65, p. 317–338.

Karl, H.A., Drake, D.E., and Schwab, W.C., 1992, Cruise narrative, chap. 1 *in* Karl, H.A., ed., Comprehensive geological and geophysical survey of the Gulf of the Farallones region, central California: U.S. Geological Survey administrative report, p. 9–21.

Karl, H.A., Schwab, W.C., Wright, A. St.C., Drake, D.E., Chin, J.L., Danforth, W.W., and Ueber, E., 1994, Acoustic mapping as an environmental management tool; I. Detection of barrels of low-level radioactive waste, Gulf of the Farallones National Marine Sanctuary, California: Ocean and Coastal Management, v. 22, p. 201–227.

Noshkin, V.E., Wong, K.M., Jokela, T.A., Eagle, R.J., and Brunk, J.L., 1978, Radionuclides in the marine environment near the Farallon Islands: University of California, Lawrence Livermore Laboratory Report UCRL–52381, 17 p.

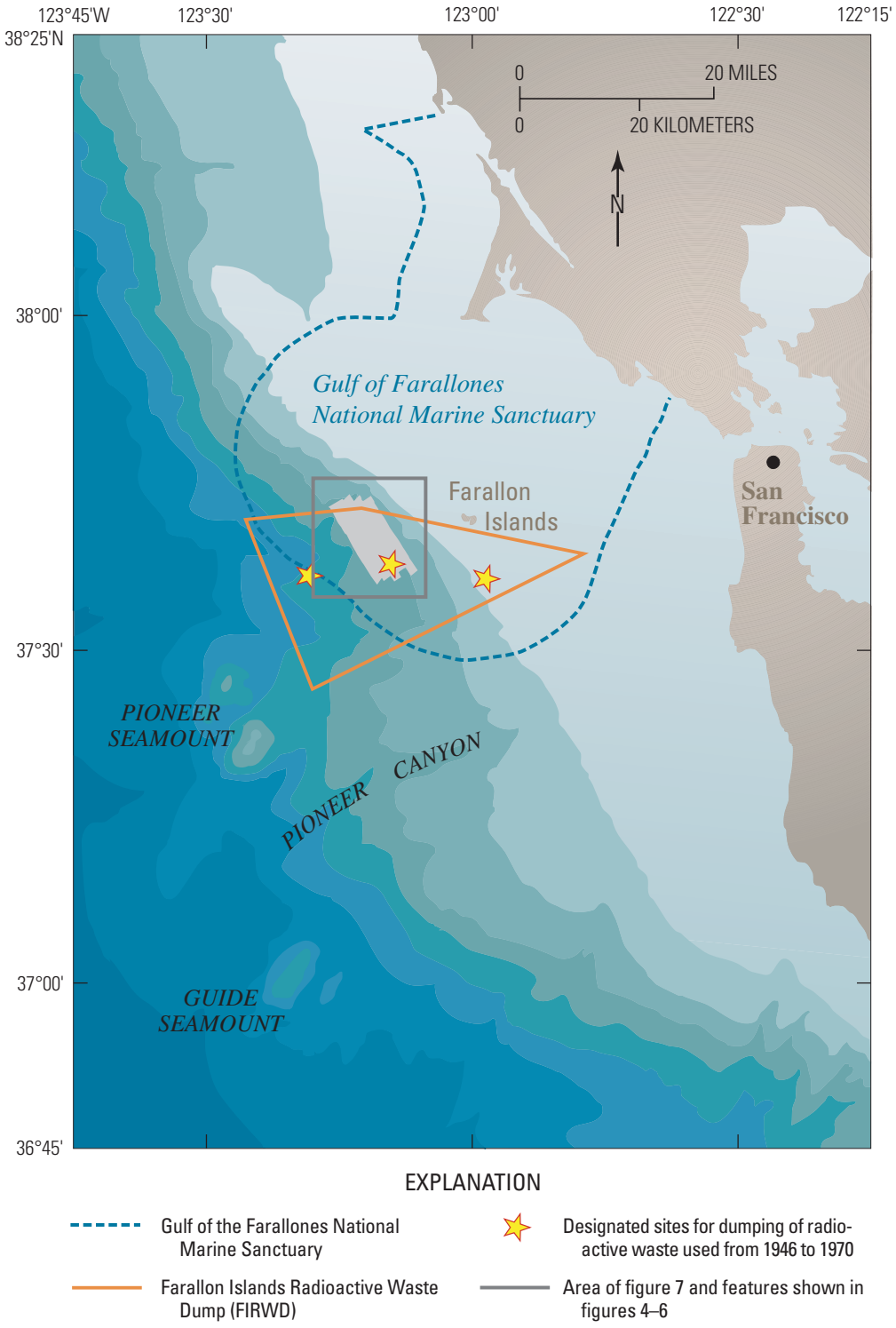

Figure 1. Map of the Gulf of the Farallones, showing areas where radioactive waste containers were dumped from 1946 to 1970.

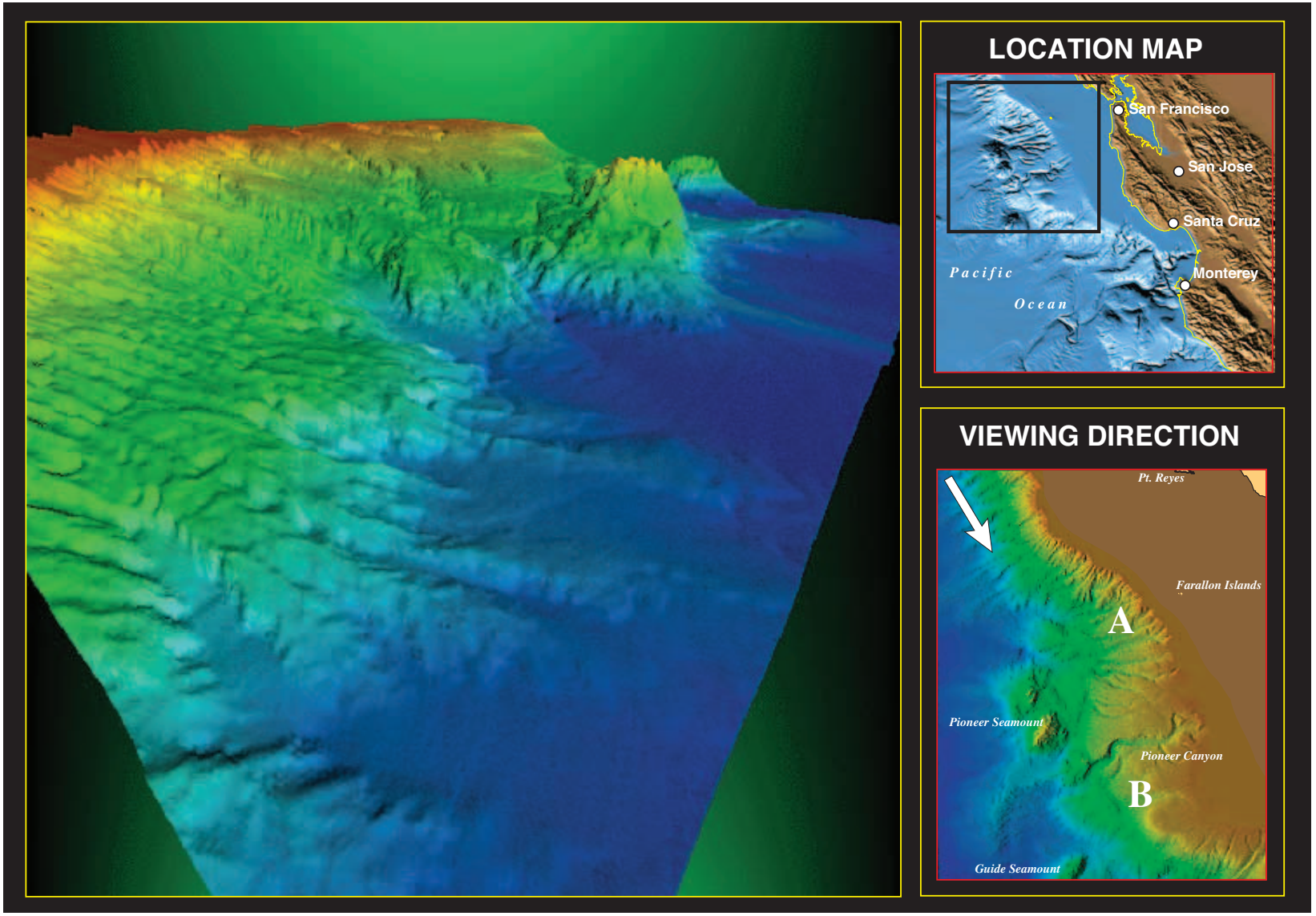

Figure 2. Perspective view of the Continental Slope west of San Francisco, showing rugged terrain around the intermediate-depth (900 m) site used for disposal of containers radioactive waste from 1946 to 1970. The rugged terrain of this area (A) contrasts with the gently sloping, smooth terrain farther south (B).

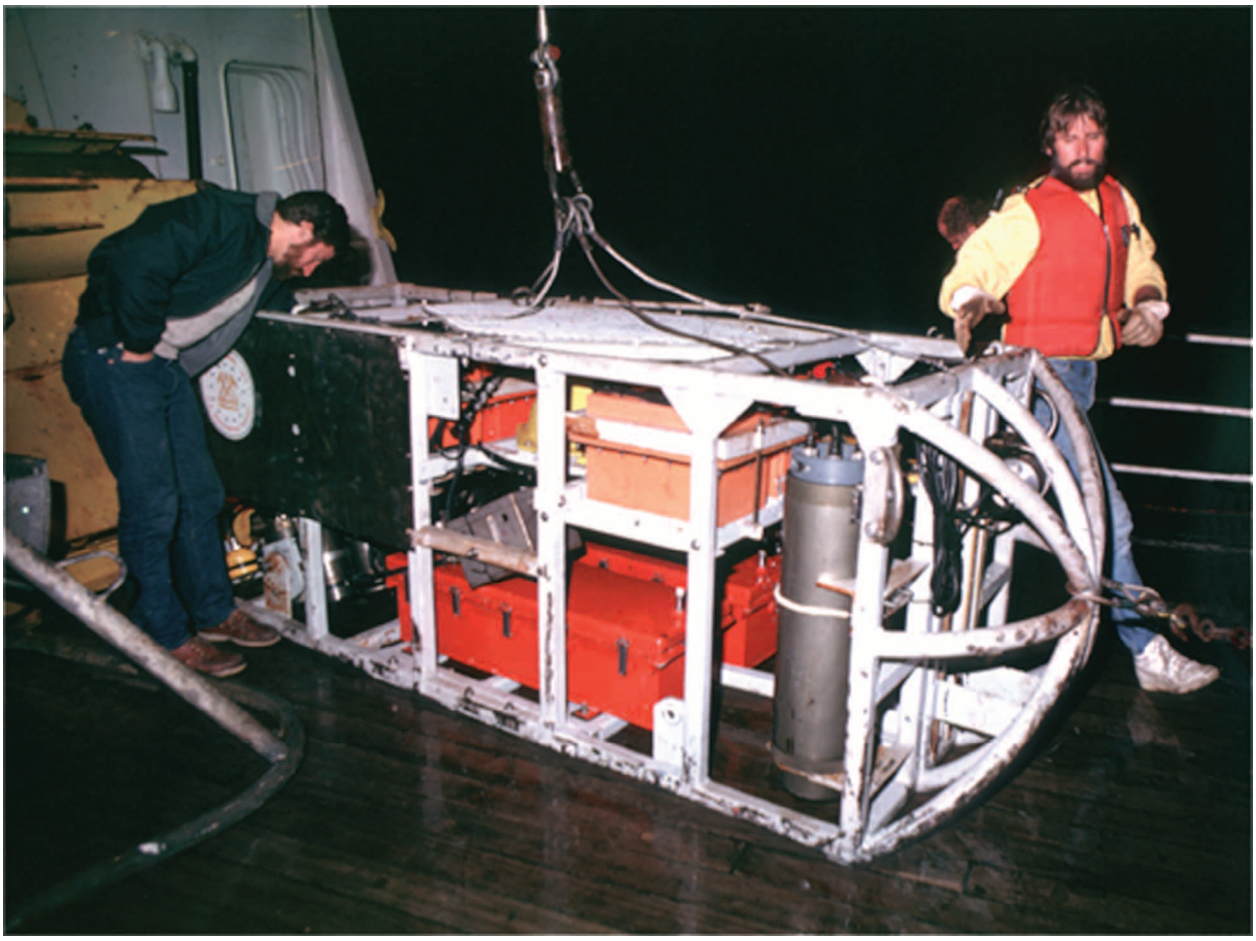

Figure 3. U.S. Geological Survey underwater-camera/video sled.

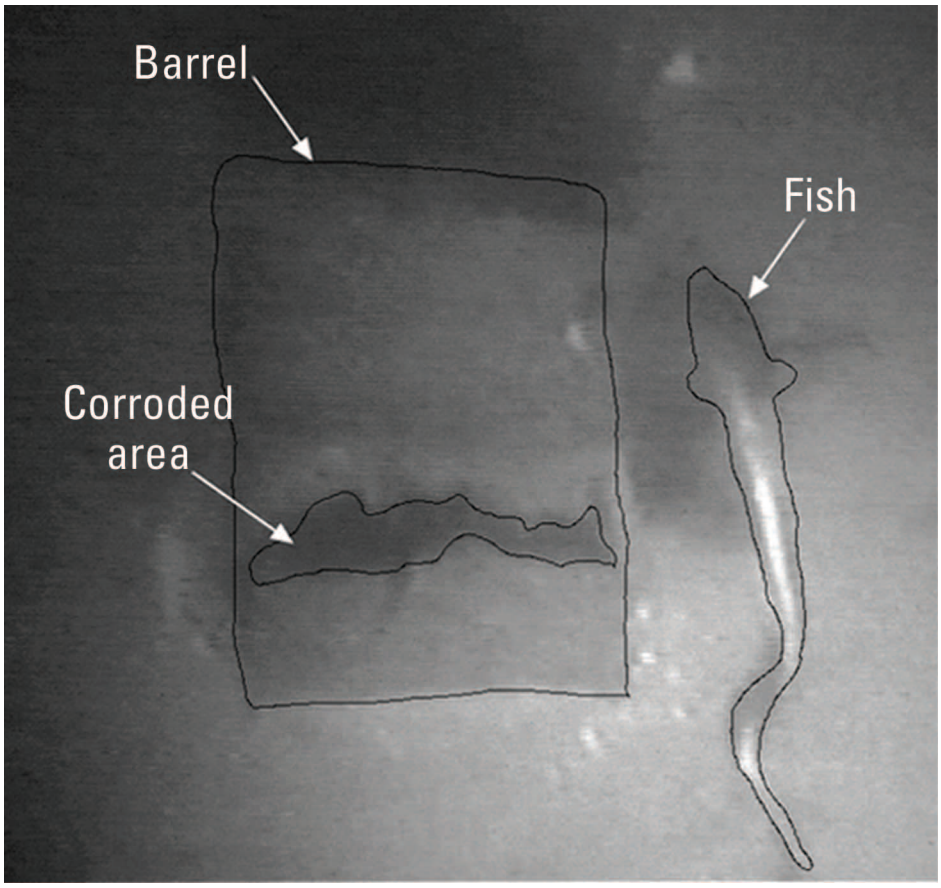

Figure 4. Corroded 55-gallon drum. Characteristics and location of drum suggest that it contains low-level radioactive waste. Note large fish resting near drum.(Photograph taken with U.S. Geological Survey underwater-camera/video sled.)

Figure 5. Intact 55-gallon drum of low-level radioactive waste. (Environmental Protection Agency photograph taken on a submersible dive in 1974.)

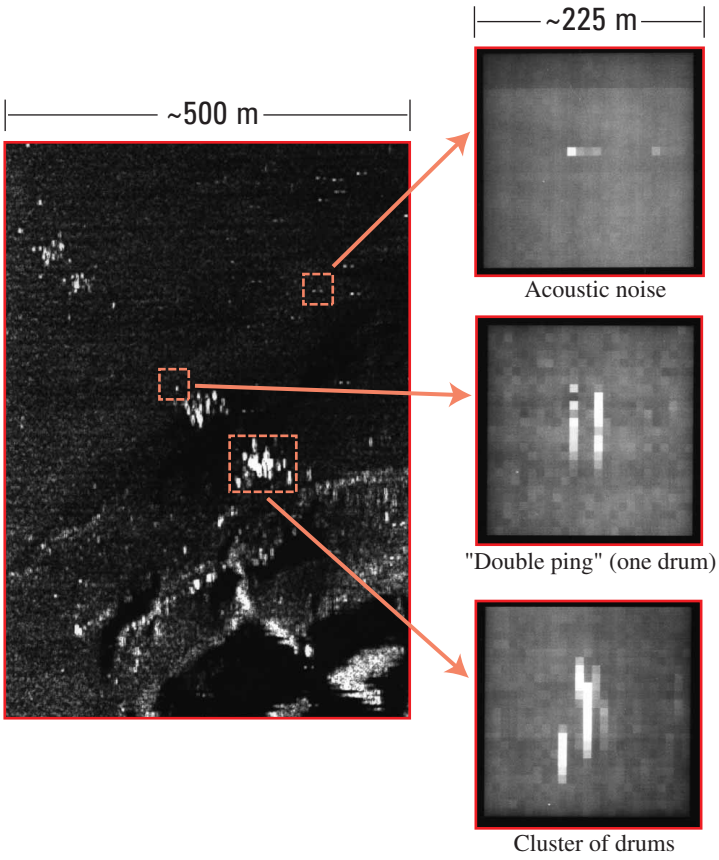

Figure 6. Computer enhanced sidescan-sonar image, showing the differences between acoustic noise, the characteristic double-ping signature of a single 55-gallon drum, and the characteristic signature of a cluster of drums.

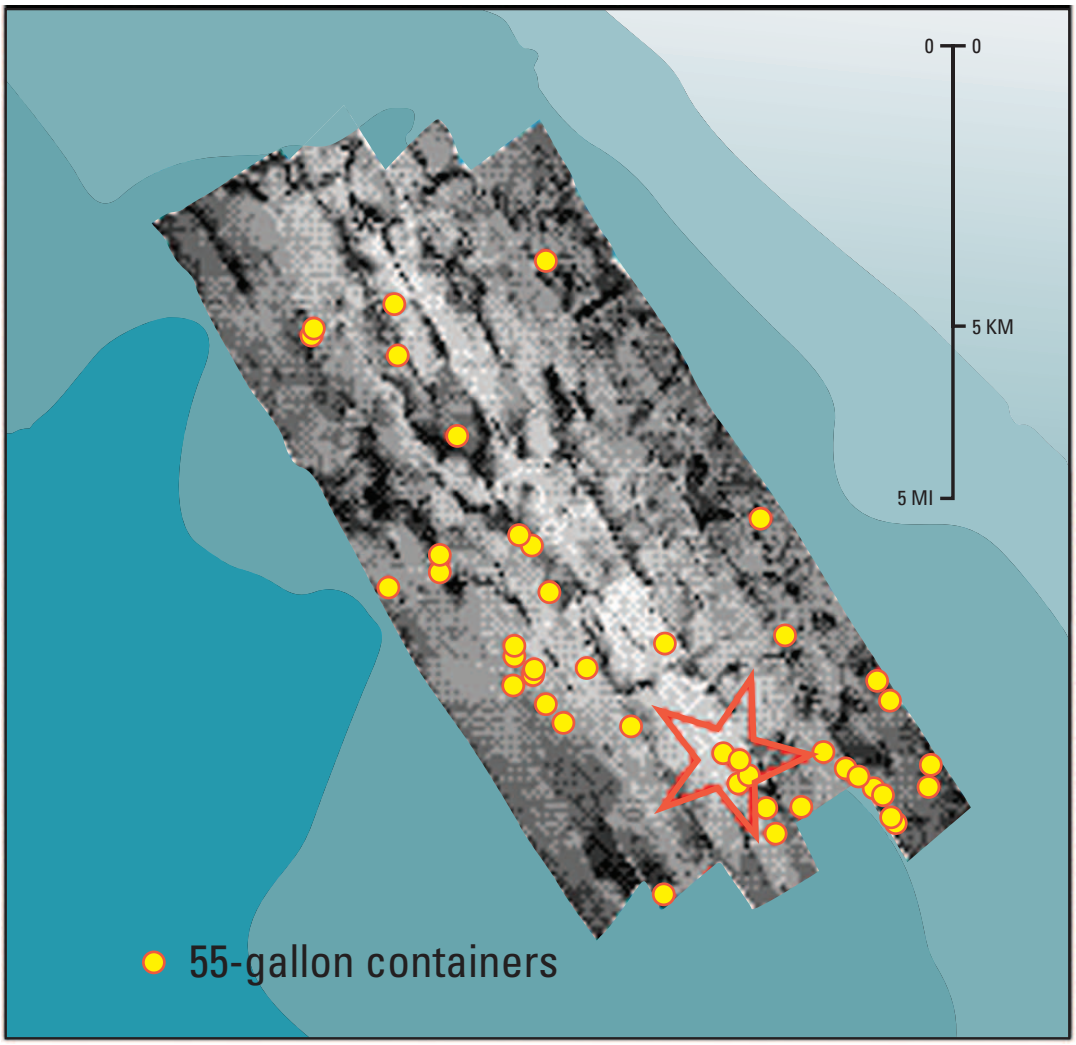

Figure 7. Locations of probable 55-gallon drums superimposed on a sidescan-sonar mosaic. Star marks the intermediate-depth (900 m) site designated for disposal of radioactive waste.

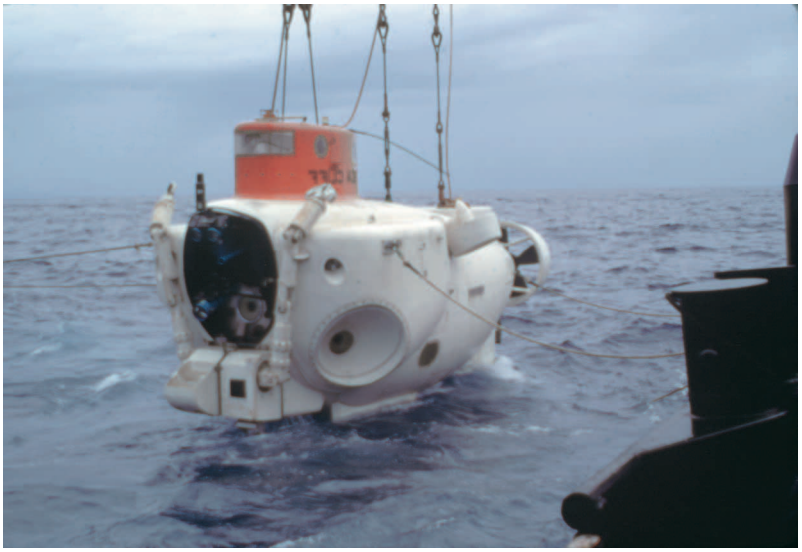

Figure 8. U.S. Navy deep submergence vehicle *Sea Cliff*.