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Sea Floor Photographs

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The collection of ocean bottom photographs made during the United States Antarctic Research Program (USARP) represents an extensive survey of the sea floor surrounding much of the antarctic continent. The geographic positions of the camera stations occupied from *Eltanin* Cruises 3 to 55 (and those of *Hero* and USCGC *Glacier*) are plotted in fig. 1. Over 20,300 individual frames from 1,064 locations are stored at the Smithsonian Oceanographic Sorting Center (SOSC) in Washington, D. C. During the past 8 years thousands of prints and much related data have been distributed to scientists involved in various research. Published results of such studies already have contributed substantially to the understanding of oceanic environments and benthos.

Because of the size of the collection and complexity of information contained in it, the bottom photographs constitute a considerable scientific resource that has been only partially tapped: few biologists, for example, have worked with the collection to any great extent. Present activities at SOSC, therefore, include establishing the capability of efficient picture retrieval coupled with availability of other data products through use of a computerized data bank. This report describes the collection, historically and materially, and then discusses the electronic data processing system selected for the photographic project, including the types of data and information to be stored. Additionally, some of the possibilities for data manipulation are suggested for new investigation.

Photographing the ocean bottom

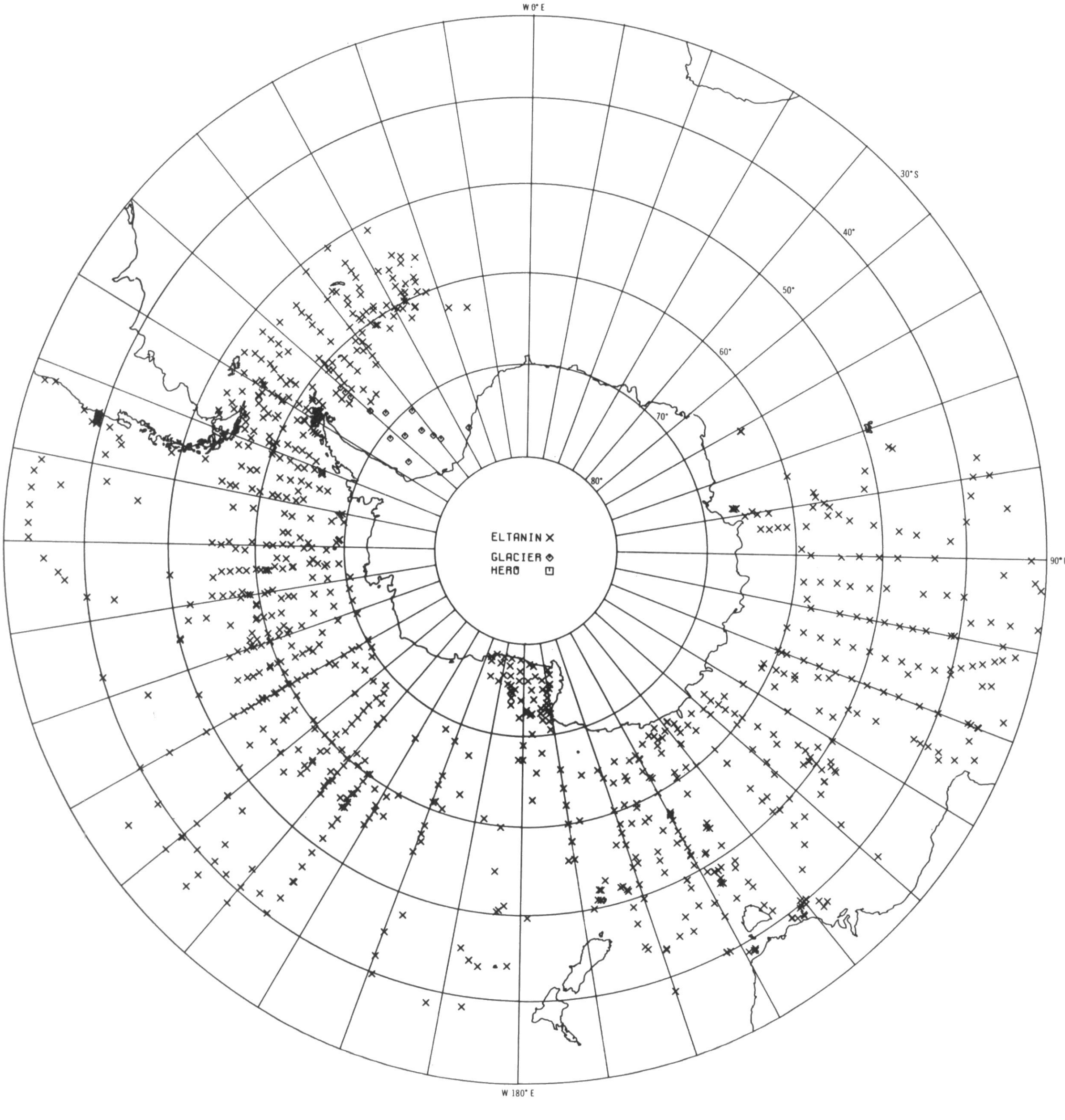
Participants on cruises of *Eltanin* produced 99 percent of the bottom photographs in the collection. The other photos were made from *Hero* and *Glacier.* On *Eltanin,* technicians employed by Texas Instruments, Inc., operated the bottom camera during Cruises 2-9; on Cruises 10 through 27 photographs were made by support staff of Alpine Geophysical Associates, Inc.; starting with Cruise 32, personnel of Lamont-Doherty Geological Observatory assumed the bottom photography project at sea, with the exception of Cruise 38 on which participants from Dartmouth Medical School made a set of photographs concomitant with specific collections of bottom organisms taken by University of Georgia participants.

Through Cruise 27 and at many stations during later cruises, photographs were made with the Alpine Model 311 underwater multi-exposure camera assembly. For their purposes, staff of Lamont-Doherty designed and constructed special camera systems (Jacobs *et al.,* 1970b, 1972) which consisted of a 35mm shutterless camera, strobe light, and an electrical source integrated with a bottom current meter and nephelometer. The units are sealed in pressure resistant housings and attached to an aluminum frame. A compass mounted to the frame extends into the camera's field of view and provides directional orientation on the photographs. The unit is lowered by cable to the sea floor. The strobe flashes and a photograph is taken when tension is released in a trigger wire as an attached weight contacts bottom. The system is then repeatedly raised a few meters and lowered again as the ship drifts. These maneuvers bounce the camera system across the bottom in a series of short arcs, taking a photograph with each hit.

During *Eltanin* operations, an average of about 20 good frames per camera station were taken. Camera operators recorded pertinent data in camera logs. Immediate development of the film alerted operators to equipment malfunctions, reduced the possibility of exposure mishaps enroute to the United States, and provided shipboard scientists with immediate information concerning the bottom. Shortly after each cruise, the negatives and camera logs were forwarded to SOSC.

Bottom photograph archives

In 1963 the National Science Foundation designated SOSC as a national repository for data and information on natural history collections made by United States investigators in antarctic regions. The following year the USARP ocean bottom photographs were included in the antarctic records program at



Smithsonian Institution/National Oceanographic Data Center

Figure 1. USARP camera stations circumscribe three-fourths of the anarctic continent.

SOSC with the understanding that prints would be provided to qualified scientists for their research.

Presently, about 19,000 black and white negatives, a file print for each, some duplicates, and numerous enlargements of portions of photographs with especially interesting features are archived. Some 1,500 color transparencies from 143 camera stations are on file with duplicates for loan purposes. Also on file are close-up photographs from *Eltanin* Cruise 35, which traversed an area between Australia and Antarctica. Reference materials include camera station logs, cruise reports, daily data sheets, and official cruise tracks. A small library contains papers illustrated with pictures from the collection and other literature on deep-sea photographs, benthic biology, marine geology, and methods for management of photographic collections.

In the past year, SOSC has established its own darkrooms for printmaking. This has enabled us to provide a degree of custom work on a routine basis. Extensive dodging and burning-in during printing often is required to produce quality prints from negatives with tremendous density variations owing to difficult lighting conditions inherent with deep-sea photography.

One of our aims in providing scientific services has been to consistently and reliably document the voluminous bottom photographic data and present them in a meaningful and useful manner to specialists. Camera station data are routinely stamped on the reverse side of each print distributed. These data include cruise number, station and frame numbers, station location, depth, date, and photo credit. When prints are shipped, they may be supplemented with copies of the camera station lists so that the user can readily review the areas, depths, etc., covered during a cruise.

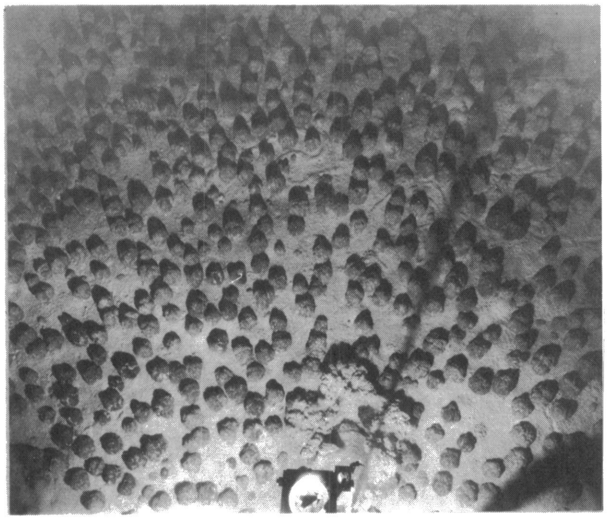


Figure 3.
A field of robust manganese nodules on the muddy bottom of the Indian Ocean. Fauna is sparce; an actinarian appears in the upper central portion of the photograph (*Eltanin* Cruise 48).

Figure 4.
Pillow lava crops out on the sea floor between Australia and Antarctica. A thin veneer of sediment coats the outcrop (*Eltanin* Cruise 54).

Distribution and usage

Prints of all negatives have been prepared routinely for four institutions engaged in long-term USARP projects; selected prints have been made on request for other researchers. The total distribution since 1964 is over 50,000 prints. For many of these investigators, studies are still in progress; others have used part or all of the prints sent them and have published results. A brief literature survey illustrates the diversity of usages by marine geologists, biologists, and physical oceanographers (table 1).

The scope of these studies demonstrates that considerable information is contained in the sea floor photographs. Because most of these reports used only limited numbers of pictures, and sometimes only a single frame showing a particular feature or organism, it is apparent that the information potential of the collection is tremendous. But new, efficient, and thorough analyses of the photographs are contingent to a large degree upon voluminous data storage, rapid retrieval, and related processing techniques for data reduction, synthesis, and correlation. In the last year we have adopted a computerized data processing system that has considerable promise in application to the problems of establishing a useful and viable data bank.

Electronic data storage and retrieval system

The criteria for an electronic data processing system developed from a philosophical approach to establish a highly organized and dynamic file whereby we might better meet the present and anticipated varied needs of specialists. Required was a system with sufficient flexibility to locate an individual photograph displaying a unique feature or combination of features and that could provide deductive information about sets of photographs.

Each USARP bottom photograph is undergoing thorough examination, and the observations are coded, keypunched, edited, and entered into the data bank. Processing, using the Smithsonian's Honeywell 2015 computer, employs a specially modified system, SELGEM, an acronym for SELF-GEnerating Master. The SELGEM system already has been applied successfully to a number of similar data storage and retrieval problems within the Smithsonian museums and at other institutions (Creighton and Crockett, 1971; Creighton *et al.,* 1972). The bottom photo project benefits enormously from the trials of these other users. Costs for modification are minimal, and in the future we will have access to useful program modifications incorporated into the SELGEM system by other users. A prime advantage in using SELGEM is that it is designed specifically for ease in modifying existing data and for later addition of new information, even if the need is unanticipated when the file originates. A user, therefore, could select portions of the data bank that are relevant to his research, readily include other data for his specific analytical purposes, and produce new results. After his research is complete, the new data could become part of the data bank and be made available to other users with related problems.

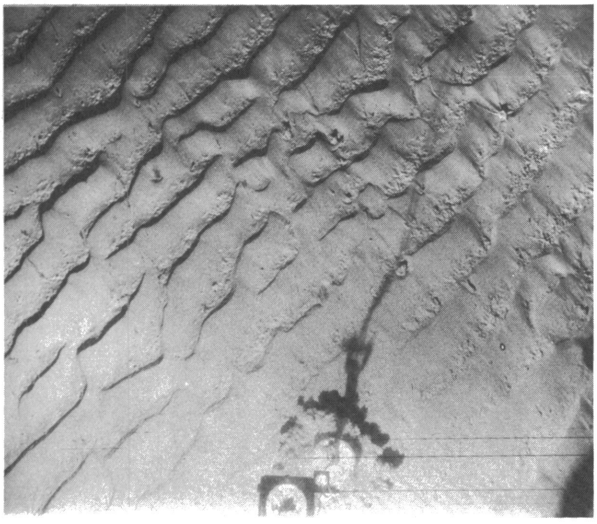


Figure 4.
Pronounced asymmetrical transverse ripple marks, crescentric scour and crag and tail structures, sorting of coarser material into ripple troughs, and sessile rheotaxis provide evidence of strong currents from the west, sweeping the bottom in an eastern portion of Bass Strait (*Eltanin* Cruise 55).

Table 1. Partial review of studies employing USARP bottom photographs.

GEOLOGY

Depositional milieu in relation to core data (Drake Passage, Scotia Sea, South Sandwich Trench): Goodell, 1964.
Depositional milieu in relation to core data (Pacific-Antarctic and Scotia Basins): Goodell, 1965.
Characteristics of the sea floor surrounding a large seamount (Peter I Island): Johnson, 1966.
Distribution and concentration of manganese nodules: Mero, 1965.
Geology of the sea floor (Bellinghausen Sea): Hollister and Heezen, 1967.
Location as a factor in mineral recovery. Hibbard, 1967.
Economic potential of antarctic regions: Potter, 1969.
Precipitation of manganese from sea water: Weyl, 1970.
Geology of the sea floor: Heezen and Hollister, 1971.
Cataloguing and correlating antarctic rocks: Simkin, 1971.
Sedimentary patterns (Indian Ocean): Conolly and Payne, 1972.
Manganese pavement production (Tasman Basin): Payne and Conolly, 1972.
Sedimentary disconformities (Indian Ocean): Watkins and Kennett, 1972.

BIOLOGY

Spirally coiled feces indicating large enternopneust population: Bourne and Heezen, 1965.
Ultraabyssal benthos (Peru-Chile Trench, South Sandwich Trench): Belyaev, 1966.
First isopod crustacea seen on deep-sea floor: Menzies and Schultz, 1966.
Tunicate distribution (Drake Passage): Caldwell, 1966.
Habitats of various isopod crustacea (antarctic regions): Menzies and Frakenberg, 1967.
Habitat of isopod crustacea *Mesosignum* (antarctic regions): Menzies and Schultz, 1967.
Dermechnius horridus in situ: *Antarctic Journal of the United States,* 1967.
First recognized brachiopods in the deep ocean (Ross Sea): Foster, 1968.
Larger members of the benthos: Heezen and Hollister, 1971.
Scalepellid barnacles (antarctic regions): Newman and Ross, 1971.
Marine ecology: Menzies *et al.,* 1973.

Figure 5.
Abundant and diverse benthos are seen in this 2-square-meter area of the southern Indian Ocean floor (*Eltanin* Cruise 47).

Benthic variety (Indian Ocean): Simmons and Landrum, 1973.

Ostracod habitats (antarctic and southern oceans): Kornicker, in press.

CURRENTS

Deep-sea current activity is substantiated: Heezen and Hollister, 1964.

Disposition of dangerous chemicals at sea: Marine Technology Society, 1969.

Bottom water formation, strength of currents (Ross Sea): Jacobs *et al.*, 1970a.

Current produced sea floor features: Heezen and Hollister, 1971.

Bottom currents and nepheloid layers (Indian-Pacific area): Eittreim *et al.*, 1972.

The initial steps in building the file include the entry of all pertinent data related to each camera station. Then, each photograph, or set of similar photographs made at a station, is examined, and the observations recorded. Table 2 lists station and frame data entered into the data bank.

On entry of sufficient quantities of data, specific and collective types of features and other data may be represented in hierarchial indices and on computer-produced plots and graphs. Plots may symbolically depict faunal diffusion, diversity, and density; vectorally indicate bottom currents; locate volcanic outcrops and debris; and represent varying concentrations of manganese nodules. These types of products will provide a new wealth of information for evaluation by specialists.

Table 2. Bottom photograph data categories.

CAMERA STATION DATA

Program, collector, vessel, cruise, ship station number, camera station number, number of frames, archiving institution.
Area topography, location
Position: Latitude, longitude, marsden square number, depths, date, time
Photograph type, film, camera equipment
Collectors of biological and geological specimens onboard
Related instrumentation, sampling
Relationships among frames

FRAME DATA AND FEATURES

Frame number(s), photo quality, directional orientation, scale
Referral and references
Striking features, man-made objects
Geologic features:
- Sediments—percentages of mud, sand; percentages and shape of pebbles, cobbles and boulders
- Outcrops—pillow lava, blocky lava, etc.
- Facies—bedrock/sediments, nodule field/sediments, etc.
- Inferences—Mn nodules, encrustation, solutioning, volcanic debris, organic debris, rafted erratics, etc.
- Gravity features—slipping, depressions
- Joints—systematic, nonsystematic
- Microtopography—ridges, slope, imposed marks

Current features:
- Scour marks—elongate marks, flutes, transverse scour, crescentric
- Deflation—rock nests, lag deposits, winnowed ridges
- Current lineations—elongation of burrows, fecal crag and tail, crag and trail
- Ripple marks—transverse symmetrical, transverse asymmetrical, linguoid, lunate, or cuspate (wave length and amplitude)
- Tool marks—continuous, discontinuous
- Suspended sediment—murky, streaming, stationary trigger weight plume, drifting plume
- Sediment cover—uniform, nonuniform, none
- Miscellaneous current features—smoothing, vague fabric, preferential organism growth, sorting, nodules, detailed lebensspuren
- Orientation—nonsessile rheotaxis, sessile rheotaxis, floral rheotaxis, embrication, oriented lebensspuren
- Current inferred—direction and strength

Biologic features:
- Lebensspuren—abundance of traces of locomotion, dwelling, defecation
- Animal with associated lebensspuren, animal inferred from lebensspuren
- Flora—macroalgae, algal debris
- Fauna present—major taxonomic groups, numbers of individuals per taxa

Conclusion

Paradoxically, while Apollo astronauts could directly observe the features of the moon's surface 250,000 miles distant, scientists on earth can only glimpse this planet's surface below the seas by remote photography, often only with a camera dangling on 5 miles of cable. The 20,300 different views of the antarctic sea floor contained in the USARP collection have contributed new and significant information concerning the marine environment, but an estimate of the actual area observed is only equivalent to that of about 12 football fields.

The continued growing national interest in understanding the world's oceans with the expectation of exploiting their resources will likely include the southern oceans. Concomitantly, sophistication of deep-sea single lens and stereo cameras, circular scanning cameras, movies, television, videotape, and time-lapse photography will probably produce large quantities of pictures. Should new and extensive photographic surveys be undertaken in future USARP investigations, the flexibility inherent with the SELGEM system will provide a means for efficient collection management, data retrieval, reduction and syntheses essential to the analyses of photographs and evaluation of the sea floor. The present USARP collection is thus not only a source of diverse information, but a model and a tool for future work in the antarctic and world ocean.

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