DEEP SEA DRILLING PROJECT
UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY

Scientific Objectives and Highlights
(From Leg 19 On)

Leg XIX - Kodiak, Alaska to Yokohama, Japan, July 22, 1971 to September 14, 1971. Dr. Joe S. Creager of the University of Washington and Dr. David W. Scholl of the United States Department of the Interior, Geological Survey, were Cruise Co-Chief Scientists.

General Purpose

In the main, Leg 19 was conceived and designed to investigate the Cenozoic and Late Mesozoic history of sedimentation and biostratigraphic development of the North Pacific and deep-water regions of the Bering Sea. It seemed highly probable that general and perhaps even restrictive statements could be made, as a result, about the structural and tectonic development of this vast region, which geomorphically includes a normal oceanic basin, a bordering trench and volcanic arc (Aleutian), and an inner marginal oceanic basin (Bering Sea).

Objectives

1) Age and source terrane of buried Aleutian Abyssal Plain turbidites. Age and paleolatitude of basal sediments atop the northwestern most seamount of the Emperor Seamount Chain. This evidence was sought to infer the range of possible movement of the Pacific Plate.

2) To determine the history of Aleutian Ridge volcanism by ash abundance and chronology.

3) To determine the nature of the Aleutian Terrace and its basement.

4) To study the nature of prominent bottom - simulating reflectors and determine whether or not they are "clathrates" (gas hydrates).

5) To study biozonations of silicious microfossils, comparing them to those of Japan, Sakhalin, and North America.

6) To study changes of carbonate compensation depths at high latitudes.

7) To sample as completely as possible the sedimentary sequence of both the Bering Sea and Kamchatka Basin.

8) To sample the sedimentary sequence of Bowers Ridge.

Conclusions and Overview

1) Rafted debris occurs in North Pacific and Bering Sea cores in sediment as old as Late Miocene, but it is most abundant after the Middle Pliocene, presumably marking the time when important ice formation began.

2) The Late Cenozoic turbidite sequence of the Bering Sea, which contains size-graded layers and displaced microfossils, began to form in Late Pliocene time, presumably in response to the first significant glacial lowering of sea level. Over the abyssal floor of Kamchatka Basin turbidites accumulated at rates exceeding 200 m/m.y.

3) Initial Pliocene and Lower Pleistocene turbidity currents entrained only relatively small amounts of fine silt and clay to which large quantities of diatomaceous debris were added. Only younger layers are characterized by size-graded sand and silt sequences.

4) The start of Late Miocene time marks the beginning of the "Age of Diatoms," when sedimentation rates maintained by the accumulation of diatomaceous debris in the northwest Pacific were as high as 70 m/m.y. and nearly 100 m/m.y. over Umnak Plateau in the Bering Sea. Pleistocene rates were, in general, slightly lower.

5) Throughout most of the deep Bering Sea and over the northwest corner of the Pacific Middle and older (?) Miocene deposits are dominantly worm-burrowed and mottled pelagic clay and claystone.

6) Over the summit of a large seamount (Site 192), the Middle Miocene claystone accumulated at a rate exceeding 200 m/m.y., nearly two orders of magnitude greater than that of typical pelagic clay. The Middle Miocene was evidently a time of prodigious continental and island arc erosion.

7) Paleogene deposits of the far North Pacific are pelagic clay and nannochalk; however, over the Aleutain Abyssal Plain Eocene and Oligocene beds are turbidite deposits. The most obvious source terrane for these deposits is Alaska.

8) The oldest beds found, Lower Maestrichtian nannochalk, occur atop the northernmost seamount of the Emperor Chain.

Paleontology

1) In the Bering Sea a notable change from calcareous to arenaceous-agglutinated foraminifera and the disappearance of calcareous nannofossils takes place below the Pliocene-Pleistocene boundary. However, the sharp change in carbonate compensation depth occurs a little below the Plio-Pleistocene boundary at Site 192, northwest Pacific.

2) The northern latitudes show a stark monotony of all calcite fossils of Neogene age, a total absence of discoasters, and a lack of calcareous zonation.

3) The occurrence of Oligocene and Eocene chalks in 4800 m of water at Site 183 indicates a very deep carbonate compensation depth for this time. This confirms the implication of coeval chalk in the Atlantic and more southerly parts of the Pacific.

4) A large unconformity at the Cretaceous-Tertiary boundary (Middle Eocene versus Middle Maestrichtian) and the occurrence of nannofossils in Middle Maestrichtian without planktonic foraminifera is notable. These relationships suggest a non-unconformity related to a shallow carbonate compensation depth.

5) An explosion of diatom flora began 11.5 m.y. ago in the Bering Sea, they are virtually absent in older sediment.

6) A scarcity of radiolarian populations characterize Neogene Bering Sea sediments, but a silicoflagellate flora was recovered back to Middle Miocene time.

7) Thin nanno oozes occur in Pleistocene and Pliocene beds in the Bering Sea, suggesting brief flurries of productivity.

Tectonics

1) A major increase in volcanic activity began about 3 m.y. ago along the eastern Aleutian Arc, Kamchatka, and the Kuril Islands. This event may correlate with the opening of the Gulf of California and strong relative movement between the Pacific and American Plates.

2) An Early Tertiary (Middle Eocene to Late Oligocene) turbidite sequence occurs beneath the Aleutian Abyssal Plain. The Eocene nannofossil assemblage has a low species diversity, suggesting high latitudes, and can be interpreted as evidence favoring limited motion (500-1000 km) between the Pacific and American Plates during Cenozoic time.

3) An exceptionally thick blanket of Middle Miocene pelagic clay floods the northwest corner of the Pacific Plate near its contact with Kamchatka; this circumstance can also be read as good evidence favoring limited Neogene motion between the two plates.

4) Somewhat more complicated patterns of oceanic sediment dispersal can account for the relationships noted above even if several thousand kilometers of Cenozoic plate displacement took place.

5) Tropical nannofossils in Maestrichtian chalk overlying a seamount at the northern end of the Emperor Chain, and one or more major unconformities in cool-temperate Paleogene beds, may favor a more oceanic position of the seamount in Late Cretaceous-Early Tertiary time.

6) Kamchatka Basin, Western Bering Sea, is shallowly (1000-1500 m) underlain by a basalt layer of unknown thickness. In Middle to Late Miocene time this basin appears to have undergone a major episode of in situ sea floor regeneration, involving the ingestment of older basin deposits.

Leg XX

On Leg 20, D/V Glomar Challenger sailed from Kodiak, Alaska, on September 17, 1971, and arrived at Yokohama, Japan, on November 10, 1971. Drs. David W. Scholl, U. S. Geological Survey, Menlo Park, California, and Joe S. Creager, University of Washington, Seattle, were co-chief scientists on Leg 20.

Although plagued with operational difficulties owing to consistently great water depths, coupled with confused swell conditions and marginal-to-poor hole conditions, Glomar Challenger drilled 13 holes at nine sites in the western Pacific and recovered sediments as old as Late Jurassic, the oldest sediments yet recovered from the Pacific. While drilling these sites, a number of new depth records were established: a) deepest water drilled in to date (20,316 feet); b) recovered core from greatest depth (21,552 feet); c) deepest combined water and penetration depth (21,552 feet); and d) successfully shot off pipe at mud line in 20,000 feet of water.

One of the major scientific results was the outlining of the western Pacific stratigraphic column and its depositional history, and its possible significance to models of sea-floor spreading and continental drift. Three major sedimentary units occur: 1) Late Tertiary silty clays, with numerous ash layers, and abundant radiolaria and diatoms, 2) Early Tertiary and Late Cretaceous zeolitic silty clays containing a minor amount of radiolaria and diatoms, and 3) Paleocene to Jurassic interlayered chalks, cherts, siliceous limestones and marls, the oldest Pacific sediments yet drilled. The silty clays constitute the upper transparent acoustic layer which thins eastward away from Asia, and is divided into an upper layered and lower unstratified unit. The former, found only within 1000 km of the mainland, is a Late Tertiary detrital wedge thinning away from the volcanic arcs. The unstratified unit is normal abyssal clay 10 to 50 m thick. Paleocene to Jurassic chalks, cherts, and limestones make up the upper opaque acoustic layer whose excessive thickness records previous equatorial crossings of the Pacific plate. Additional deeper reflectors indicate a Jurassic or earlier crustal age. All the units are time transgressive, generally beoming older from east to west. Mean sedimentation rates for the lower, middle, and upper units are approximately 20, <2, and 10 m/m.y., respectively. A simple model involving carbonate sedimentation, changing to abyssal clays as the aging oceanic crust subsides, fits the overall sediment pattern with additions contributed by equatorial organic debris and Asiatic volcanic ash.

The final three holes were on the flat top of Ita Maitai guyot. These penetrated a pelagic sequence of foraminiferal sand some 70 to 100 meters in thickness before entering a dense, oolitic limestone, approximately 35 meters in thickness. This is underlain by coralline muds, indicative of a reef environment. The top of Ita Maitai guyot is presently 1500 meters below sea level, but the recovered sediments show that the guyot must once have been at sea level, permitting corals to grow in a reef environment. The guyot then subsided, allowing the accumulation of oolitic sands; by the Middle Eocene, the top of the guyot was at or near its present depth, allowing pelagic ooze to be deposited.

Leg XXI

Leg 21 took the Glomar Challenger from Suva, Fiji, to Darwin, Australia, and extended from November 16, 1971, to January 11, 1972. A brief port call was made in Wellington, New Zealand, in early December for the repair of some broken drilling equipment. Drs. Robert E. Burns, of the Pacific Oceanographic Laboratory, National Oceanic and Atmospheric Administration, Seattle, Washington, and James E. Andrews, of the University of Hawaii, Honolulu, were cruise co-chief scientists.

This leg of the Project traversed one of the most geologically complex regions of the Earth's surface. Fourteen holes were drilled at eight sites. Of principal interest to the scientists was the structural history of the region and the development of a chronology for the breakup of New Zealand, New Guinea, and Australia. Drilling results support the hypothesis of a major deformation and a breakoff of continental crust along Eastern Australia more than 70 million years ago. This sector migrated eastward with the opening of the Tasman Sea, and the northern portion (forming the present day submarine Lord Howe Rise) was submerged more than 50-60 million years ago. Drilling at the southern end of the Lord Howe Rise penetrated more than 100 m into glassy rhyolite, a type of lava commonly found only on the continents.

Further evidence, from drilling in the Coral Sea, indicates that New Guinea probably separated from Northern Australia at least 50 million years ago.

The eastern portion of the area investigated on Leg 21 does not have continental characteristics and appears to have been formed in association with extended periods of volcanism by accretion of new oceanic crust or by extension of the sea floor eastward behind a migrating Tonga-Kermadec Island arc. Drilling results indicate that the South Fiji basin was formed as early as 40 million years ago and that the Lau-Havre basins are more recent - perhaps less than 15 to 20 million years ago.

In addition to these relative movements within the region, the area as a whole appears to have migrated toward the Equator with older fossil forms showing greater affinity to temperate latitudes and younger ones more to subtropical and tropical affinities.

A completely unexpected discovery was the finding of a 'missing section' in the fossil record which is present over the whole of the western part of the region. This represents a gap in the record from about 45 to 30 million years ago which could be related to the major differences in the oceanic current systems in the past. One explanation could be the divergence of a world circling Circumpolar Current from an original path north of Australia to its present path south of Australia. This change in pattern could be related to the separation of Australia and Antarctica and the general northward migration of the Australia, New Zealand, New Guinea area.

Leg XXII

On Leg 22, during which Glomar Challenger sailed from Darwin, Australia, on January 13, 1972, and arrived in Colombo, Ceylon, on March 6, eight sites were drilled in the eastern Indian Ocean. Three of these sites are in the Wharton Basin, and three more along the crest of Ninetyeast Ridge. The remaining two sites are west of Ninetyeast Ridge, one at the extreme end of the Bengal fan and one on the fan due east of Ceylon. Dr. Christopher von der Borch of Flinders University, Australia, and Dr. J. G. Sclater of the Marine Physical Laboratory of Scripps Institution of Oceanography, University of California at San Diego, were cruise co-chief scientists.

The major scientific conclusions of the cruise are as follows:

(1) The central and deepest part of the Wharton Basin is probably no older than Cretaceous. Site 212 with a water depth of 20,477 ft. (6243 m) and a total depth of 22,185 ft. (6764 m) was both the deepest water depth and greatest length of drill pipe.

(2) Ninetyeast Ridge was part of the old Indian plate in the late Cretaceous. Sites on the Ridge show that this plate moved rapidly north during this epoch. Sites on either side of the ridge show a unified history and little or no relative motion since the Early Tertiary.

(3) The basal sediments on Ninetyeast Ridge get older to the north, and sediments at all three sites were deposited close to sea level. Early in its history the ridge reached sea level, and it is inferred that it has subsided as it migrated northwards.

(4) At 8° S, 102° E in the Wharton Basin and at 8° S, 86° E in the Central Indian Basin, Miocene or younger turbidite sediments were found that were analogous with those from the same age span in the Bengal fan.

(5) At Sites 211, 213, and 215, the lowermost unit is a pillow lava basalt. At Site 211 a sill of andesine diabase composition was encountered about basement. At Site 212 the lowermost unit is a pillow lava meta-basalt, and at Sites 214 and 216 the lowermost unit is an amygdular and vesicular basalt.

LEG XXIII

The Leg 23 cruise commenced 8 March 1972 in Colombo, Ceylon, proceeded across the Arabian Sea and into the Red Sea, finally terminating at Djibouti, F.T.A.I. on 1 May 1972. The Leg was split, geographically, objective-wise and in the matter of staffing into an Arabian Sea and a Red Sea portion. Dr. Robert B. Whitmarsh, The National Institute of Oceanography in Wormley, Godalming, Surrey, England and Oscar E. Weser, Scripps Institution of Oceanography, La Jolla, were co-chief scientists for the Arabian Sea investigations. Dr. David A. Ross, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, replaced Weser for the Red Sea studies.

During its 56-day voyage, the Challenger drilled 12 sites, six in the Arabian Sea and six in the Red Sea. Continuing improvements in drilling techniques and technology resulted in a record number 306 cores being taken as well as a new depth penetration figure of 1300 meters being established.

Drilling in the Arabian Sea uncovered several features of its geological history not the least being the presence of Eocene chert beds, similar to those recognized in other oceans, acting as a widespread acoustic reflector. In addition, several datings of oceanic crust indicate the pattern and chronology of sea-floor spreading is quite complex and differs considerably from previous concepts. Large transform fault offsets are required to explain the crustal datings which were recorded. Finally, sites in the southeastern and northwestern portion of this sea show the widespread influence of Indus Cone sedimentation.

Of importance in the latter region, was the discovery of a large submarine ridge at least 300 miles long bounding the west side of the Owen Ridge. This large non-magnetic feature was apparently first uplifted in earliest Miocene time and locally acquired a relief of up to 6000 feet.

Drilling in the Red Sea focused on evaluating the metal-rich brine pools as well as observing aspects of rifting in a newly forming ocean.

The thickness of the heavy-metal-rich sediments underlying the hot brines remains unknown, but if none underlies the recent basalts, the total thickness is probably less than 20-30 meters thick (representing that portion above the basalts). An evaluation of the source of the metals suggests that they may have been derived from nearby evaporites and shales.

The sediment history recorded at several sites shows that sea-floor spreading has not acted in a continuous fashion, rather it transpired in at least two phases. An initial phase took place before early Miocene evaporites were deposited. The later movement, which occurred in post-Miocene time, formed the present axial valley. It appears that the aforementioned evaporites may be the same age as those drilled on Leg 13 in the Mediterranean Sea.

HIGHLIGHTS OF LEG 24

Leg 24 navigated a 4450 nautical mile tract between Djibouti, F.T.A.I. and Port Louis, Mauritius in the northwestern Indian Ocean. Eight Sites were drilled and sampled in three geologic provinces (1) Gulf of Aden, (2) western Somali Basin, and (3) Mascarene Plateau area and a portion of the Central Indian Ridge. The Leg scientific effort was led by Co-Chief Scientists Dr. Robert L. Fisher, Scripps Institution of Oceanography and Miss Elizabeth T. Bunce, Woods Hole Oceaonographic Institution.

In the Gulf of Aden, interest focused on the sedimentary history of a region where an active oceanic spreading center is moving apart the Arabian Peninsula and Africa. A fairly uniform section of hemi-pelagic Quaternary to Miocene sediments was penetrated. This suggests that water depth, biologic carbonate input and the amount of detrital material received has not changed greatly since this young oceanic area first developed.

Two sites in the Somali Basin demonstrated the general inaccessibility of this region to detritus from the African landmass. Variations in calcareous sediments suggest a history of fluctuation in the carbonate compensation depth. Good basalt recovery at one site was indicative of a deep magmatic source.

In the region of the Mascarene Plateau, a deep site to the north was drilled to evaluate the spreading history of the Proto-Carlsberg Ridge which is presumed to have sundered the Plateau area from the Indian Continent. The age of the basement sampled was Late Paleocene rather than Cretaceous as had been anticipated. The data suggests that the initiation of sea-floor spreading was later than currently believed.

Drilling on the Mascarene Plateau itself showed that two kilometers of subsidence have occurred since the deposition of shoal Paleocene sediments. Although basement was not reached, a good Tertiary stratigraphic section was recovered.

A final site on the Central Indian Ocean Ridge was marked by a penetration of 80 meters of basalt after penetrating a Quaternary to Oligocene sediment section. This basalt penetration provided abundant information on the mineralogy, physical condition, alteration and eruptive history of volcanic rock emplaced in a tectonic lineation.