Federal Program in Marine Polymetallic Sulfide Research

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Summary

The largest pool of federal resources available for research directed solely toward polymetallic sulfides is derived from three agencies: The National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce, and the Geological Survey (USGS) within the Department of Interior. Programs of these three agencies are the subject of this paper. A fourth, the Office of Naval Research (ONR) in the Department of Defense sponsors activities which are supportive in a peripheral way. Each program reflects the missions of its parent agency, and through various techniques, including cooperation among bench level scientists, is mutually supportive and nonduplicative. Support for the DSRV ALVIN is a joint effort among NSF, ONR, and NOAA.

National Science Foundation

The NSF supports a broad based program of research in marine geology, geochemistry, and geophysics. The development of the plate tectonics theory in the 1960's focused attention on oceanic spreading centers and the processes which controlled their formation. Early studies concentrated on the tectonics, structure, and petrology of oceanic ridge systems. Disagreements between theoretical heat flow calculations and observed heat fluxes led to models of active hydrothermal circulation. This coupled with studies of ophiolite complexes on land and the geochemistry of basalt alteration from marine samples led to the development of several elegant but unverified models for sulfides, metal-rich sediments, and sea water chemical balances. The first project that proposed to find active vents was FAMUS (French American Mid-Ocean Undersea Study). This study used the U.S. submersible ALVIN and French submersible ARCHIMEDE and CYANA to examine a section of the Mid-Atlantic Ridge in 1974. The research team was unsuccessful in finding active vents but proved the worth of research submersibles as an open ocean geological research tool. The next two field programs supported by NSF were more successful--Galapagos Rift in 1977 and the East Pacific Rise at 21°N in 1979.

The Galapagos study was designed to locate and sample vent systems and found low temperature thermal systems. The big surprise was the unique biological communities with ecosystems based on microbial reduction of hydrogen sulfides. The East Pacific Rise (21°N) program found the now-classic "sulfide chimneys" and "black smokers" with 350°C hydrothermal waters. Since the initial discoveries both areas have been visited by several later research expeditions. Models for the basic oceanographic, geochemical, and geological processes are being tested in follow-on academic studies supported by NSF in both regions. For the program 1981-83, NSF has provided \$4.4 million (including ship and submersible costs) for marine hydrothermal studies on the East Pacific Rise, the Galapagos, Guymas Basin, and a joint effort with NOAA to re-examine the Mid-Atlantic Ridge (TAG area).

No new submersible programs are being done in 1983 owing to the conversion of the ALVIN and support ship ATLANTIS II for global operations. A number of multi-beam bathymetric surveys (SEABEAM studies), tectonic studies, and a continuation of laboratory analyses were supported. In 1984 and 1985 the NSF will support major field programs to continue definition of the basic processes along the East Pacific Rise--dredging and submersible programs from 10°N to the Gulf of California; a major effort on the Gorda and Juan de Fuca Ridge systems, coupled to complementary studies by NOAA and the U.S. Geological Survey; and exploratory studies of Loihi seamount off Hawaii and the Marianas region of back-arc spreading the western Pacific. Approximately ten field programs will be supported as part of a new initiative in marine crustal studies at a level of \$3.5-\$4.0 million (including ship and submersible costs) per year. A primary goal of the NSF program is to understand the fundamental geological, geochemical, and oceanographic processes that lead to marine polymetallic sulfide deposits.

In addition to these studies, NSF is providing approximately \$1.5 million in support for research in mineral resources through the Earth Sciences Division. This research program is focused on the nature of ore deposits, the geochemical processes by which they are transported and deposited, and the formation of general theories of ore formation which have accurate predictive capabilities in mineral exploration. The depletion of near-surface ore reserves, particularly those involving strategic minerals, requires a better understanding of how ore deposits form deep in the crust and how the location of ore deposits is related to regional structure and tectonic setting. A major element of this program is relating the observations of the formation of ore deposits associated with marine hydrothermal vents to terrestrial Cyprus-type massive sulfide deposits on land. Quantitative reconstructions of such systems, based on comparative studies of active and extinct hydrothermal systems, are yielding important three dimensional information about the spatial, physical, and chemical evolution of sulfide deposits. New instrumentation, new field studies, and modern computational approaches are essential for this type of research which, by its nature, is multidisciplinary.

Geological Survey

A major element of the U.S. Geological Survey marine-geology program deals with studies of seafloor energy and mineral deposits, their occurrence and processes of origin. In polymetallic sulfide research, most of the work so far has focused on the southern end of Juan de Fuca Ridge, where six or possibly several, sulfide sites have been discovered. Some of these are active "smokers". Results include an array of 10,000 photographs of the seafloor around the sulfide vents; samples typically containing more than 55 percent zinc,

0.05 percent cadmium, and 0.03 percent silver; and multichannel seismic, gravity, and magnetic data collected on a single long traverse across the spreading-center ridge and adjacent oceanic crustal plates.

Because the sulfide vents are considered an invaluable laboratory for studying the formation of massive sulfide deposits, and because so little is known about the size of the seafloor deposits and their resource potential, activities will increase in late 1983 and 1984. During the time of the Oceans '83 meeting, plans call for two new surveys. One survey in cooperation with the Geological Survey of Canada will involve several days' use of drill positioned on the seafloor and capable of recovering 10-m cores. The drilling will provide badly needed information on the third dimension of the observed deposits, and may reveal details such as mineral zonation. This survey also is expected to obtain wide-area photographs, using the ANGUS camera. Samples obtained will be studied intensively in order to develop an understanding of the processes by which the sulfide deposits form, and to compare the deposits with analogous deposits on land. The other survey is to obtain medium-resolution side-scan sonar images of the southern Juan de Fuca and the Gorda Ridges, together with high-resolution seismic, magnetic, and gravity data, as well as geological samples.

The planned studies will involve probably as many as 30 scientists from the U.S. Geological Survey (USGS), the Geological Survey of Canada and related institutions that developed the seafloor drill, the Hawaii Institute of Geophysics, and universities. From the studies should come a model linking the observed deposits with their precise geologic settings and the processes of deposit formation. Thus, it is hoped, it will be possible to use maps and geophysical data of the remainder of two ridges, not yet examined for deposits, and infer from orphology and spreading-center geologic character what potential for other deposits may exist.

In fiscal year 1983 the USGS program involved an expenditure of about \$1 million in the study of polymetallic sulfides. Although the budget for 1984 is not yet certain, a similar amount is expected to be available to continue and extend the studies.

National Oceanic and Atmospheric Administration

At NOAA the marine polymetallic sulfide program has organizational aspects similar to both the NSF and USGS programs, with whom there are several coordinated and cooperative activities. The in-house program is a coordinated, cohesive multidisciplinary effort of several line organizations (National Ocean Survey, Environmental Research Laboratories, National Sea Grant College Program, and National Marine Fisheries Service) directed to seafloor mapping and oceanographic aspects of geological, biological, and chemical processes at seafloor spreading centers and mid-plate hot spots. Building upon previous NOAA programs on a slow spreading center (the TAG hydrothermal field) medium-rate spreading centers (the Galapagos and the Gorda-Juan de Fuca Ridge) and mid-plate hot spots (the Hawaiian Islands), long term objectives are to understand the temporal and spatial variations of processes on a global scale. Selected sites will be re-occupied to provide a time series of data on observable and measurable processes. Results should serve as a basis for encouraging the development of marine resources as well as the basis for formulating the regulatory framework necessary for commercialization and for assessing the role of marine minerals in the global arena.

Initial emphasis has been on systematic mapping of the Gorda-Juan de Fuca (GJDF) Ridge. Using the SEABEAM swath bathymetric mapping system, over 40,000 line km of seafloor has been surveyed centered upon the axis of the GJDF system from the Mendocino Fracture Zone (FZ) north to Sovanco FZ. At the present rate of processing the data, it is anticipated that navigationally corrected digital depth data (suitable for producing machine contoured maps) will be available in September 1984. In a cooperative program with the Naval Research Laboratory, an airborne magnetics survey has been run over the GJDF with a line spacing of 8-16km. Deep-towed side-scan sonar and deep tow video and camera imaging surveys have been run along the ridge crest of the northern JDF and have confirmed five new active vent sites (Hammond, et al. 1983). Using the ALVIN, in situ geological observations and sampling of these vents is scheduled for the summer of 1984. Follow-on chemical and biological programs will commence in 1985. Examination of over 14,000 color photographs obtained during the May 1983 cruise of the northern JDF is underway. This will provide an initial survey of species abundance and diversity. Water chemistry (suspended particulates and dissolved gases) of sites in the southern JDF, first extensively sampled this past Spring, will be re-occupied during 1984 and periodically over the next several years. Preliminary analysis of suspended particulates and trace gases from a few stations on the Gorda Ridge indicate active venting occurs there too (Curl, Massoth, and Feeley, 1983). Additional cruises are planned for 1985 following further interpretation of existing bathymetry, bottom photographs, and water chemistry data.

The massive sulfide deposit discovered in the Galapagos (Malahoff, 1982) will be revisited in late 1983 with ALVIN and its new mother ship, ATLANTIS II. Purpose of the dive is further definition of the dimensions and character of the original sulfide body, and confirmation of others in the region.

Investigation of hydrothermal processes and the distribution of activity at a slow-spreading oceanic ridge is focused on the TAG site and vicinity on the Mid-Atlantic Ridge (MAR). Investigation in 1982 of a 1600km long segment of the MAR, applying a characteristic magnetic signature as an indicator of hydrothermal deposits, dredging to verify their presence, and delta-³He measurements in the water column to determine the state of activity has identified five hydrothermal sites, two of which are active (Rona, 1983). Another cruise to the MAR is tentatively scheduled for late 1984 with an expanded program beginning in 1985. Much of the previous MAR Ridge work had been a jointly funded and cooperative program between NOAA and NSF. It is likely this coordinated effort will continue.

A somewhat analogous situation holds for the Hawaiian Islands. As mentioned previously, NSF has supported work in the Loihi seamount southeast of Hawaii, a project which is coordinated with a NOAA project. Off the northeast corner of the island, the National Sea Grant College Program is supporting study of the hydrothermal system of the Puna seamount. Based upon proposal pressure, it is probable that Sea Grant will support additional research projects, which enhance the objectives of the NOAA program, as well as other related issues (legal, socio-economic, geopolitical) which fall under the purview of Sea Grant.

To-date each of the NOAA field programs has involved the university community, commonly other agencies (e.g., USGS and GSC), and often industry. Such cooperation is a continuing objective. During fiscal year (FY) 1983, the NOAA effort involved an expenditure of \$3 million

(including ships and submersibles). The same level of effort is planned in FY 84. NOAA has a work plan continuing the program through FY 89.

References

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