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Leg 67, Site 498A

COVER: Gas Hydrate recovered from Hole 498A, Leg 67

GAS HYDRATES

The GLOMAR CHALLENGER has recovered gas hydrates on several legs. Most recently gas hydrates were encountered on Leg 66, where there was a clear Bottom Simulating Reflector (BSR), and on Leg 67 where no BSR was recorded. Both of these legs were in the Mid-America Trench region. Gas hydrates were recovered in previous passive margin drilling (e.g. sites 102, 103, and 104). They are anticipated to be a safety consideration during the Atlantic program. In view of this, the Safety Panel held a one-day symposium on Gas Hydrates at their October meeting.

Gas hydrates* are crystalline compounds in which the ice lattice of water expands to form cages that contain the gas molecules. The hydrates are solids resembling wet snow in appearance, and they form both above and below the freezing point of water under specific pressure-temperature conditions. The water molecules form two kinds of unit cell structures. The smaller unit structure contains 46 water molecules, which will hold up to 8 methane molecules. Gases such as CH_4, H_2S, CO_2, and C_2H_6 will fit into this structure. The larger unit cell contains 136 molecules of water. Gases such as propane and isobutane will fit in it. These are the only gaseous hydrocarbons that will form hydrates. The pentanes and n-butane molecules are too large.

Hydrates are formed by increasing pressures and are decomposed by increasing temperatures. Assuming a normal pressure gradient, a methane hydrate will form under about 274 m (900 ft) of permafrost, providing there is sufficient methane available. On the continental margins, where ocean bottom temperatures are around 2°C (36°F), a methane hydrate can form in the surface sediments under about 335 m (1,100 ft) of water. The other gases, ethane, propane, isobutane, CO_2 and H_2S, all tend to lower the pressure requirements when forming mixed hydrates with methane. The salinity of water lowers the temperature at which the hydrate forms, the effect being greater at high temperatures than at low temperatures.

Since the pressure required to form gas hydrates increases logarithmically with a linear increase in temperatures, it is apparent that the hydrates in most sedimentary basins will decompose in the temperature range 21-27°C (70-80°F), because the pressures are inadequate to preserve them. This puts a depth limit of about 1,524 m (5,000 ft) on hydrate formation.

Hydrates can be recognized in the subsurface by seismic data and variations in drilling rates, but sampling with a pressure core barrel is required for proof of a hydrate. Stoll et al. (1971) based their suggestion that there were gas hydrates in the deep ocean on the fact that seismic reflectors tended to follow surface contours, as would a hydrate, rather than to follow the bedding planes. Stoll formed hydrates in the laboratory and found that the seismic velocity increased from 1.85 km/s to 2.69 km/s as the solid crystalline hydrate was formed. Drillers on the Deep Sea Drilling Project have noted a marked decrease in drilling rates from less than 1 minute per meter to 5 or 6 minutes per meter when crystalline hydrates were encountered.

The bottom of a hydrate interval is usually well defined on seismic records due to the sharp drop in velocities from around 3 km/s to 0.5 and even 0.2 km/s. Sometimes a bright spot shows up, indicating free gas to be below the hydrate.

*This information is taken from: John M. Hunt, 1979, Petroleum Geochemistry and Geology, San Francisco: W. H. Freeman and Co., pp. 156-162.

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DUE TO PRINTER'S ERROR, THE LAST LINES OF THE GLOMAR CHALLENGER SCHEDULE WERE OMITTED. THIS REPLACES THAT PAGE.

LEGS 71-82—Tentative GLOMAR CHALLENGER Schedule*

Leg	Port of Departure	Leg Begins	Leg Ends	Days At Sea	Purpose
71	Punta Arenas	10 Jan, 1980	22 Feb	40	Falkland Plateau Paleoenvironment
72	Santos, Brazil	27 Feb	09 April	42	Rio Grande Rise Paleoenvironment
73	Santos	14 April	01 June	48	Mid-Atlantic Ridge Paleoenvironment
74	Cape Town	06 June	16 July	40	Walvis Ridge, Cape Basin Paleoenvironment
75	Walvis Bay	21 July	09 Sept	50	Walvis Ridge, Angola Basin—Paleoenvironment
TRANSIT—Recife to Port of Spain (Curacao)					
76	Port of Spain	23 Sept	12 Nov	50	Mid-Atlantic/Continental Rise-Passive Margin
77	Nassau	17 Nov	14 Jan, 1981	48	Blake-Bahama/Florida Straits—Passive Margin
78	Curacao	09 Jan	22 Feb	44	Caribbean
79	Curacao	03 March	26 April	54	Off W. Africa/Portugal Passive Margin
80	Brest	01 May	16 June	46	Bay of Biscay Passive Margin
81	Plymouth	21 June	15 Aug	55	Rockall—Passive Margin
82	Halifax	18 Aug	07 Oct	50	Canadian-Nova Scotian Rise—Passive Margin
83	Norfolk				

*This schedule is only approximate and is subject to change.

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SUMMARY OF DEEP SEA DRILLING PROJECT

LEG 67

THE MID-AMERICA TRENCH TRANSECT OFF GUATEMALA

(Co-Chiefs: R. von Huene and J. Aubouin)

The Mid-America Trench Transect off Guatemala is the second of two active margin geophysical and drilling transects across the convergent margins of southern Mexico and Central America. The first, a transect north of the Tehuantepec Ridge off Oaxaca, was drilled on Leg 66 to investigate a convergent margin where tectonic erosion may have occurred. Off Guatemala, and south of the Tehuantepec Ridge, the principal objective was to study an accretionary convergent margin where imbrication may be the dominant tectonic process.

The Mid-America Trench was recommended for this study by the IPOD Active Margins Panel on the basis of past drilling experience along other convergent margins. An early transect across the Aleutian Trench (Leg 18) first showed that the detailed resolution of age is required to demonstrate repetition of section. This detailed resolution is easier to obtain in low latitudes where microfaunal diversity is greater than in the high latitudes. In high latitudes, the influx of terrigenous sediment during glaciation obscures structural relations. It was virtually impossible to differentiate ocean basin deposits from slope deposits by their lithologies when both environments have been overwhelmed by the terrigenous sedimentation associated with glacial periods. Thus it was reasoned that optimum conditions for a tectonic study of convergence would be found in an area where terrigenous sources are small, where faunal diversity is great, and where subduction is relatively rapid. These conditions appear to exist along Central and South America.

Another factor influencing the choice of a transect was the paper by Seely, and others (1974) showing a well-processed multichannel seismic reflection record across the Mid-America Trench off Guatemala. In their article, and at a Penrose Conference in December 1972, those authors made a convincing case for the imbricate thrust model based on their seismic record and proprietary drill hole information. During the following year, two multichannel lines were shot across the Peru Trench. The interpretation of these lines was more complex than off Guatemala (Hussong and others, 1976). When it became apparent that either the transects off Peru or the one off Guatemala could be studied during the first phase of IPOD, the Active Margins Panel recommended a first priority for the latter with addition of the Oaxaca Transect to study tectonic erosion. In the opinion of the panel, more could be learned by investigating the Mid-America Trench because of the existing data base and because of less extensive logistic requirements. This choice resulted in the multichannel site surveys by the University of Texas Marine Sciences Institute (UTMSI). In 1977, the initial grid was shot and then processed. After review by an Active Margins Panel Working Group, a transect was selected off Guatemala that includes San Jose Canyon. Drilling in the section cut by San Jose Canyon allows deep penetration, possibly into the Paleocene. Seely (1979) reports that uplift of the present edge of the shelf occurred in Paleocene time.

In the initial period of planning for IPOD I, the principal objective along the Mid-America Trench Transect was to test the model of subduction proposed by Seely and others (1974). Despite the limited depth of GLOMAR CHALLENGER drilling, these authors indicate a 300 to 500 m thick layer of slope deposits, a layer easily penetrated with CHALLENGER capability. Water depths, even in the trench axis, are also within reach of the CHALLENGER drill string. Thus with the CHALLENGER drilling, the thrusts seen in seismic records can be penetrated and the inferred landward progression of increasing age of the rocks in the imbricate stack can also be verified.

Records made during the pre-drilling site surveys were used to define more specific objectives. The records made by UTMSI (Ladd and others, 1978) do not show as many clear reflecting horizons as does the record of Seely and others (1974). The UTMSI records are obscured much more by diffractions in the area where Seely and his co-workers show imbrication, and the cover of seismically defined deposits on the upper slope. However, intervals with a high seismic velocity (4.9-5.8 km/s) observed in OBS seismic refraction data indicate landward dipping slabs of igneous rocks (Figure 1). The UTMSI records can also be interpreted consistent with the imbricate thrust model. To test the seismic interpretation, reference sites on either side of the seismically defined accretionary zone and within the zone were proposed (Figure 1).

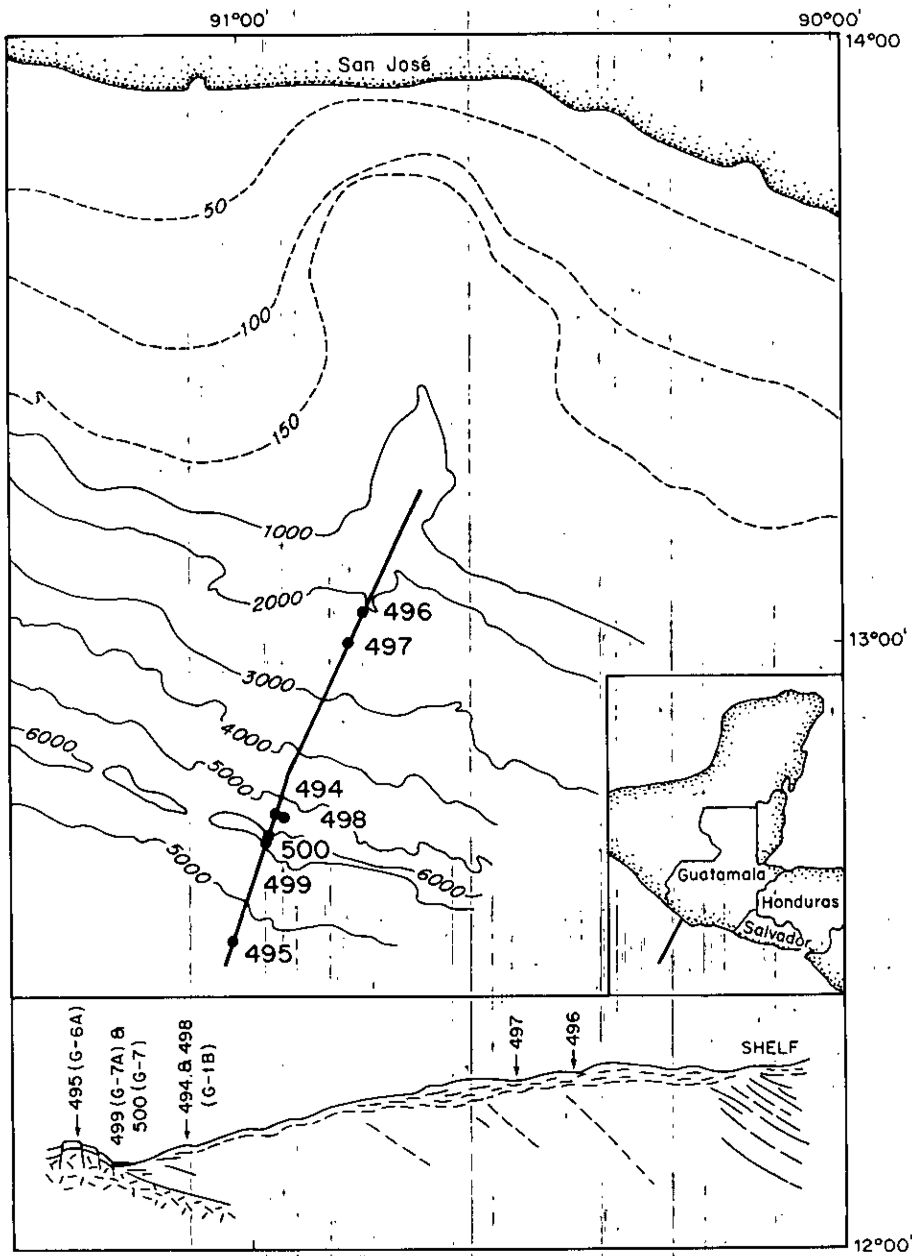

FIGURE 1

Location map for DSDP Leg 67, sites off Guatemala, and cross-section inferred from UTMSI multichannel seismic reflection profile.

Within the zone of seismically determined accreted and imbricated materials, sites were positioned to sample the material with high seismic velocity (4.9-5.8 km/s). Perhaps these materials are the source for ultra-basic rock fragments in gravel on the lower slope. The remaining sites on the trench slope were positioned to investigate progressive deformation, diagenesis, and the ordering of the age of units within the subduction complex. The model of Seely and others (1974) predicts that these site will yield material with oceanic affinity.

The following are summaries for each of the sites actually drilled. They are arranged in a seaward to landward order and not in the order of drilling. These summaries are followed by a discussion of integrated conclusions for all of the sites and the seismic transect.

Site 495 (G-6A)

Site 495 is the oceanic reference for the Mid-America Trench transect off Guatemala. It is on ocean crust, 22 km seaward of the trench axis, and about 1925 m above it, on an isolated ridge or hill formed by a horst-like structure (Figure 1).

Bathymetric profiles made as the CHALLENGER came on site indicate a seafloor depth within 25 m of that at the position selected in seismic record GUA-13, however, the morphology around the site seems to differ somewhat from that in the record. The sediment cover is of generally uniform thickness (0.4 s) mimicking topography as is typical in oceanic pelagic areas. Magnetic anomalies at the site are only known from reconnaissance data and are indicated to be of Eocene age on the map of Pitman and others (1974).

Forty cores with 75% recovery were obtained. The sequence of sediment is typical of low latitude oceanic areas and it has a hemipelagic cover.

1. 0-171 m hemipelagic, diatomaceous green and olive-gray mud;
2. 171-178 m brown abyssal clay;
3. 178-406 m chalky carbonate ooze with chert in the lower section;
4. 406-428.5 m manganiferous chalk and chert;
5. 428.5-446.5 m basalt.

The sediment is highly bioturbated in general but some thin intervals of finely laminated material were recovered. Immediately above the basalt, and in the thin chalky layer intercalated between flows, no baked sediment was recovered.

Microfossil assemblages indicate an unbroken sequence from Quaternary to lower Miocene. Foraminifera are well-preserved except in the mid- and upper Miocene section. Benthic assemblages indicate a gradual increase in depth with perhaps a slight uplift at the end of the Quaternary. Radiolarians are common to abundant through most of the section and are absent in the lower part where chert layers were drilled. Nannoplankton occur throughout the section and are well-preserved. Tertiary movement of the Cocos Plate with respect to the equatorial belt of high productivity is recorded by a lower and mid-Miocene increase in the rate of biogenic sedimentation (50 m/Ma). Today, this belt is near the Galapagos and at water depths between about 2500-3000 m. A pronounced absence of carbonate sediment and slow rates of sedimentation (8 m/Ma) in the upper Miocene may correspond to the environments presently found in the region between 10°-15°N, just beyond the carbonate belt. In the hemipelagic sediment the biogenic component may correspond to the present belt of upwelling near the Central American continent.

This section has a regular increase in density with depth as seen in the GRAPE and logging data. Velocities could only be measured in the laboratory because the sonic velocity downhole logging tool did not function. Thus, there is little information from which to resolve the disparity between the depth to basalt from drilling (428 m), and the depth from calculations using laboratory velocities (av. 1.7 km/s) and the basement reflection intercept time (0.38 s; 320 m). Plots of effective overburden as a function of depth suggest that the Quaternary sediment may be underconsolidated, and the section below, normally consolidated. Essentially no measurable quantities of gaseous hydrocarbon were found at this site.

Conclusions

The sediment section at Site 495 records the northward passage of the Cocos Plate through the equatorial carbonate belt to a deep ocean environment of slow deposition and finally to an environment in the proximity of a terrigenous source.

Superimposed on this trajectory are the effects of subsidence as the newly formed ocean crust moved away from the ocvean ridge. The section provides observation of a well-ordered, gradual diagenesis of deep ocean sediment with increasing depth of overburden and finally the mobilization of silica.

The development of the hemipelagic cover, especially its thickness, is impressive because the site is now almost 2 km above the trench and 20 km seaward. The Mid-America Trench is about 3000 km long, therefore, silt and even sand size material must have been transported across the trench. If the present rate of convergence, 9 cm/yr, is assumed back to the age of the first appearance of hemipelagic material (10 Ma), the resut is a transport distance of 900 km. Interpreted simplistically, the terrigenous source first affected sedimentation when the area of the site was 900 km away. This number is not consistent with the results of other DSDP drilling in this region. For instance, only volcanic ash and no hemipelagic mud was recovered from Sites 156 and 157, about 500 km off South America, or from Sites 84 and 158, which are 240 km and 300 km from land, respectively. Thus, projecting plate convergence rates back 10 Ma may be too simplistic, although the occurrence of hemipelagic sediment seaward of trenches has now been observed in DSDP cores from at least four regions.

The lowest Miocene or possibly late Oligocene age of the crust now entering the trench is considered to have been established by the results from Site 495 and other Leg 67 sites despite the conflict with the map of Pitman and others (1974).

Site 499

Site 499 is on the Mid-America trench floor and the five holes drilled there are at water depths between 6126.5 and 6132 meters. In seismic reflection records across the trench in this location, a sequence of horizontal reflections is underlain by a sequence of gently landward dipping reflections.The first hole (499) was sited to avoid sampling the thickest parts of both sequences. Hole 499 is also slightly seaward of the trench axis to avoid an axial depression and suspected channel fill where excessive sand might prove impenetrable, as happened on Leg 66. After drilling an upper section that is largely mud, the bottom of the channel was drilled (499A) to see if there were more sands in it. When it became known that Site 494 could not be drilled, 499 was paralleled (499B) and drilled to basement depth. The rubbly nature of the basalt recovered impeded drilling to the point where there was danger of getting struck. However, the basalt rubble did not seem to be a convincing basement indicator so another hole (499C), offset .3 km along strike, was washed to basement to try to obtain a better sample. Again the rubbly nature of basement caused sticking of the drill, and drilling had to be stopped. To get a log, 499D was washed, but it encountered a rubbly conglomerate about 50 m above basement.

The lithologic sequence at 499 is the same as at 495, the oceanic reference site, but with the addition of a cover of trench fill turbidite. Trench filling turbidites, 117 m thick, are predominantly muddy, although preferential recovery of mud versus sand is suspected. The same turbidite units appear in the channel, about 1 km away, at Hole 499A without any apparent lateral change. In Site 499 turbidites end abruptly, and burrow mottled hemipelagic muds, calcareous ooze and chalk, and basalt rubble, follow in that order. However, the calcareous section is about 1/3 as thick as it is at Site 495.

The measurements of physical properties and gaseous hydrocarbons also break between the trench fill and the underlying deep ocean section. There is a surprisingly large amount of gas in the trench fill. Methane was the most abundant. Ethane, although in much lower amounts than at site up the landward slope, was unexpected in trench fill (present in quantities up to 20 ppm); it may have been transported with the sediment flowing down slope into the trench.

Conclusions

The trench is filled with a rather uniform upper Quaternary sequence (slightly less than .4 Ma) of alternating muddy and sandy turbidites. The fill was transported from shallower areas landward and deposited rapidly. The young age of these deposits is consistent with rapid subduction, but is not known with enough precision to test more than gross rates of plate convergence. Beneath the turbidite fill there is an abbreviated but complete oceanic section, and thus the sequence of sediment is consistent with that suggested by the seismic data. The cause of the abbreviated oceanic section is indeterminate but it may result from basement irregularity perhaps inherited from conditions at the spreading center. The section at 495 was anomalously thick based on a comparison of the seismic and the drilling evidence.

Site 500

Site 500 is at the base of the Mid-America Trench landward slope at the juncture of the slope and the trench floor. Lithologies and ages are basically the same as at Sites 499 and 495, but basement and hard undrillable cobble conglomerate zones were encountered at unexpectedly shallow depth. In Hole 500 the Quaternary trench-fill turbidite sequence is either faulted or deposited against a fault scarp in lower Miocene chalk; basalt basement occurs at 161 m. At 500A and 500B near the center of the trench, the trench fill turbidites are deeper. Coarse basalt and sandstone cobbles were encountered at 114 and 125 m depth, respectively and proved undrillable in both holes. Neither the basement nor the conglomerates can be clearly identified in seismic records although in hindsight, a strong reflection in GUA-13 may correspond to the basement at Site 500.

Structurally, the bedding in both turbidite and chalk units is nearly horizontal, as is also indicated in seismic records. The chalks preserve structure best and show one or two local, small (less than 50 mm displacement), reverse faults and a well developed slickensided normal fault. Some of the small reverse faults appear to be caused by syn-sedimentary deformation and they are no better developed at this site than at Site 495.

Generally, however, the section at 500 shows no more deformation than the equivalent sections at Sites 499 and 495. A large fault between turbidite and chalk cuts out at least 100 m of section and is interpreted as a normal fault, because given horizontal bedding, it is geometrically difficult to place young rock over old rock and reduce the thickness of the section at the same time by reverse faulting. Furthermore, in brittle chalk, which should be readily deformed, compressional deformation is essentially absent.

Biostratigraphy, as lithostratigraphy, is the same as at the oceanward sites. Surprisingly the depositional rate of trench fill turbidite is about 1/3 the rate previously observed. Very likely this is a function of not having recovered the base of the turbidite. The trench fill contains biogenic components, such as wood fragmens that are more characteristic of slope deposits at 494 than the turbidites at 499.

Physical properties of the section at 500 m are similar to those at 499. The first 80 m appear underconsolidated and the last 40 m are slightly overconsolidated. This pattern is common in the sites drilled on Leg 67.

The composition of gaseous hydrocarbons is similar to what would be expected in a trench. Ethane values are low and most of the gas is methane. It appears that anoxic conditions may exist in the trench as indicated by the development of the large amount of pyrite and H_2S, even in some cores of the chalk.

Conclusions

Site 500, at the front of the subduction zone, does not reveal any more signs of compressive deformation than the two sites further seaward in the trench and on the oceanic plate. Deformational features and physical properties are essentially the same at 500, 499, and 495. The largest structure appears to be a normal fault but there is no way to be sure whether it represents down faulting from the oceanward or landward side (a landward or seaward dip), or whether it is a structure inherited from normal faulting along the trench seaward wall. Nor can the possibility of a transcurrent fault be ruled out. From the drilling and seismic evidence the least likely possibility appears to be a reverse fault.

The structural complexity of the trench at Sites 499 and 500 were unexpected from seismic records alone. The limit of resolution of the seismic reflection technique is demonstrated well by comparison of two multichannel, three single channel, and 3.5 kHz seismic reflection records at this site, with the drilling results.

Site 494

Site 494, on the lower slope of the Mid-America Trench off Guatemala, is just 3 km from, and 580 m above, the trench. It is situated on a terrace, as much as 2 km wide and at least 18 km long, that is like the one Seely and others (1974) interpreted as a large thrust slice. A major objective of the drilling at Site 494 was to test the model of Seely and his co-workers.

A landward continuation of strong reflections from the igneous oceanic crust pass from the ocean basin under the trench and below the site, as shown in the University of Texas (UTMSI) seismic record.

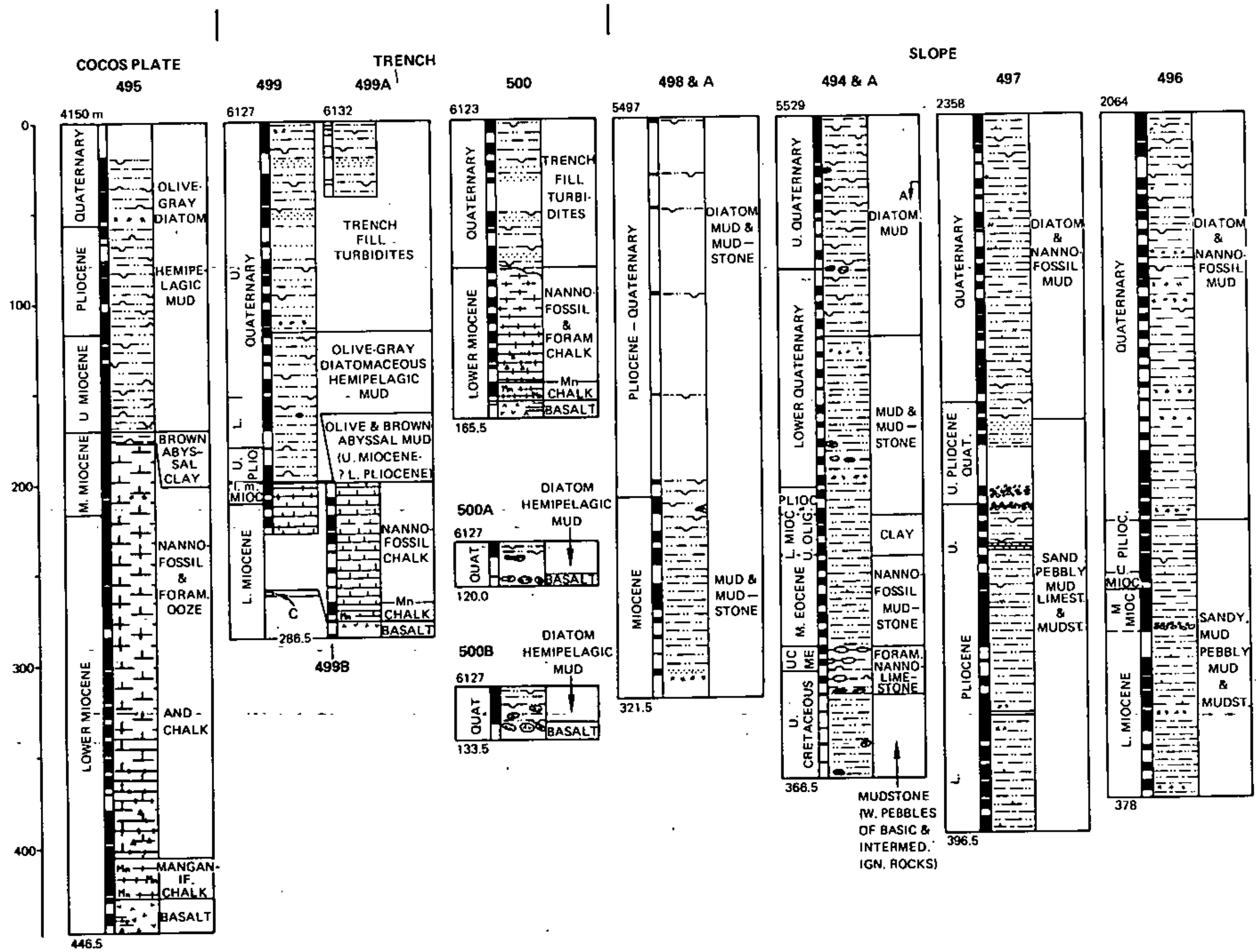

FIGURE 2

Lithology of Sites 494 to 500, Guatemala Transect of the Mid-America Trench

Above the oceanic crust, other reflections suggest a landward dipping section. Above the landward dipping section, at 0.3 and 0.4 sec below the seafloor, some relatively strong sub-horizontal reflections are seen, above which weak, discontinuous sub-horizontal reflections are observed. Drilling at the site penetrated 367 m through the section of weak discontinuous reflections, perhaps to the underlying strong ones, but lack of accurate velocity data precludes precise determination of depth to the seismic reflectors. Study of a detailed high resolution seismic survey around the site, made by the KANA KEOKI during the drilling, shows a strong transverse topographic trend that projects through the site. Thus, the site may be near a major transverse fault.

Below the Pleistocene, the recovery of whole core pieces was rare (average recovery less than 30%), yet overall, the strata occur in an orderly stratigraphic sequence of young over old. From top to bottom, the lithologies recovered are:

1. 213 m of Holocene to Pliocene dark gray diatomaceous mud, decreasing in diatom content downward, containing abundant reworked material from water less than 2000 m deep and sometimes rich in biogenic gas. This sequence is interpreted as a deposit of material transported by downslope sediment movement.

2. 27 m of blue-gray hemipelagic clay separated from units above by an unconformity and identified by early Miocene–late Oligocene nannofossil assemblages consisting of species found in open ocean environments.

3. 54 m of dark gray sandy mudstone of middle Eocene age in which one undisturbed and very complete section has many closely spaced faults with small displacement.

4. 19 m of dark gray mudstone mixed by faulting or drilling disturbance with blue-gray micritic limestone of mid-Eocene and Upper Cretaceous ages, respectively.

5. 9 m of medium gray mudstone of Upper Cretaceous age containing abundant Globotruncana, and the unit has an open ocean character.

6. 5 cores with recovery of small amounts of altered mafic and intermediate igneous rock atypical of ocean floor basalts: it was not possible to determine the type of deposit sampled from the material recovered.

At deeper levels, seismic records indicate continuation of layered material.

Effective overburden pressure and Atterberg limits show apparent over consolidation for the section below 48 to 80 m, a pattern consistent with the response of the section to drilling. Average drilling time in the first 200 m is more than 4 times longer than drilling time required at equivalent depths in 495, the ocean reference site. Below 80 m, the drill cuttings are lithic chips rather than the drill slurry normally produced by drilling mudstone. Such lithic chips have been observed at previous sites (434, 441) when drilling in microfractured rock. Despite the clearly microfractured rock at 290 m, poor recovery precludes establishing the beginning of microfracturing. However, based on core recovery and drilling character, it appears abnormally shallow.

A relatively complete sequence of microfossil assemblages was recovered at the site but with the exception of Quaternary diatoms representatives of most groups are sparse. Benthic foraminiferal assemblages are displaced downslope, especially in the post-Miocene and perhaps post-Cretaceous interval. Nannofossil assemblages lack index species and diversity due to water depth. Radiolarian assemblages are less than abundant, often fragmented, and lack certain index species. Radiolarians were found in older clasts throughout the Pliocene–Pleistocene section.

The paleontology indicates three long hiatuses separating sections of different age and provenance. The sequence, with sedimentation rates uncorrected for compaction, is as follows:

<u>0 - 3.5 Ma</u>

(Pleistocene–upper Pliocene) fauna displaced from 1000–2000 m water depths, sedimentation rate 55 m/Ma.

<u>3.5 - 18 Ma</u>

Unconformity, contact observed.

18 - 25 Ma

(Middle Miocene-Upper Oligocene) fauna deposited near CCD, about 3000 m, sedimentation rate 3 m/Ma.

25 - 45 Ma

Unconformity or fault, contact not observed.

42 - 46 (?) Ma

(Middle Eocene) fauna deposited below the foraminiferal CCD but above the nannofossil CCD, sedimentation rate 10 m/Ma.

46 (?) - 68 Ma

Unconformity or fault, contact not observed.

68 - 71 (?) Ma

(Upper Cretaceous) open marine fauna, above CCD, sedimentation rate 2.5 m/Ma (?).

71 (?) Ma

Contact not observed.

Gaseous hydrocarbons in the section are mainly methane and only minor amounts of ethane were observed. The ethane might be concentrated in a specific interval and migration may be controlled by lithology.

Conclusions

If the Mid-America Trench transect off Guatemala is viewed as a test of the imbricate accretionary model proposed for this margin by Seely and others (1974), the results from study of the cores from 494 are surprising in two respects. First, the discovery of rock as old as the Upper Cretaceous within 3 km of the trench, which is underlain by subducting ocean crust of early Miocene age, is unexpected. Second, the regular downward ordering of rock age over 360 m and 70 Ma time, young on top to old below, at the foot of a convergent margin indicates that the section isn't itself cut by thrust faults, because imbricate thrust faulting would reverse the order of rock age from young to older above. However, the total section could be contained in a larger thrust slice. The data from this single site seems somewhat inconsistent with the simple imbricate thrust model, but they are not complete enough to change the model or to convincingly constrain an alternate model. The data are minimal because the length of hiatuses in the section exceeds the period of time represented by the rock samples, and the overall core recovery was less than 30%.

The sequence drilled could have been transported as a large block from a landward location or part of it from a seaward source, or it might have originated near its present position with respect to a continental sediment source. The original environments represented by the sequence, and the nature of the hiatuses between them, are interpreted from top to bottom as follows:

1. A Plio-Pleistocene deposit consisting principally of material transported from the shelf and upper slope to the site.

2. An upper Miocene unconformity coincident with the widespread upper Miocene unconformity on the shelf.

3. A lower Miocene hemipelagic clay that accumulated in water near 3000 m and at rates an order of magnitude slower than age equivalent deposits on the adjacent shelf (3 m/Ma vs. 100 m/Ma), and thus recovered section is a distal terrigenous sequence.

4. An upper Eocene-Oligocene hiatus, the age equivalent of a widespread unconformity in the adjacent shelf section but of unknown origin in the section drilled.

5. An Eocene hemipelagic clay deposited below 3000 m depth at rates at least 5 times slower than age equivalent shelf deposits (maximum 10 m/Ma vs. 55 m/Ma).

6. A hiatus of unknown origin and of an age represented by thick, widespread Paleocene sediment on the adjacent shelf.

7. An Upper Cretaceous claystone that accumulated in an open ocean environment, above the CCD, and at depths about equivalent to, but at rates apparently lower than the age equivalent rocks on the present shelf.

8. A contact of unknown origin.

9. Igneous rocks originally of basaltic and andesitic composition and atypical of igneous oceanic crust; the type of deposits or body sampled is unknown.

10. A layered sequence of rock at least 500 m thick as indicated by seismic and magnetic records and resting on probable Miocene igneous ocea crust. The lithology and age of this sequence remains unknown without further drilling.

The sequence shows apparent signs of tectonic stress from the base of the Pliocene section, but the age of various episodes of deformation earlier than the Pliocene is undetermined. Although there are hiatuses of unknown origin below the Miocene, the sequence of ages remains essentially normal and there are no major repeated sections. Thus, major thrust faulting and subduction must be confined to the undrilled section.

Site 498

Site 498, on the landward slope of the Mid-America Trench, is located in about 5440 m of water, and on a narrow terrace about 400 m above, and 4 km from the adjacent trench axis. This position is about 1.8 km ESE or down strike from Site 494. A preliminary compilation of KANA KEOKI bathymetric and seismic records made during GLOMAR CHALLENGER drilling at Site 494 suggested that the site is located in a zone of faulting transverse to the trend of the trench, a coincidence perhaps responsible for the low core recovery at 494. Based on geophysical data, Site 498 is in a less faulted but structurally identical position as Site 494. Site 498 was drilled to fill the gaps in the stratigraphic section of Site 494 and to establish the nature of critical contacts missed during the previous drilling. However, the recovery of clathrate caused abandonment prior to reaching depths greater than at Site 494.

The mud and mudstone from the first 213 m of 498 is esentially identical to that at Site 494. This dark olive gray sediment resembles the downslope apron recovered at previously drilled sites. Abundant biogenic material transported from upslope was observed. This unit, which is of Plio-Pleistocene age, is underlain by a unit of similar lithology of Miocene age. The Miocene lithology is dissimilar from the lithology of equivalent age rock in 494. The unbrecciated part of the section is dark olive gray mudstone although chips of the familiar blue-gray Miocene mudstone of 494 are abundant in the drilling breccia, which constitutes most of the recovered material. Additionally, at 498, the Miocene section is thicker than at 494 where the equivalent interval is not only of Miocene but also of Eocene age. The poor core recovery and drilling conditions below 213 m at 498 indicate that fracturing is well developed.

The disparity between the Miocene lithologies at these two sites, 1.8 km apart, indicates a degree of variability in rocks and ages along strike. Perhaps the regularity of horizontal reflections in seismic records gives a deceivingly simple picture of the lower slope structural complexity.

The biostratigraphy of this site appears disordered in part by the mixed and poorly recovered drill breccia. Three intervals of repeated ages are evident and poor recovery can explain two of them. The third repeated age sequence may be caused by downslope reworking of older mudstone clasts, for instance the blue gray Miocene mudstone or tectonism.

Gas hydrates were encountered at about 310 m. The single occurrence of hydrates was accompanied by a single rapid increase of the methane/ethane ratio. The presence of hydrates was again confirmed by placing the icy sediment in a sealed vessel and measuring pressure as the hydrate came to ambient temperature.

Conclusions

The similarity of Plio-Pleistocene downslope lithologies at Site 494 and 498 is indicative of comparable structural histories during this time interval, but the differences between Miocene lithologies at equivalent depths is suggestive of tectonic displacement between Miocene units one mile apart.

The presence of gas hydrate was the most dramatic difference between Sites 494 and 498. On deck, the "smoking," unopened core betrayed the now familiar association of coarse grained vitric sand, between 300-400 m depth, and clathrate. The recovery of clathrate and a single low methane/ethane ratio caused the premature end of drilling at this site.

Site 497

Drilling was stopped for reasons of safety at Site 497 prior to reaching the original objectives. The Plio-Pleistocene section cored was recovered previously at Site 496 only 5 km away. The dominant lithology encountered is olive gray, hemiterrigenous mud, with varying minor biogenic and vitric constituents. A short period of rapid deposition of sandy mud and pebbly mudstone occurs at about 280-295 m.

Near vertical dark veinlets, probably associated with dewatering and syn-sedimentary tectonism, occur in the lower, more lithified part of the section.

Microfossils of Quaternary and Pliocene age are generally abundant in the section and no unusual age discrepancies were observed. Ages increase linearly with depth except in the pebbly mudstone interval where the rate is high, and immediately below the interval where for a short time, the rates are exceptionally low.

The sediment has physical characteristics that change with depth in much the same manner as those at Site 496. The effects of gas and perhaps gas hydrates are obvious in the small change of void ratio with depth. Perhaps excess pore pressure, related to expansion of gas, has affected the lower part of the recovered section.

Seismic records between 496 and 497 indicate a thinning of the Neogene section toward 497. Drilling shows, however, that the Pleistocene is thinner but the Pliocene is much thicker at 497 than at Site 496. The reason for this discrepancy between the seismic interpretation and drilling is not obvious.

Several lines of evidence were used to document the presence of clathrate at this site. Probably the most convincing evidence is from pieces of frozen vitric sand allowed to come to ambient temperature in a pressure vessel. However, the overall methane/ethane ratio was much higher (more biogenic) than at equivalent depths in Site 496. Variation of the ratio and the accompanying variation of trace amounts of heavier hydrocarbons, indicates local variability between the sites with respect to hydrocarbon composition.

Conclusions

The section recovered at Site 497 is a monotonous, hemipelagic hemiterrigenous slope section with a thin, pebbly mudstone probably representing downslope mass movement. The rate of sedimentation decreases for a short period in the upper Pliocene. Clathrates at this site and frozen materials (probably clathrate) at Site 496 occur at about the same depth but in sediment of different age. Clathrate occurs in vitric sand and not throughout the core indicating an association between lithology and the occurrence of clathrate.

Site 496

Drilling at Site 496 ended at 376 m, about 500 m short of the principal objective. This objective was to sample rock represented in seismic profiles by landward dipping reflections at the top of a high velocity body. The section above this body is a cover of slope deposits that appears to unconformably drape the sediment and rock comprising the bulk of the continental margin. Drill samples showed that the slope cover consists of an upper sequence of biogenic mud (0 to 226 m) of Quaternary age. Beneath this sequence is a similar but semi-lithified biogenic sandy mudstone (226-387 m) of Pliocene to Miocene age. Both units are rich in terrigenous detritus, some volcanic ash, and rare lignite.

All three microfossil groups being studied onboard are represented in this section. Radiolarians are sparse due to dilution by terrigenous debris, and reworked older species indicate an area of older source rock. Nannoplankton are rare to abundant. Above Core 31, nannoplankton assemblages are oceanic; below Core 31, they are typical of shallow water. Benthic foraminifera also indicate subsidence of this area in Miocene time, from shelf to lower bathyal depths. A well-defined reduction in rates of sedimentation or perhaps a hiatus is seen in the upper Miocene and Pliocene.

Physical properties measurements show a clear difference between the upper soft mud and the lower semi-lithified mudstone. No velocity measurements were possible because of gas content. The upper sediment appears underconsolidated whereas the lowermost sediment appears overconsolidated.

Gaseous hydrocarbons were abundant at this site. The methane/ethane ratio decreases abnormally fast, and in the last three cores heavier components up to C-5 appeared. This evidence of proximity to petroleum and apparent high pressure in the core, caused abandonment.

Conclusions

Litho- and biostratigraphic data in the section penetrated at Site 496 are consistent with the seismic interpretation of a downslope apron of sediment. The section is at least as old as early Miocene at which time deposition was in much shallower water than at present. This period of shallow water deposition may correspond to the period of erosion on the shelf in Oligocene and earliest Miocene time (Seely, 1979) but, unfortunately, drilling had to be terminated before this possibility could be adequately tested. There is another curious period of relatively slow deposition or perhaps a hiatus in late Miocene and Pliocene time that may correspond to a hiatus on the shelf during this period. The subsidence of this site in early and mid-Miocene time is consistent with the interpretation of Seely (1979) for the adjacent shelf.

Lithology, sedimentation rates, and paleo-depths based on microfossils indicate that the lower and mid-Miocene sediment recovered at 496 is of a facies more proximal to a terrigenous sediment source than the sediment facies recovered at Site 494 on the trench lower slope. The Miocene section at Site 494, therefore, must originally have formed seaward of the Miocene section at Site 496. A long distance of tectonic transport from a landward source seems unlikely for the Site 494 Miocene section unless there has been lateral faulting of one section with respect to the other.

LEG 67 CONCLUSIONS

The discovery of clathrate greatly changed the emphasis of Leg 67. Originally most of the time was planned for drilling on the trench landward slope; however, the repeated recovery of clathrate, which for reasons of safety prevented drilling there, resulted instead in our spending about one-half of the drill time in the trench and on its on oceanward slope. Thus, the original plan, to link the geology of the Nicoya Complex and the shelf to that of the trench slope, and to understand the geology of the slope in terms of the origin of the trench wall, was not realized. Nonetheless, the results of Leg 67 show a change in rock and structure at the trench more fundamental than expected from the simple accretionary model, a change that only becomes fully apparent in the pre-Pliocene rock. Lower Miocene chalk and basalt of the incoming ocean basin lithosphere are immediately adjacent to the trench landward wall which consists of continentally derived Upper Cretaceous through Miocene mudstone. The implications of this discovery are that a great amount of oceanic sediment has been subducted without accretion to the continent and that the theoretical orderly imbricate stack resulting from subduction is too simplistic a model to explain the age and rock sequence recovered.

The rock recovered from sites of the Leg 67 Mid-America Trench transect, particularly those of pre-Pliocene age, can be separated into an oceanic and continental group (Figure 2). The oceanic group, best sampled at the ocean reference site (495), has sediment that clearly records northward passage of the Cocos Plate beneath the equatorial carbonate belt, and into proximity of a terrigenous source. The sediment also records subsidence of ocean crust with age and distance from the ocean ridge. This oceanic reference sequence is normally faulted as it enters the trench (Sites 499 and 500) and before subduction it receives ponded turbidites that collect in the trench. Surprisingly, the composite, oceanic sediment section recovered at the foot of the trench landward wall has recorded little added deformation or consolidatin to mark its passage across the trench into proximity of the assumed thrust zone.

The continental material recovered 3 km away from the trench on the landward wall appears more deformed, and also includes rock of greater age. The Miocene rock is a distal, terrigenous mudstone sequence deposited near 3000 m water depth. The Eocene rock is of similar facies deposited in water deeper than 3000 m and the Upper Cretaceous rock has a continental source but was deposited under open ocean conditions and above the CCD. Rocks of Upper Cretaceous and Eocene age on the oceanic plate are carbonate: rocks of Upper Cretaceous to Eocene age on land are largely shelf and shelf basin clastics. Therefore, much of the pre-Pliocene sections recovered at 494 appear to have greater continental than oceanic affinities. Just where these rocks under the trench landward slope were originally deposited is not known, but large tectonic transport is not required to explain their position.

The apparent few hundred meters separating older mudstones at the foot of the trench slope from incoming Miocene ocean crust is hardly sufficient to accommodate accretion of the vast quantity of ocean sediment that passed through the trench as crust of Eocene or Upper Cretaceous to Miocene age was subducted. Therefore, since little material could have been accreted at this part of the margin, most of it must have passed under the slope.

The contrast in original provenance of rocks at the trench-slope juncture diminishes in the Plio-Pleistocene sediment. The trench landward slope consists of mud and sand, much of which was deposited during the downslope transport that also carried material to the trench. Ponded sediment in the trench has the highest rates of sedimentation but a small volume, and rates measured locally on the slope (Figure 3) are almost equally as great. Paradoxically, a foraminiferal fauna transported from very shallow water was recovered from the trench. Thick (170 m), hemipelagic mud recovered 20 km seaward and 2000 m above the trench (495) has a transport history across the trench that is more difficult to explain. Foraminifera foreign to the deep ocean were recovered at the ocean reference site. These interesting observations not withstanding, the Plio-Pleistocene sequence of sediment from landward to seaward is consistent with the present geologic setting. Thus it seems that a trench has been in this area since at least the Pliocene. But from the Leg 67 data it cannot be established exactly when the present trench first formed. Either a late Miocene initial age, as has been proposed for the trench north of the Tehuantepec Ridge or an earliest Pliocene age is consistent with our data. The pre-Pliocene configuration of the margin is as yet problematical.

The Leg 67 drill and seismic data give a revealing but incomplete picture of the complex local structural fabric superimposed on the trench. We showed by drilling that the seismically deduced sequence of basalt, ocean basin sediment, trench turbidite does in fact, exist. A few normal and reverse faults were observed in cores from both the ocean reference and trench sites. The reverse faults have small displacement (less than 50 mm) and are sometimes syn-sedimentary. The normal faults in cores are larger and tectonically more significant. Normal faulting also dominates the trench seaward wall in seismic records and are covered by trench fill. A normal fault was apparently penetrated at the foot of the landward slope (Hole 500). This fault, with more than 100 m displacement, is obscure in the seismic records, and thus its dip direction and extent are conjectural (Figure 4). Three seismic lines a few hundred feet apart, navigated accurately using the CHALLENGER positioning system and seafloor beacons, each differ with regard to the local structure recorded. A similar degree of complexity was found in comparing the Miocene rock from Sites 494 and 498, 2 km apart, and in comparing seismic and drill results between Sites 496 and 497 on the mid-slope. The limited resolution of the reflection seismic technique in deep water is demonstrated well at all Leg 67 sites, even at the ocean reference site where 100 m more section was recovered than is illustrated on the multichannel seismic record. However, the gross features in seismic records, especially when constrained by limited drilling and logging, appear to give resolution within roughly 100 m. Although it would seem more comfortable to have evidence for compressional structure at the base of the landward trench slope, the combined drill and seismic data are most simply interpreted as showing normal faults, perhaps, but not necessarily, inherited from the normal faulting along the trench seaward wall. Additionally, there is no direct evidence of imbrication of underthrusting to the levels drilled, which emphasizes the great importance of penetrating the master thrust fault of the subduction zone with the drill.

Leg 67 results bearing on regional geology are the dating of the Cocos Plate and some possible limits on Caribbean Plate movement. If the direction and succession of magnetic anomalies is parallel to the East Pacific Rise, than the Cocos Plate is oldest at the Mid-America Trench where drilling in three holes recovered lowest Miocene sediment on top of ocean basalt. Formerly, this area was thought to be of Eocene age. Thus the same disparity between magnetic anomaly determinations and sediment ages of the Cocos Plate found on Leg 16, was found also on Leg 67. If the Miocene age is accepted, it removes the presently proposed complex and nonsymmetric spreading from this area.

Another regional implication is related to the history of the Caribbean plate. The Cretaceous and Eocene rocks recovered at Site 494 appear to have affinities with rocks that crop out in Costa Rica and Panama. Those rock outcrops are extended by geophysics along the Mid-America Trench to the Tehuantepec Ridge. Since they have terrigenous affinities it appears that the influence of the North American continent extended south of the proposed transform Caribbean plate boundary during this time. Thus it is possible that the proposed large eastward movement of the Caribbean plate did not occur after Maastrichtian time.

Leg 67 samples verified the existence of clathrate. Melting of the ice liberated greater quantities of gas than is soluble in water at <u>in situ</u> pressure and temperature. Gas hydrates were recovered a two sites and are suspected to have been recovered at a third. Using uncorrected temperature gradients from logging (probably maximum gradients), pressure-temperature conditions on much of the margin are far into the gas hydrate stability field. Sutiable pressure-temperature conditions however, are only a partial requirement for clathrate; gas in proper quantity and composition is also necessary. The regular association of vitric sand and clathrate on Leg 67 suggests that greater porosity than that of the hemipelagic mudstone is required to accumulate sufficient gas to form enough clathrate so that the ice can be recovered at the surface.

Rock-Eval and C-H-N data indicate a terrestrial origin for most of the sedimentary organic matter. Lignitic or woody material is present on the slope and even 20 km seaward of the trench on the oceanic plate. Carbon values for the slope sites average about 2-3.5% in Quaternary sediment, and about half as much was measured in the underlying sediment. The history of the closing of the former Panamanian waterway may have affected the organic carbon input. One expected consequence of a landmass between the Americas is a change to more tropical climate which could in turn affect the composition of terrigenous input.

On Leg 67 we drilled through a trench sequence into the ocean crust. Our study indicates that subduction necessitates neither accretion of ocean plate sediment at the foot of the trench landward slope nor pervasive compressional structure. We also recovered physical evidence of clathrate from the trench slope.

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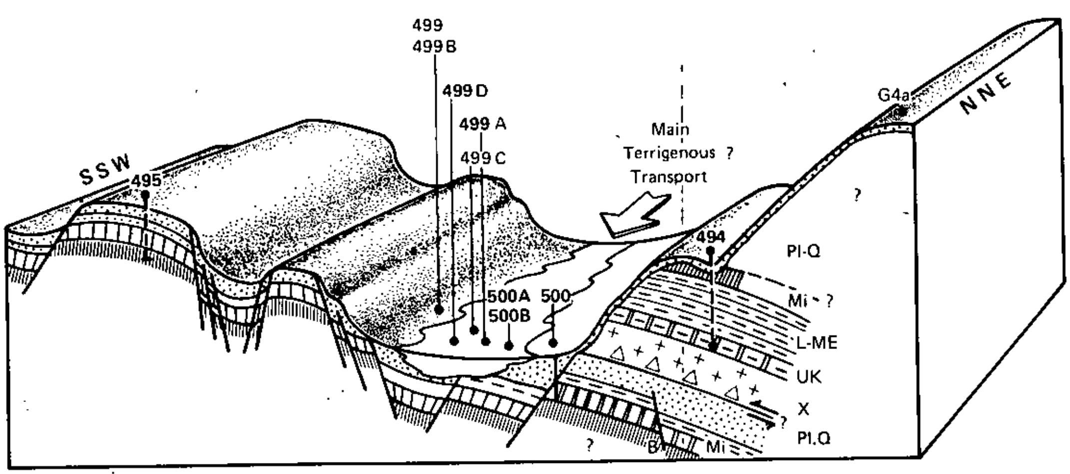

FIGURE 4

Block diagram of Mid-America Trench axis.
Drilling at Sites 499 and 500 suggests normal faulting of the oceanic sedimentary section buried beneath turbidites of the trench axis

LEG 68/HPC
(Co-Chiefs: J. Gardner and W. Prell)

The recovery of undisturbed sections of unconsolidated deep-sea sediment has long been a goal of DSDP. Unfortunately, rotary drilling usually disturbs unconsolidated sediment which renders them useless for high-resolution investigations. However, the recently developed DSDP Hydraulic Piston Corer (HPC) provides an opportunity to obtain these previously unrecoverable sediments. Leg 64 used the HPC and successfully recovered a spectacular section of varved, diatomaceous sediment at Site 480 in the Gulf of California (Curray, Moore, et al., 1979).

Leg 68 took advantage of the HPC capability by devoting an entire leg to recovery of two undisturbed Neogene sections from sites previously drilled by conventional drilling techniques. Drilling at Site 154 in the Caribbean and Site 83 in the eastern equatorial Pacific recovered very disturbed sediments but the section did allow the recognition of sediment thicknesses, gross accumulation rates, and abundances and preservation of microfossil groups. Leg 68 was to return to these two sites and recover an undisturbed and continuous Neogene section. During Leg 68 two sites were cored (Figure 5).

Our major scientific objectives for Leg 68 were:

1. To determine the high-resolution Neogene biostratigraphy of each site and correlate it to the detailed paleomagnetic stratigraphy;

2. To determine the detailed oceanic record associated with events such as the closing of the Isthmus of Panama and the initiation of glaciation in the northern hemisphere; and

3. To study the inter-relationships of Quaternary and Neogene paleoceanographic phenomena. The planned coring also provided an extensive test of HPC operations on-board the GLOMAR CHALLENGER that will define the limitations of the HPC system, the number of holes necessary at a site to ensure complete recovery of the stratigraphic section, and the best means of processing HPC cores onboard the ship.

The use of the HPC to obtain long, continuous sections of undisturbed sediment poses several questions concerning the continuity of section and detailed correlation between multiple holes. Because the sediments recovered by the HPC should be largely undistrubed, they will be used for studies of high-frequency biotic and sediment variations. The precision required by such studies places new demands on the CHALLENGER coring operations and on the level of detail of shipboard duties.

Two specific questions which concern the correlation of cores and holes were raised on Leg 68. First, is any section lost between successive HPC cores, and second, can a continuous stratigraphic section be recovered by overlapping cores?

Overall the HPC worked flawlessly throughout Leg 68. We found that the HPC strokes out to its full 4.4 m length in sediment with shear strengths 1200g/cm^2. Shear strength between 1200 and 2500 g/cm^2 did not inhibit coring, but the HPC did not extend its 4.4 m. Shear strengths 3000 g/cm^2 halted recovery and we feel that this is the limit for coring with the HPC. When the HPC did not fully extend during coring, we lowered the drill string to the nearest 0.5 m less than the previous recovery. This scheme worked exceedingly well for us. Recoring unrecovered intervals was not successful.

The HPC cores are virtually undisturbed when compared with conventional DSDP drilled cores. Special attention was given to deformation of any kind in this series of holes because of its possible influence on paleomagnetic measurements and as an indication of the performance of the HPC. We estimate that about 90% of all sediment recovered had no deformation of any kind. When present, disturbed sediments almost always occur in Section 1 of the cores and probably represent downhole contamination rather than uncored section. Our HPC coring procedure almost insures overcoring of previous cuttings in order to recover a complete section. This type of deformation is easily identified and presents no problem in constructing complete sections.

We examined the possibility of missing sediment between successive cores by comparing the detailed records of carbonate and paleomagnetic intensity (NRM) for Holes 502 and 502A. We estimate that the 30-cm sampling interval for carbonate represents 12.5 x 10^3 yr intervals, respectively. Figure 6 shows the percent carbonate plotted versus depth in Holes 502 and 502A along with the core breaks and intervals of no recovery.

We believe that the sediments recovered from the Brunhes Epoch are virtually complete based on the correlation of

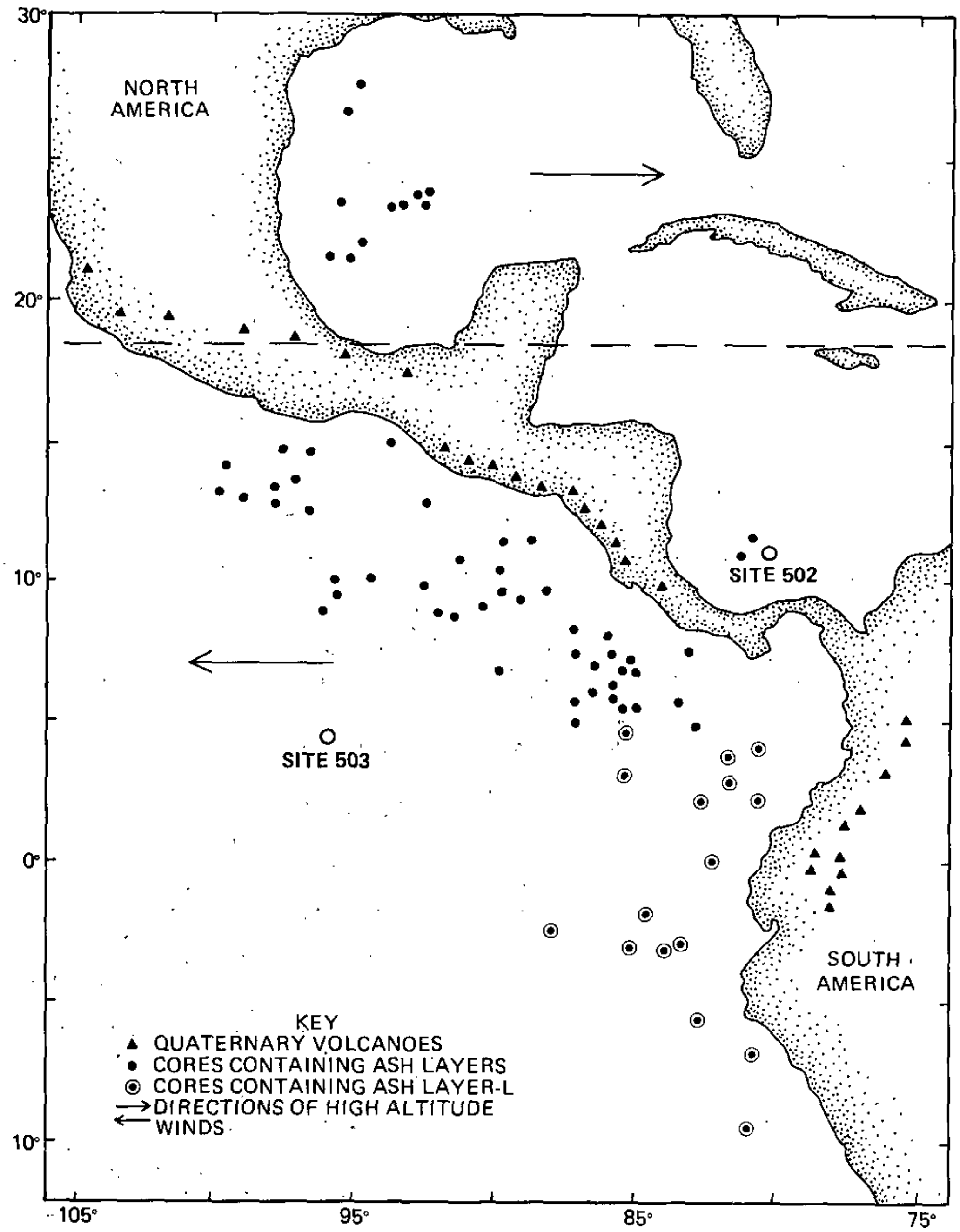

FIGURE 5

Location map of Sites 502 and 503

carbonate stages between Holes 502 and 502A and comparison of these carbonate data to the oxygen-isotope curves of V28-238 and V28-239 (Shackleton and Opdyke, 1976). We have identified all the isotope-carbonate stages in the Brunhes Epoch (Figure 6). No stage was eliminated due to non-recovery. The largest gap occurs in Stage 7 of Hole 502A and is 50 cm in length (about 20 x 10^3 yr). A similar case can be made for the NRM data although they contain high-frequency noise due to occasional particles of rust from the drill pipe.

The strategy of overlapping cores in adjacent holes was successful and insured a complete section. We found the major obstacle to recovering a continuous section was failure of the core catcher and brittle fracturing of the core liner.

We encountered minor problems, especially at Site 502 in correlating paleomagnetic boundaries, ash layers, and biostratigraphic horizons between holes on the basis of sub-bottom depths of discrete events. Sub-bottom depths of discrete events at Site 502 varied by as much as 5 m. Events at Holes 503A and 503B were within 1 m of each other. Differences in the sub-bottom depth of events would not be recognized in rotary-drilled sediment because of the disturbance and the large distance between holes. The possibility of correlating adjacent holes on a scale of cm's or tens of cm's also places new demands on our ability to measure the length of the drill string.

Sites 502 and 503 were selected to provide continuous records of the biostratigraphy and magnetostratigraphy of the low latitude Atlantic and Pacific Oceans. We recovered virtually complete sections by continuously coring several holes at each site, and overlapping the cored intervals in one hole and the core breaks in adjacent holes.

Site 502

Site 502 is located at 11°29'N and 79°23'W in the Western Caribbean. Site 502 is near Site 154 but is located on a topographic high to avoid the turbidite sands encountered at Site 154. The acoustically-transparent section has diffuse reflectors which suggests that Site 502 should have a longer record and possibly more pelagic sediment than Site 154.

The primary objectives at this site were:

1. To recover a complete record of the late Neogene and Quaternary in a carbonate section with a relatively high accumulation rate; and
2. To obtain a detailed paleomagnetic stratigraphy to correlate with the biotic and volcanic history associated with the closing of the Isthmus of Panama.

Four holes were cored to a maximum depth of 228.7 m. Although recovery varied, the composite section is a virtually continuous, undisturbed record from lowermost upper Miocene to Holocene (Figure 7a). The sediment consists of foram-bearing nanno marl which grades to calcareous clay with depth. The top 7 m of the section is yellowish brown but the remainder is various shades of gray to greenish gray. The later colors indicate reduced conditions and because the upper section is oxidized, we feel that post-depositional reduction of sediment is pervasive.

We divided the section into four lithostratigraphic subunits, based on differences in color, foram content, and the ocurrence of siliceous microfossils. We found distinct cyclic variations in carbonate content, foram abundance, and physical properties of the sediment superimposed on the dominant lithology. We found that shear strength increased uniformly from about 100 g/cm^2 to 3000 g/cm^2 with a rapid increase at 88 m and 110 to 130 m. The shipboard carbonate data for Holes 502 and 502A show a cyclicity which correlates with oxygen-isotope cycles of the Brunhes Epoch (Shackleton and Opdyke, 1976) and carbonate fluctuations from the Caribbean (Prell, 1978) and inversely with carbonate cycles from the Pacific (Hays, et al., 1969). The periodicity in carbonate for the Brunhes Epoch from Site 502 averages about 70,000 years per cycle, similar to other isotope and carbonate records (Shackleton and Opdyke, 1976; Hays, et al., 1969; Dean, et al., 1977). The record at Site 502 extends these carbonate cycles back through the early late Miocene. Although the amplitude is variable, we find that the length of the carbonate cycles does not change with depth, and the accumulation rate is almost constant. Climate-related variations in sea level and carbonate dilution, productivity and dissolution have been used as the predominant forcing function for both the carbonate and isotope fluctuations for the Quaternary (Cline and Hays, 1976; Prell, 1978). Our data supports the suggestion by Dean, et al.

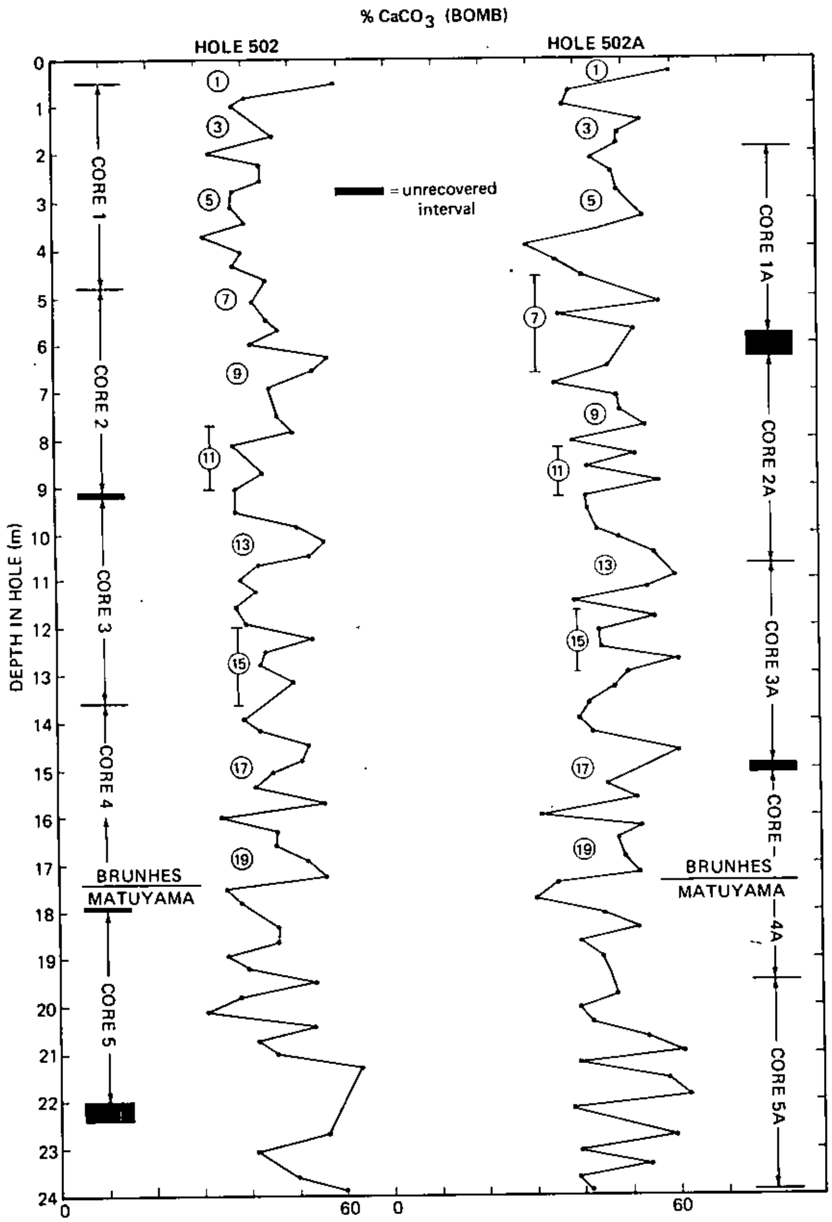

FIGURE 6

Correlation of carbonate curves for Brunhes Epoch of 502 and 503

(1977) that these climatic events can be extended at least back into the Miocene. However, in the case of Site 502 we have a detailed, high resolution record of the history of these fluctuations.

The high accumulation rate and long record (>7 Ma) of Site 502 provides a unique section for identification of paleomagnetic epochs and events, and increases the resolution of the paleomagnetic stratigraphy by a factor of two. We can identify all 19 major paleomagnetic events of the Pliocene and Quaternary in this section (Figure 7). Although the record continues into the Miocene, shore-based work is necessary to resolve the details of that period. This record should provide a new high resolution standard for age calibration of biostrtatigraphic horizons.

In addition to the major paleomagnetic events, several excursions of the field were observed within the Matuyama Epoch near the Jaramillo Event. These normal-polarity excursions appear to be real (several are 30-cm long) and will provide new paleomagnetic datums.

We found the calcareous microfossils of Site 502 to be generally well preserved, diverse, and abundant. Well-preserved siliceous microfossils are found in the top few meters of the section and then not again until lower upper Miocene sediment was encountered. We do not observe enhanced preservation in association with volcanic ash. Very rare fragments of radiolarians, sponge spicules, and diatoms did occur throughout the whole section which suggests that silica dissolution has been very active throughout most of the Neogene.

With curious exceptions, the assemblages were tropical throughout the section. Early Pliocene and older sediment has abundant sinistral Neogloboquadrina pachyderma associated with predominantly tropical assemblages. N. pachyderma is a planktonic foraminifer that, in Quaternary sediments, is known to inhabit polar waters. The sinistral-coiling form is the coldest water affinity of the genus. This same association was noted in sediment from Site 154A (Keigwin, 1978). To our knowledge this peculiar association has not been described elsewhere. At this point, we can only speculate that either the Columbian Basin experienced a time of increased seasonal upwelling or that the early form of N. pachyderma was not a cold water species. We also identified occasional specimens of Discoaster icarus, a species which has been reported only from the late Miocene of the Mediterranean. The occurrence of this species in sediment from Site 502 occurs stratigraphically lower than it does in the Mediterranean but its environmental significance is presently unknown.

The basalt sediments of Site 502 are early late Miocene, based on nannofossils (D. neomamatus Zone, D. bellus Subzone), radiolaria (O. antepenultimus Zone), and diatoms (occurrence of N. porteri and T. burkliana).

Accumulation rates at Site 502 reflect the complex interaction of carbonate productivity, carbonate dissolution, terrigenous influx and tectonic uplift. The bulk rates decrease from late Miocene (4.85 $g/cm^2/10^3$ yr) to Quaternary (2.6 $g/cm^2/10^3$ yr) with an interval of high accumulation (4.7 $g/cm^2/10^3$ yr) at approximately 3.6 Ma and a rapid decrease from 3.45 $g/cm^2 10^3$ yr at 2.1 Ma to the Quaternary rates. The ratio of non-carbonate to carbonate flux decreases from 2.43 g/cm^2 in the late Miocene to approximately 1.14 10^3 yr at about 3.6 Ma and then remains constant through the remainder of the Pliocene and throughout the Quaternary (Figure 8a).

The decrease in accumulation of non-carbonate (mostly clay) sediment at Site 502 may be explained by a decrease in the source of clay or by the site being uplifted above the active benthic boundary layer of transport of clay. Comparison of the reflector (turbidite sands) in Site 154 and reflection profiles in the adjacent basin indicates that turbidite deposition has been active from late Miocene through Holocene. The lack of turbidites indicates that Site 502 was uplifted above the level of turbidite deposition prior to 7 Ma. We note that this uplift substantially predates the uplift of Site 154 which is located on a much smaller ridge between Site 502 and Central America.

Because the terrigenous flux has not decreased, we interpret the time when the non-carbonate/carbonate flux became constant (about 3.6 Ma) to reflect the site's elevation above the level of dominantly benthic boundary layer deposition. The 3.6 Ma datum is an interesting time because it falls within the period that the Isthmus of Panama is thought to have closed (Kaneps, 1970; Saito, 1976; Keigwin, 1978).

Site 503

Leg 9 of DSDP drilled Site 83 on the eastern flank of the East Pacific Rise and recovered sediment which indicates that an almost continuous pelagic section of the past

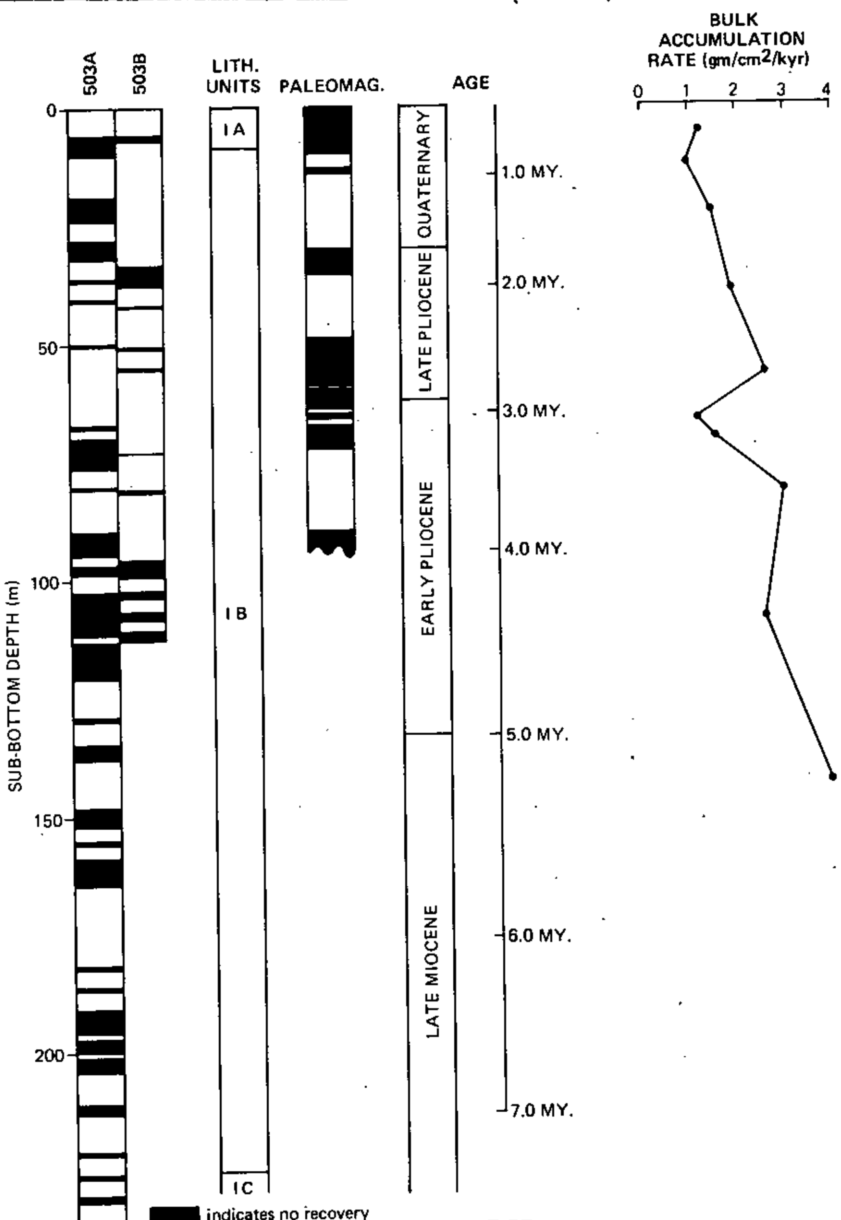

FIGURE 7B

Summary Diagram of Site 503

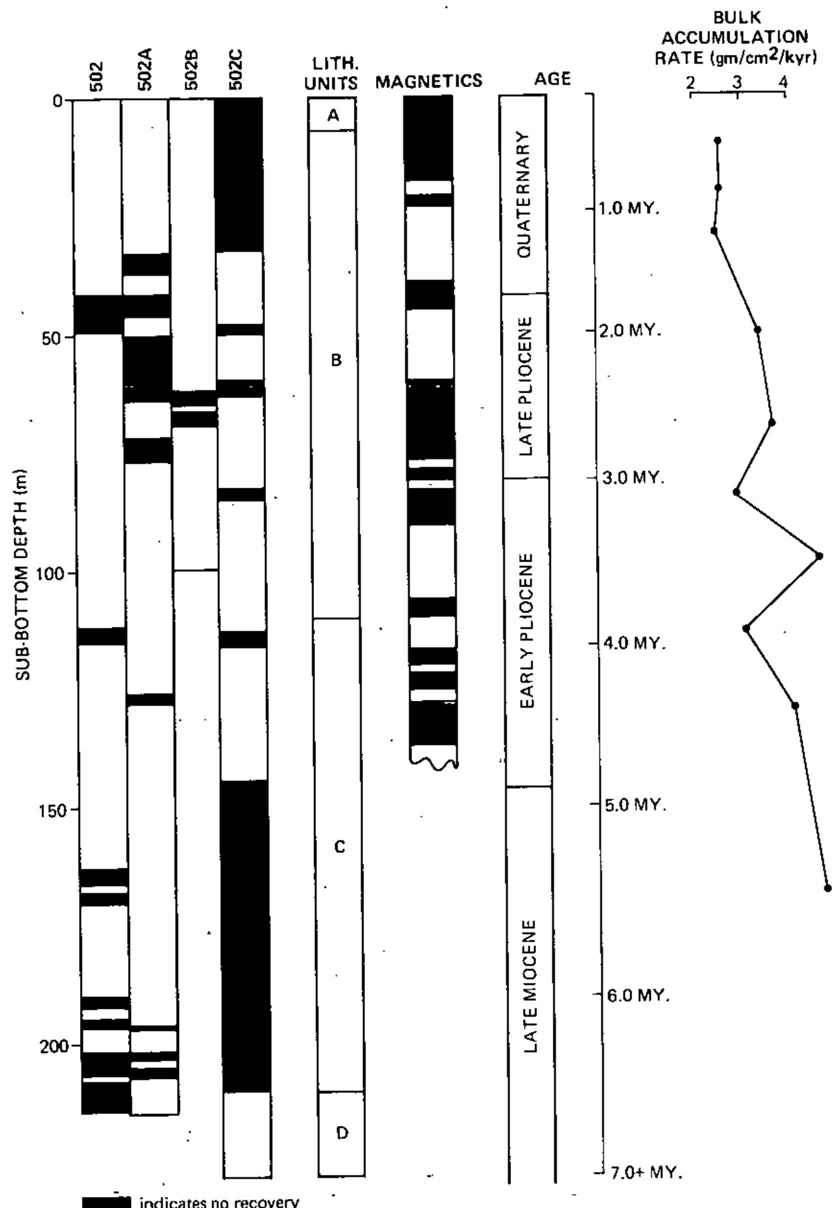

FIGURE 7A

Summary Diagram of Site 502

10 Ma of the Neogene (Hays, et al., 1972) exists there. Unfortunately, the sediments recovered at Site 83 are badly disturbed by rotary drilling and most of the detailed record is lost. Overall, the section has a uniform accumulation rate of 2.0 to 2.5 cm/10^3 yr with good to moderate preservation of all the major microfossil groups. We returned to Site 83 to recover the same section using the hydraulic piston corer (HPC).

Our primary objective was to recover a complete, undisturbed Neogene section, to compile, together with the data collected at Site 502, a high resolution intercalibration of the Neogene magnetostratigraphy with both Atlantic and Pacific biostratigraphy. In addition, the evolution of equatorial foraminifera, nannoplankton, radiolaria, and diatoms throughout the Neogene should be available for study in one section with excellent time control. We should find a detailed history of the Neogene oscillations in oceanographic conditions, as revealed by fluctuations in isotopes, carbonate and opal contents, and faunal and floral assemblages. We should be able to address the questions of timing of the closing of the Isthmus of Panama and initiation of Northern Hemisphere glaciation by combining the record at Site 503 with that obtained at Site 502.

The sediments at Site 503 should record changes in surface circulation, especially the Equatorial Undercurrent and the South Equatorial Current which respond to changes in atmospheric circulation. The record of intensity changes of the southeast trade winds may be reflected in the quartz content of the sediments (Molina-Cruz, 1977). We hope we have provided the high quality cores that are necessary to approach these major areas of interest.

Our major objective was met by coring two holes to a total depth of 235.0 m and recovering an almost complete section which represents approximately the past 8 Ma (Figure 7b). We recovered 62.5% of the cored interval in Hole 503A and 85.5% in Hole 503B with 80./9% and 85.7% of the recovered sediment undisturbed, respectively, in each hole. The HPC performed spectacularly well throughout the operations.

The scientists of Leg 9 felt they drilled Site 83 on the east flank of the East Pacific Rise (EPR). The possibility exists, however, that Sites 83 and 503 are located on the north flank of the Galapagos Spreading Center (GSC). Bathymetry, of the detail available for both sites, cannot easily resolve this problem. The magnetics of the basement, however, can define which flank was sampled. The total-field magnetometer data recorded on our approach to Site 503 suggests we crossed the north flank of the Galapagos Spreading Center, not the east flank of the East Pacific Rise. The data show no magnetic anomalies up to Site 503. The magnetic data from our transit to Ecuador suggest we steamed at an angle to the magnetic anomalies. This could only be the case if we were over the northern flank of the Galapagos Spreading Center. Therefore, we feel both Sites 83 and 503 are located on the north flank of the Galapagos Spreading Center and not on the east flank of the East Pacific Rise.

The section at Site 503 consists of uniformly-pelagic sediments with only minor compositional changes. Carbonate and color cycles are apparent throughout the entire section with periodicities on the order of 4 x 10^4 yrs per cycle. Curiously, very little volcanic glass and no zeolities were found. The sediment changes from an oxidized to a reduced oxidation state at 8.45 m and is reduced throughout the remainder of the section. The lack of sediment disturbance is illustrated by open burrows which were observed from 9.3 to 64.0 m. Burrows, cemented with carbonate or silica(?) to form nodules, occur from 13.5 to 235 m and are common from 13.5 to 60 m. Clay content remains fairly constant at low percentages to 226 m where it abruptly increases to greater than 25%. This increase occurs within 10 m of the basement and may be caused by hydrothermal or thermal alteration of the sediment.

Detailed measurements of shear strength, sonic velocity, bulk density, water content, porosity, and penetration were made on the sediments. The section proves to be exceedingly undercompacted. Shear strengths vary around 400 g/cm^2 from 15 to about 210 m. Similar values were obtained at 25 m depth at Site 502 but continued to increase with depth. The maximum value of 1686 g/cm^2 occurred below 210 m. Porosities are approximately 90% and water contents are about 80% down to a depth of 210 m. Sonic velocities average 1510 m/s down to a depth of 210 m. The change in all physical properties at about 210 m may indicate a "collapse" of the section at this level. One explanation may be that the siliceous microfossils, especially radiolaria, may hold the sediment in a highly porous state until some threshold lithostatic load is applied. The section collapsed at loads above the threshold and became less porous which resulted in higher velocities, shear strengths, and lower water contents.

The recovered sediment contains microfossil assemblages which range in age from Quaternary through the latter part of the late Miocene. Both calcareous and

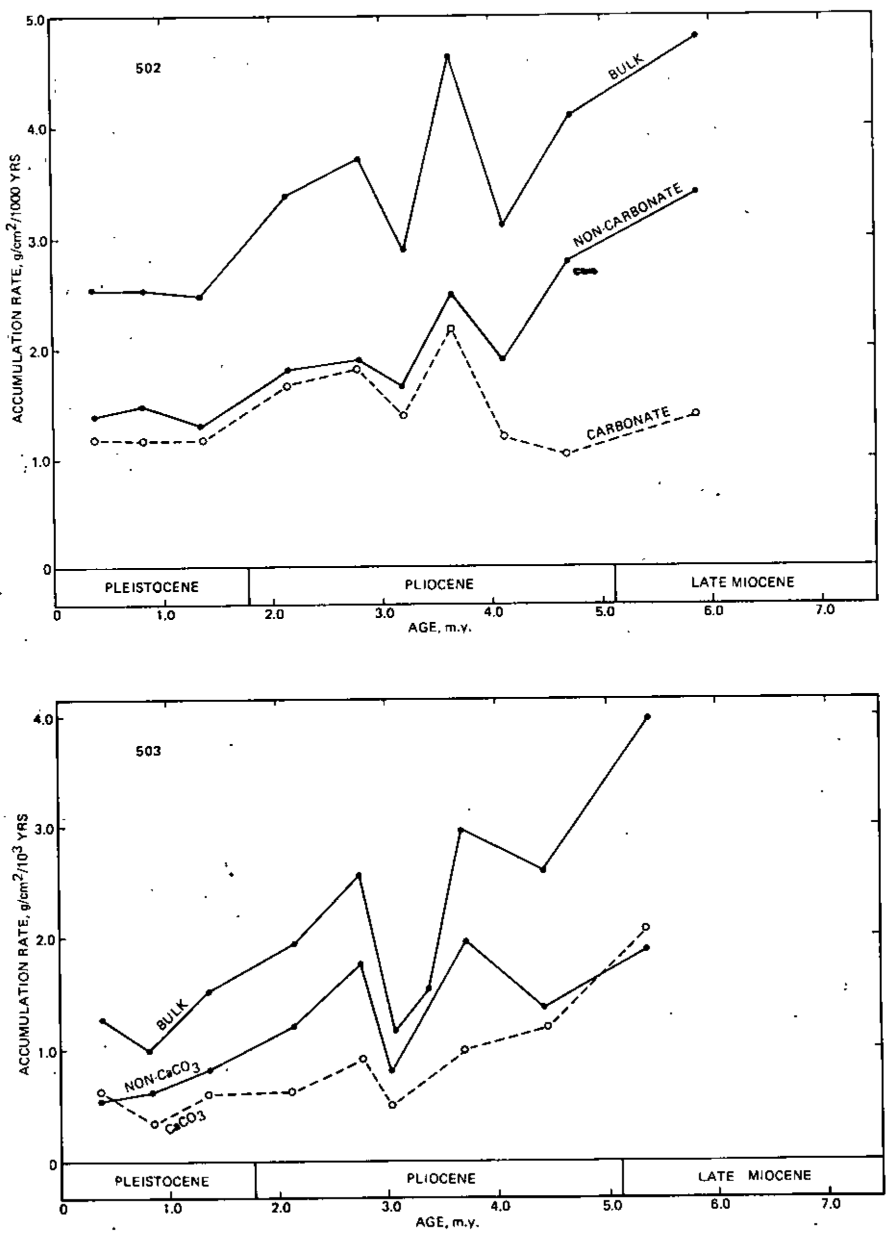

FIGURE 8

Accumulation Rate Curves for Sites 502 and 503 siliceous microfossils are sufficiently numerous and well-preserved for detailed stratigraphic interpretation. Cyclic zones of carbonate dissolution principally occur in the Quaternary but are also apparent in the Tertiary section. Reworked assemblages of nannofossils and a single species of diatom appear in the late Miocene. Radiolaria and diatoms show effects of dissolution in Quaternary sediment but preservation is good in the Tertiary section.

We were able to identify most magnetostratigraphic boundaries (events) above the Gauss-Gilbert Boundary even though rust contamination was a serious problem, especially in Hole 503A. Most boundaries are located to the nearest 1 m interval because discrete samples were used to avoid rust contamination. We observed clear cycles of NRM intesity with wave lengths comparable to the carbonate cycles which implies a direct correlation of intensity with lithology. Unfortunately, the rust problem obscured many trends, but as was found at Site 502, we see a decrease in the NRM intensity during the lower Gilbert Epoch.

The magnetostratigraphics of Site 502 and 503, combined with their biostratigraphy, provide the most detailed records of their kind available and together are very likely to become reference sections for, at least, the Plio-Pleistocene, and probably into the Upper Miocene. For perspective, it should be considered that ordinary piston cores that penetrate into Upper Miocene sediments are only about 25 m long (e.g., RC 12-66, equatorial Pacific) whereas between 130 m and 145 m were recovered at Sites 503 and 502, respectively, which represents the same time interval. Also, prior to our coring at Site 502, no paleomagnetic record even through the Brunhes was available from cores in the Caribbean. An important product of our work will not only be detailed biostratigraphy tied directly to the magnetic polarity reversal time scale, but also an unprecedented record of paleomagnetic field behavior should emerge.

Bulk accumulation rates at Site 503 steadily decrease from late Miocene (4.0 $g/cm^2/10^3$ yr) to late Quaternary (1.2 $g/cm^2/10^3$ yr) with a distinct interval of low accumulation rates (1.2 to 1.6 $g/cm^2/10^3$ yr) in the mid-Pliocene. The data from Site 502 in the Caribbean also show a period of low accumulation rates during this same time. The rate of both carbonate and non-carbonate accumulations mimics the trend of bulk accumulation and non-carbonate components (silica and clay) generally reflects carbonate.

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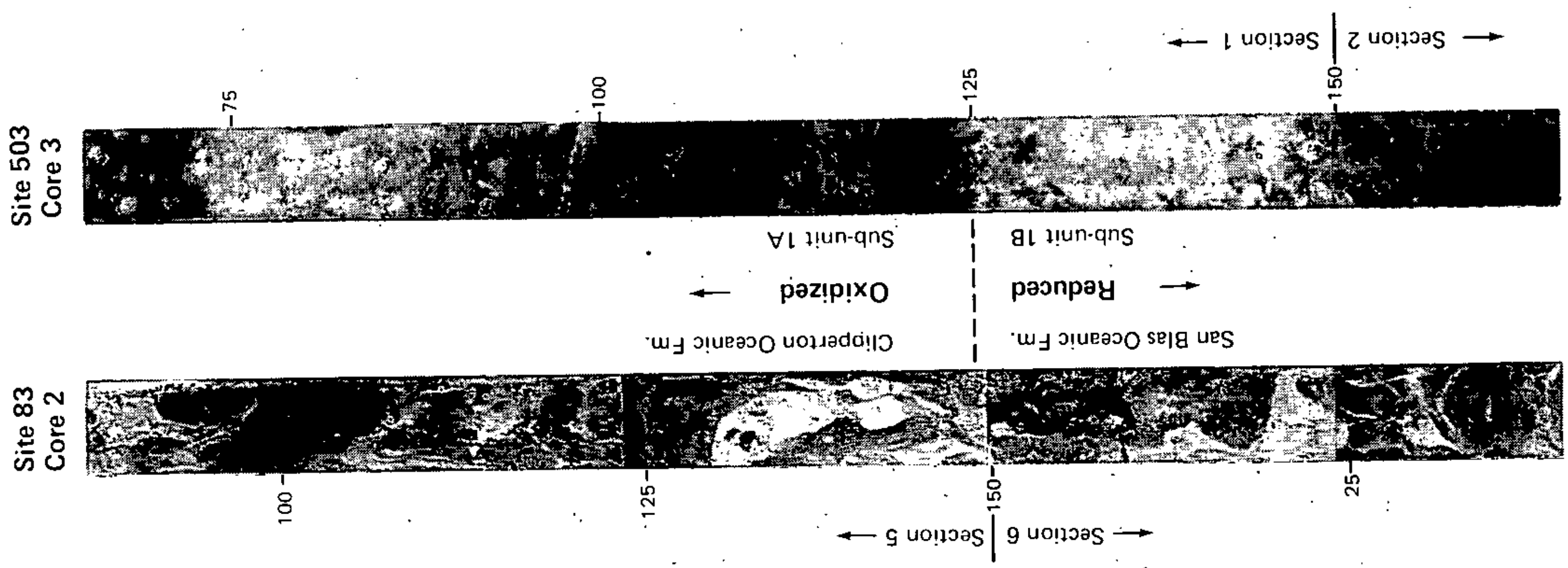

FIGURE 9

Photo of undisturbed vs. rotary disturbed core; Site 83, Core 3 vs. Site 503, Core 3

SITE REPORTS

Leg 68

Co-chief scientists J. Gardner and W. Prell report:

Site 502 (WC-1)	Lat:	11°29.42'N
	Long:	79°22.78'W
	Water Depth:	3051.5 m

Four holes were cored. A maximum depth of 224 m was reached at Hole 502C. The HPC stopped fully stroking out when the shear strength of the sediment reached about 9.6 kPa (1000 g/cm^2). This did not impede recovery of a continuous section.

The length of each core recovered was recorded. For the next core, the drill string was dropped 0.5 m less than the previous recovery. The only problems were attributed to poor performance of core catchers or failure of the core liner. Intervals of no recovery did occur. The presence of a mudline on the outer core barrel suggested that sediment had been penetrated. When these intervals were recored, very disturbed sediments were recovered.

Maximum shear strengths of 28.8 kPa (3000 gm/cm^2) were encountered. For the western Caribbean, this was the limit for coring. We are confident that we can correlate between the cores and that we have recovered a high-resolution, high-quality, continuous section for the past 6.5 Ma. We have correlated carbonate data taken at 30 cm intervals for the entire Brunhes and find all 19 cycles in each core. This detailed correlation eliminates the possibility of having more than 0.6 m of section missing at any interval.

The sediment at Site 502 consists of foram-bearing nanno marl grading into calcareous clay at about 155 m. Carbonate cycles are obvious throughout almost all of the section, but the baseline shifts from a range of 40 to 50 percent in the upper section to less than 30 percent in the lower section. Ash horizons were found, with the greatest number occurring in the late Miocene. We used the long-core spinner magnetometer to obtain more than 4500 measurements of NRM for the Quaternary and Pliocene. All 19 recognized magnetic reversals from 0 to 5 Ma were found. NRM intensity shows a rough correlation with carbonate fluctuations.

A precise correlation has been made between the magnetostratigraphy and the nannofossil biostratigraphy. All nanno zones were found. Radiolaria and spo ge spicules were found in the top 6 m (Quaternary) and below 211 m. The evidence suggests that the absence of siliceous microfossils in the Caribbean from early Miocene to Quaternary is the result of dissolution within the sediment. Abundant sinistral-coiled N. Pachyderma were found in sediments older than 3.8 to 4.1 Ma which were also found at Site 154A. This may provide new insight into the evolution and environmental interpretations of N. Pachyderma Average sedimentation rates are uniform from 0 to 2.37 Ma at 2.35 cm/1000 years and increase to over 3.85 cm/1000 years at the base of the recovered section. Calculated accumulation rates of bulk sediment and carbonate indicate an event in the mid-Pliocene where carbonate accumulated at much higher rates than before or after. Non-carbonate material has steadily decreased since the late Miocene.

Site 503	Lat:	04°04.04'N
	Long:	95°38.21'W
	Water Depth:	3672 m

Site 503 was located within a few kilometers of Site 83. Site 503 consists of three holes. Hole 503 is only one core (4.4 m long) taken to recover the sediment-water interface. The drill string was then raised 3 m and commenced coring hole 503A. We recovered 54 cores at Hole 503A while drilling to a total depth of 235 m sub-bottom. Coring stopped less than 10 m from volcanic basement. We were cautious not to core in the basalt for fear of bending the HPC in the bit assembly which would necessitate a round trip of the drill pipe and almost certainly preclude any significant additional coring in the time remaining. Total recovery was only 62.5% because of core catcher failure and cracker liners. Part of nearly every core was disturbed.

The ship was then offset 100 m and began Hole 503B with modified core catchers and shear pins which allowed the HPC to fire at 5.5-6.9 kPa (800 to 1000 psi) rather than those previously used which fail at 25.7-28.6 kPa (1800 to 2000 psi). We attempted 26 cores, continuously coring to a total depth of 112.8 m and recovered 85.5% with little disturbance. Our modifications were significant in improving the performance of the HPC. Coring was terminated because of time constraints associated with our arrival at Salinas, Ecuador. The section consists of cyclic color alterations of siliceous-bearing calcareous ooze overlying siliceous-bearing marl which rests on siliceous nannofossil ooze. The sediment changes from oxidized to reduced colors below 8.5 m sub-bottom. Low shear strength (1.92 - 3.84 kPa or 200 to 400 g/cm^2) and high water content and porosity throughout most of the section suggest that the sediment column is under-compacted. The HPC was able to extend fully as deep as we cored. We recovered undisturbed, and in many cases still open, burrows. Many features referred to as both indurated burrows or nodules of carbonate silica were also recovered in situ. These were not reported at Site 83. Carbonate cycles with periods of 50.000 to 100,000 years are found throughout the section. The same lithostratigraphic succession can be described from the sediments at Site 83 but the high quality of the cores at Site 503 gives us much more detail. Initial shipboard paleomagnetic measurements detected the Jaramillo event, the Matuyama-Gauss boundary, and the Gauss-Gilbert boundary. Unfortunately, rust flakes from the drill pipe added high-frequency NRM intensity noise to the data and decreased the high quality of the long core spinner data. Rust was less of a problem in Hole 503B.

All four microfossil groups were found in abundance and used to subdivide the section. Samples indicate distinctive zones of carbonate dissolution and generally good preservation of siliceous microfossils. The oldest sediment recovered is early late Miocene (Hole 503A) and is thought to be approximately 8 Ma old. This sample is within 10 m of basement and probably within 6 m of it. Data from Site 83 indicates the age of the oldest sediments to be 10.2 Ma We are uncertain of the discrepancy but we believe neither Site 83 nor Site 503 are located on the east flank of the East Pacific Rise but rather are on the north flank of the Galapagos Ridge. Our age of about 8 Ma for the age of the basement is consistent with this conclusion. The HPC exceeded our wildest expectations in its ability to recover undisturbed continuous sections. We believe that Sites 503 and 502 will become the standards for Neogene stratigraphy, whether it be isotope, bio-carbonate, magneto, etc.

Leg 69

Co-chiefs J. Cann and M. Langseth report:

Site 504	Lat:	01°13.6'N
	Long:	83°43.9'W
	Water Depth:	3470 m

Site 504 was located 250 m east and 90 m south of Hole 501. Hole 504 was cored using the hydraulic piston corer to sample the sedimentary section prior to re-entry. Coring was continuous from 10 to 235 m sub-bottom, with 76% overall recovey, and 90% recovery of the top 130 m. The penetration rate was 73 m per day. The core contains a continuous section into uppermost Miocene sediments. Siliceous fossils were well preserved but calcareous nannofossils were increasingly corroded with depth.

Sedimentary units are:

1. 10-66m greenish gray to grayish yellow green siliceous nannofossil ooze with volcanic ash layers.

2. 66-99 m dusky yellowish green to olive gray siliceous siliceous nannofossil ooze with dark to very dark grayish brown layers.

3. 99-130 m greenish gray to olive gray siliceous nannofossil ooze with increased clay content.

4. 130-143 m light gray to light olive gray marly siliceous nannofossil ooze.

5. 143-235 m light gray to light greenish gray siliceous nannofossil chalk with volcanic ash layers.

Chert was recovered at 235 m, which caused the hole to be terminated.

Paleomagnetic measurements in the sediments show a low intensity of magnetization, on the order of 10^{-6} e.m.u./cc throughout. Declinations measured using the long core spinner were variable within all cores, and expected correlations with reversal history were not observed.

The pore water chemistry shows Ca and Mg profiles similar in shape to those at Site 501, but with systematically smaller gradients. Mg decreases to a nearly steady level of 17 millimolar at 183-231 m. X-ray fluorescence analysis of the sediments shows a high manganese level at one point in Unit 2, and that the ash layers are rhyolitic. In summary, the hole was satisfactory and our objectives were achieved.

Site 504B was re-entered on 3 December. See page 34.

Site 504B	Lat:	01°13.6'N
	Long:	83°43.8'W
	Water Depth:	3473 m

Hole 504 B was established as a multiple re-entry hole 500 m east of Hole 501. The hole was cased into the

top of the basement at 280 m. The sediments were 274.5 m thick and similar to those at Site 501. Cores of limestone and chert were recovered from the lower part while the top part was washed. The basement was cored for 214.5 m with a recovery of 36%. Downhole logs, the Russian magnetometer, the borehole televiewer, and the packer were all run successfully in the hole. The basalt section cored and seen by the televiewer consists mostly of pillows with some thin sheet flows and one massive flow unit. Zones of brecciated basalt found at 10 and 205 m into basement are perhaps faults. Three types of basalt were recovered, one with phenocrysts of plagioclase. olivine, and minor chromite; a second with plagioclase, olivine, and phenocrysts. The basalts are all similar and rather basic in chemistry with TiO_2 = 0.9, Ni = 120 ppm and Mg/Mg+Fe = 0.62; although some are somewhat evolved, none are ferrobasalts. Alteration to saponite and other clays is moderate to intense. The physical properties are typical of those for submarine basalts. Paleomagnetic studies show that the rocks are reversely magnetized with consistent inclinations and intensities within magnetic units. The reverse magnetism was confirmed by the downhole magnetometer which also detected breccia zones. The Lynes packer was set at the bottom of the hole and also 40 m from the top. Flow tests gave a mean hole permeability of about one darcy and thus showed that water must convect in the crust. The water sampler obtained a .057 m^3 15 gallon sample split into six fractions with increasing (up to 20%) formation water content. Two dramatic temperature logs show ocean water being drawn down into the hole to a depth of 90 m sub-basement at a calculated rate of one-half cubic m per hour. During the course of drilling, this circulation cooled the sediments and basement near the hole to less than 10°C. Below the outlet, the regime seems conductive. The caliper log shows the hole to be clean and to gauge, while the density logs show generally low porosity. Preliminary correlation of drilling and downhole televiewer results look very promising. A massive flow unit shows up clearly on all logs. The hole drilled quickly and cleanly with little trouble and only minor torquing. The hole seems ideally suited for further geothermal work.

Site 505 (CR-2)	Lat:	01°54.82'N
505A	Long:	83°47.39'W
505B	Water Depth:	3538 m

Three single bit holes were drilled at Site 505 (CR-2) in a valley located in an area of low heat flow and more rugged relief than at Site 504. Hole 505 was rotary cored through 233 m of sediment and 9.5 m of basalt. Very difficult basement drilling conditions forced abandonment of the hole The sediments consist of siliceous nannofossil ooze very similar to that at Site 504 but with darker coloration, a higher sedimentation rate and less advanced diagenesis. The pore water chemistry shows a marked contrast to that at Site 504; the calcium content decreases and the alkalinity increases with depth to 100 m, below which the gradients reverse towards basement. H_2S is abundant and Mg is constant with depth. Four downhole temperature measurements indicate a linear temperature gradient of 2°/100 m and a basement temperature of 9°C. The heat flow is about 12.7 mW/m^2 (0.4 HFU). No cherts are present. Good stratigraphic correlation of lithology and physical properties between Sites 504 and 505 suggest regional control of sedimentation.

The basement consists of highly plagioclase-olivine-clinopyroxene-chrome spinel porphyritic basalt. The Lynes Packer was included in the bottom hole assembly but the inflatable element was shredded during drilling. Hole 505A was located 500 m north of Hole 505 in 3525 m of water. The basement was reached at 196.5 m sub-bottom after washing through the sediments. Twelve meters of plagioclase-olivine-chromite phyric basalt were cored before the hole was again abandoned because of poor drilling conditions.

Hole 505B was located 250 m farther north in 3517 m of water and washed through the sediments to basement at 3654 m sub-bottom. The basement was cored to 3695 m with considerable difficulty. The basalts, which are similar to those recovered in Hole 505A, are highly calcic and rather basic, with Mg/Mg + Fe = 0.64 and TiO_2 = 0.96. Downhole magnetometer measurements show that the section is uniformly reversed and shipboard paleomagnetic measurements indicate that the basalts have high intensities and low susceptibilities. Downhole logs show a complex basement structure consisting of interlayered pillow flows, breccia zones and thick low density sediment (?) layers to a depth of 3790 m. The difficulty of drilling was ascribed to this structure and to the small alteration of the basalts. Fresh olivine and glass are still abundant and the rocks display high seismic velocities and bulk densities.

Leg 70

Co-chief scientists R. von Herzen and J. Honnorez report:

Site:	506	Lat:	0°36.59'N
		Long:	86°05.49'W
		Water Depth:	2713.7 m
	506A	Lat:	0°36.59'N
		Long:	86°05.48'W
		Water Depth:	2713.7 m
	506B	Lat:	0°36.61'N
		Long:	86°05.48'W
		Water Depth:	2721.6 m
	506C	Lat:	0°36.46'N
		Long:	86°05.48'W
		Water Depth:	2716.6 m
	506D	Lat:	0°36.42'N
		Long:	86°05.48'W
		Water Depth:	2716.9 m
	506E	Lat:	0°36.59'N
		Long:	86°05.48'W
		Water Depth:	2713.7 m
	506F	Lat:	0°36.63'N
		Long:	86°05.48'W
		Water Depth:	2721 m
	506G	Lat:	0°36.59'N
		Long:	86°05.49'W
		Water Depth:	2741.0 m
	506H	Lat:	0°36.42'N
		Long:	86°05.48'W
		Water Depth:	2743.0 m
	506I	Lat:	0°36.46'N
		Long:	86°05.48'W
		Water Depth:	2743.0 m

Seven holes were drilled or cored, and three heat flow measurements were attempted at Site 506 in an area of high heat flow within the Galapagos Mounds, about 19.5 km south of the Galapagos Spreading Center.

Two holes were drilled in the mounds themselves using the hydraulic piston corer (HPC): Hole 506 which was 37 m deep with 63% recovery, and Hole 506C which was 31 m deep with 93% recovery. Two holes were cored using the HPC in the sediment cover off the mounds: Hole 506B which was 21 m deep with 96% recovery, and Hole 506D which was 32 m deep with 87% recovery. All four holes are thought to have hit basement.

Two holes were drilled into the basement beneath the mounds: Hole 506G and 506I which penetrated 5 and 3.5 m of basement, respectively, for recoveries of 20% and 6%. One hole, 506H, was drilled 8 m into the off-mounds basement for a recovery of 2%. Heat flow measurements and pore water samples were collected in Holes 506A, 506E, and 506F which were washed through the sediments.

The most remarkable observations about the sediment stratigraphy are the following:

1. The mudline was at almost the same depth (± a few meters) at all four holes in the sediment.

2. In the mounds, Mn-hydrated oxides (mainly todorokite) form a layer up to 30 cm thick resting on an alternating sequence of thin pelagic sediment layers and green smectite layers, the latter being up to 5 m thick. X-ray diffraction was used for the first time on the GLOMAR CHALLENGER, allowing the todorokite and smectite identifications. Both minerals are thought to be of hydrothermal origin on the basis of their similarity with Leg 54 material and their occurrence which is restricted to the mounds. The "hydrothermal" (?) units are separated from the basaltic basement by an 11 to 13 m thick basal unit of foraminifer nannofossil ooze, and they are overlain by a 1.3 to 3.7 m thick unit of foraminifer siliceous nannofossil ooze. No detailed correlation can be made between the "Hydrothermal" (?) units of Holes 506 and 506C.

3. Off the mounds, the "hydrothermal" (?) components are either completely missing (Hole 506B), or their presence is reduced to an 80 cm thick layer of green smectite-rich sediments. This indicates that, contrary to the conclusions of the Leg 54 Scientific Party, the lateral extent of the "hydrothermal" (?) sediments is limited to the mounds themselves. In Holes 506B and 506D the sediment column consists respectively of 31 and 21 m of nannofossil ooze.

The reduced thickness of the pelagic sections in the mounds themselves compared to those of the off-mound holes indicates either that the "hydrothermal" (?) deposits are at least partly a product of replacement and/or dissolution of pre-existing pelagic sediments, or that the pelagic sediments have been removed from the mounds by slumping into the off-mounds areas. No clear evidence for or against either of these hypotheses was found at this site.

Preliminary NRM measurements on the long core spinner show no apparent difference in the direction and intensity of remanence between the off-mounds sediments and the Mn-hydrated oxide or green smectite-rich sediments from the mounds.

A significant density change in the sediments from Holes 506 and 506C corresponds to the lithological change from pelagic ooze (specific gravity 1.3) to "hydrothermal"(?) material (specific gravity 1.3 to 1.7). All the physical properties in both Holes 506B and 506D vary continuously with depth. The depth gradients of the physical properties in Holes 506, 506B and 506C are significantly larger than those at Sites 504 and 505, but are compatible with those at Site 424 (Leg 54).

The only sample of basalts from the basement which was studied shows typical values of physical properties for Layer 2 rocks.

Two successful heat flow measurements at depths of about 30 m sub-bottom in Holes 506E and 506F located respectively on and off the mounds gave values of about 587 and 1007 mW/m^2 (24 and 14 HFU). A non-linear temperature gradient measured in the former hole suggests significant upward movement of pore waters.

The pore water chemistry is complex, reflecting the influence of biogenic debris, diagenesis, convection, and reactions with the basement. The dominant features are:

1. A low concentration of elements produced by biogenic decay indicating that both on and off the mounds the sediments are flushed out by convecting waters.

2. A 10% to 20% calcium enrichment believed to be due to seawater basalt reaction.

The basement samples retrieved in the holes at Site 506 appear to be mostly fresh, finely crystalline, aphyric to sparsely plagioclase-phyric basalt. Fresh glassy rinds are observed. No alteration minerals of unequivocally hydrothermal origin are present. The basalts appear to be similar to those observed on Leg 54 and on the ALVIN dives.

The basalts display high magnetization intensities, high ratios of remanence to induced magnetization and shallow negative inclinations consistent with the high amplitude magnetic anomalies and equatorial location of the site.

Site 507

Lat:	0°34.0'N
Long:	86°05.4'W
Water Depth:	2701 m

Site 507 is located within a concentration of mounds and mound ridges. It is about 4 km south of Site 506 and 23.5 km south of the Galapagos Spreading Center. The mounds occur on the north flank of a relatively broad elevation, the slope of which appears interrupted by small faults. Six holes were cored or drilled. Four heat flow measurements and in situ pore water samples were collected.

Hole 507D was cored 38.7 m into a mound for a sediment recovery of 94%. Hole 507F was cored at the edge of the same mound for a recovery of 98%. We attempted drilling two holes into the basement off the mounds with little success. Hole 507B penetrated 7 m for a recovery of 9%, whereas Hole 507C penetrated 29.5 m with a 96% recovery in the sediments and a 6% recovery in the basement. Hole 507E and 507G were respectively drilled to take heat flow measurements and pore water samples near the center and edge of the same mound. Holes 507A and 507I were drilled north and south of the mound, respectively, for heat flow measurements and pore water samples.

Hole 507D cored into a mound recovering 26 m of interbedded green "hydrothermal"(?) clays and pelagic sediments underlain by 8 m of pelagic oozes overlying basement. In contrast to Site 506, the "hydrothermal"(?) products extend virtually up to the surface of the mound where a thin manganese oxide crust is present, suggesting that some "hydrothermal"(?) materials were recently deposited. In Hole 507F, apparently on the flank of a mound, 2 m of green "hydrothermal"(?) clays were found interbedded in the upper portion of a 31 m thick section of pelagic calcareous ooze. Smectite, todorokite, and clinoptilolite were identified by X-ray diffraction in the green clays, the Mn-oxides and the pelagic oozes, respectively.

The fossil assemblages at Site 507 were essentially the same as those at Site 506. The radiolaria and diatoms, however, are less abundant and more poorly preserved, especially below a depth of 12 m sub-bottom. At age of 0.27 to 0.44 Ma is inferred for the basalt sediments from the paleontologic data, leaving a hiatus of at least 0.25 Ma since the basement is estimated to be 0.69 Ma old from the spreading rate.

There appears to be better evidence at this site for the formation of the green clays by the coating and partial replacement of siliceous organisms. The possibility of sediment slumping from the mounds down to off-mound areas still exists.

The pore water chemistry, as at Site 506, is characterized by a slight Ca excess and a Mg deficiency relative to bottom water, reflecting reaction with the basement. Low ammonia and constant Ca concentrations indicate rapid convection. Physical and thermal properties of the sediments are basically the same as those at Site 506. Heat flow measurements agree with previous short probe determinations, giving values of 334.9 to 501.4 MW/m^2 (8 to 12 HFU). Nearly linear temperature gradients suggest a present-day conductive thermal regime.

The basement rocks recovered in the various holes at Site 507 are either fine-grained aphyric to sparsely plagioclase-phyric basalt or coarse-grained subophitic basalt. The latter appear to be fresh whereas the former display black aureoles indicating low temperature alteration accompanied by the filling of pore spaces by green smectites and iron hydroxides. No sign of hydrothermal alteration has been observed. The shape of the alteration bands indicates that the basalt piecves belonged to a fragmented basement which has been further broken during drilling.

As at Site 506, the basalts from Site 507 have high magnetization intensities (the average NRM intensity = 22 mgauss), high ratios of remanence to induced magnetization (average Q = 33), and shallow inclinations (both positive and negative, less than 15°), consistent with the high amplitude magnetic anomalies and equatorial location of the site.

Site 508	Lat:	0°32'N
	Long:	86°06'W
	Water Depth:	2787 m

Site 508 is located about 28 km south of the Galapagos Spreading Center and 4 km south of Site 507. Hole 508 was continuously cored through a 35 m thick sediment cover for an average recovery of 99%. In Hole 508B only a mudline core was recovered after which the bit was washed down to the basement. Basement drilling was attempted with only 8 m of penetration and 6.5% recovery. Drilling was slow with excessive torquing and was finally abandoned when the bit became jammed. Hole 508C was drilled within 15 m of Hole 508B for the purpose of recovering the sediments directly overlying the basement. Heat flow measurements were carried out in Holes 508A, 508D and 508E. The sediments in Hole 508 consist of siliceous foram-nannofossil ooze. It is not certain that the basement was reached since no basaltic fragments were found in the core catcher of the lowest core from this hole. Holes 508B and 508C were drilled through 51.5 m of sediments similar to those found in Hole 508. The recovery of a 10-cm thick interval of semi-lithified sediments about 1.5 m above the bottom of Hole 508, the presence of an indurated chalk pebble in the last core above the basement in Hole 508B, and the recovery of partly indurated sediments in the only core of Hole 508C indicated that several m of at least partly lithified sediments directly overlie the basement.

Compared to the sediments from other sites drilled on this leg, the sediments from Site 508 show the following principle differences:

1. The pelagic oozes in the lowermost portion of the sediment column are lithified or semi-lithified. Diagenesis related to compaction is unlikely to explain the formation of such rock.

2. The sediments at Site 508 do not show a decrease in the amount of siliceous organisms toward the bottom of the sedimentary column. The sediments display the best microfossil preservation of all the sites.

3. The presence of hydrogen sulfide and traces of pyrite indicate that reducing conditions are present throughout much of the sedimentary cover at Site 508. The fossil assemblages are essentially identical to those in Holes 506 and 507. Similarly, all of the physical properties are approximately the same as those of the pelagic sediments from Hole 507, in spite of the differenceves between the thermal regimes of the two sites.

The heat flow measurements yielded relatively low values ranging from 134 to 197 mW/m^2 (3.2 to 4.7 HFU), in agreement with previous short probe measurements from research vessels. Each measurement shows an increasing temperature gradient with depth, possibly due to hydrothermal recharge at rates on the order of 10^{-6} cm/s.

Pore water Mg and Ca concentrations are close to bottom water values, suggesting that there is little input of formation waters in this area of presumed recharge. The relatively high ammonia concentrations found at this site are compatible with such conclusions.

Basement drilling was attempted in one hole (508B), with relatively poor results. Drilling conditions were the same as the mound sites and penetration (8 m)) and recovery (6.5%) were poor. The basalts are fine- to medium-grained and aphyric to sparsely plagioclase-phyric. The gragments are often partly surrounded by a dark alteration rim and a few are slightly altered throughout. The alteration products consist of smectites, unidentified zeolites, and Fe-oxyhydroxides in vesicles and pore spaces. No sign of unequivocal hydrothermal alteration could be found.

Site 509 — Lat: 0°35.34'N; Long: 86°07.90'W; Water Depth: 2702 m

Site 509 is centered on a mound field 21 to 22 km S of the Galapagos Spreading Center, and 4 km west of the north-south line passing through Sites 506 and 507. Site 509 coincides with Site 424. Holes 509 and 509B are located, respectively, off and on a mound about 30 m and 200 m west and slightly north of Hole 424A. Three heat flow measurements were carried out at these same locations. The sediment cover is 32 to 34 m thick and the underlying basement is assumed to be 0.60 to 0.63 Ma old on the basis of a half-spreading rate of 3.5 cm/yr inferred from magnetic anomalies.

The overall thickness and lithological sequence of the mound sedimentary column in Hole 509B is very similar to those from the other two mound sites drilled, i.e., Sites 506 and 507. The stratigraphy observed in the 33.4 m of sediments cored in Hole 509 B consists, from top to bottom, of the following units:

1. About 4 m of manganese oxyhydroxide crust in fragments up to 2.5 cm thick.

2. About 12 m of green clays interbedded with pelagic ooze.

3. About 17.4 m of non-siliceous foraminifer-nannofossil ooze overlying basaltic basement.

The sedimentary column cored in Hole 509, located on the edge of a mound, is made up of 31.9 m of siliceous foraminifer-nannofossil ooze. This observation demonstrates that the "hydrothermal" material is not regional in extent at this site either and, therefore, could not explain the sub-bottom reflectors observed by Lonsdale (1977). The fossil assemblages present at Site 509 were essentially identical to those at the previous sites.

Small enrichment of Ca and depletion of Ma again imply a flow of formation water through the mound area sediments. Ammonia concentrations are also low, especially in Hole 509B suggesting rapid flushing by upward convection.

Heat flow values were quite high in each hole at this site, about 418.7 and 773.6 mW/m^2 (10 and 18.5 HFU) in Holes 509 and 509B respectively. The thermal gradients in Hole 509B decreased with depth, suggesting hydrothermal discharge through the mound at a rate of 40 cm/yr. The gradients were almost linear in Hole 509, suggesting that a conductive thermal regime exists in the off-mound area.

Manganese oxide crusts have the highest density, sonic velocity and lowest porosity of all the sediments recovered on this leg: the wet bulk density = 1.98 g/cc, the grain density = 3.75 g/cc, the porosity = 58.1%, and the sonic velocity = 2.22 km/s. The green clays have a slightly higher density and sonic velocity and a lower porosity than those from the previous sites: the wet bulk density = 1.66 g/cc, the grain density = 3.12 g/cc, the porosity = 70.1%, and the sonic velocity = 1.72 km/s. On the other hand, all of the physical properties of the pelagic sediments are similar to those from the previous sites.

The preliminary results of the magnetic measurements on the sediments are similar to those for Sites 506 and 507. However, the Mn-oxide crusts exhibit surprisingly coherent NRM directions despite their very low intensities (which latter are consistent with their presumably low Fe content).

In summary, the major differences between the Site 509 sediments and those from the other sites are:

1. The manganese crust fragments are much larger and they form a thicker layer in Hole 509B. Moreover, the oxidized "mudline" layer is much thinner and no other pelagic sediments overlie the hydrothermal material. These observations may indicate that Hole 509B was cored closer to the top of the mound than the other holes, and/or that the hydrothermal activity was more recent (or still active?) at this location than at any of the previous sites.

2. Unlike the sediment sections from the other off-mound holes, the lower halves of which are almost

devoid of siliceous microfossils, the Hole 509 sediments contain (include?) such siliceous remains down to the bottom of the sedimentary column. No basement drilling was attempted at this site.

Site 510	Lat:	1°36.79'N
	Long:	86°24.60'W
	Water Depth:	2798 m

Site 510 is located in a moderately high heat flow region 167.5 to 209.4 mW/m^2 (4 to 5 HFU) about 90 km north of the Galapagos Spreading Center and 35 km west northwest of Site 425. The sediment cover is about 115 m thick. The site is near magnetic anomaly 2; assuming a 3.25 cm/yr half spreading rate, the curst should be 2.7 Ma old.

The main objective of Site 510 was to determine whether the basement could be drilled in a region of the Galapagos Spreading Center which was older than that of the three mound fields previously studied.

One hole was cored by washing the drill bit down to 38.5 m sub-bottom, "punch-coring" the sediments between 38.5 and 48 m, and then washing the bit down to 67 m. Thereafter the sediment column was continuously punch-cored down to the basement at 114.5 m sub-bottom. Sediment recovery varied between 93% and 100%. Eighteen m of basement rocks were drilled, with about 27% recovery, until the drill bit became jammed and the hole had to be abandoned for fear of losing the bottom hole assembly.

The sedimentary column appears to be uniformly made up of foraminifer diatom nannofossil oozes. The diatoms are particularly abundant and the biogenic silica content is therefore higher than in any of the other pelagic sediments studied during this leg. There appears to be no decrease in siliceous organism content with depth. Reducing conditions prevailed in the sediments as indicated by their distinctive olive green color, H_2S odor and minor pyrite content.

Both calcareous nannofossils and planktonic foraminifers indicate an age of 3.0 to 2.6 Ma. The planktonic foraminifer assemblages are dominated by warm water species. The Pliocene-Pleistocene boundary is located at about 90 m sub-bottom. The abundance of benthic foraminifers and the presence of poorly preserved planktonic foraminifer tests at 105 and 112 m depths, respectively, indicate dissolution.

The physical property gradients with depth are very small compared to those at the other sites, except near the basement. The lowermost 20 m of the sedimentary column exhibits larger depth gradients, as found at other sites. This trend could be explained by some interaction between the sediments and the basement, but there was no other evidence of such a process.

In situ temperatures measured at 39.5, 67 and 95.5 m sub-bottom yielded a linear gradient of 0.22°C/m. An average thermal conductivity of 2.1 mcal/cm°C s gives a conductive heat flow of 190 mW/m^2 (4.6 HFU), which is about two-thirds of the value predicted by the cooling plate model for a 2.7 Ma old crust.

The Site 510 pore waters have Ca enrichments and Mg depletions of up to 15%, extremely high SiO_2 concentrations (up to 1100 ppm) reflecting biogenic silica dissolution, and NH_3 and H_2S concentrations indicating the production of about 400 ppm of CO_2 by sulfate reduction.

The basalts retrieved are significantly different from those from the other Galapagos Spreading Center sites. The main differences are:

1. The basalt is more phyric with 15% to 40% plagioclase phenocrysts.

2. The average size (1.5 mm) of the phenocrysts is larger.

3. The basalts contain olivine phenocrysts.

4. The primary Fe-T oxides are only about half as abundant.

The basalts are surrounded by a thicker alteration rim than those from Sites 506 and 507. The dark rim ranges in thickness from 5 to 40 mm. In addition to variously colored smectite, calcite is present in the vesicles and other pore spaces of these alteration rims. The more pronounced alteration may be due to a longer interaction of the crust with sea water, or to higher permeability of the basalts.

The average basalt magnetization intensity at Site 510 is 6 x 10^3g, i.e., less than one-third of that observed at Sites 506 and 507. The remanent magnetization is dominant over induced magnetization with a mean Q ratio of 22. The remanent magnetization is stable to A.F. demagnetiation with an average NRM inclination of -13° and an average stable inclination of -16°.

The basalts have higher sonic velocities and lower grain densities than those at the previous sites. The latter is probably due to alteration.

Site 504B Lat: $01^{o}13.6'N$
Long: $83^{o}43.8'W$
Water Depth: 3473 m

On 3 December, Hole 504B, drilled during Leg 69, was re-entered. During fourteen consecutive days on site, the hole was re-entered three more times and 347 m of basement were cored. A final depth of 836 m sub-bottom (561 m into basement) was reached on 13 December. Penetration rates varied from about 2-6 m/hr, with an average close to 4 m/hr. Recovery varied from 0 to 100% with an average of 26.4%.

The 347 m of basement cored during Leg 70 in Hole 504B consist of 26 petrographic units corresponding to 15 paleomagnetic units. Unfortunately, the unavailability of XRF chemical analyses prevented correlation of the petrographic or paleomagnetic units to magmatic units. Three major kinds of lava were encountered: massive flows (at least 23 m thick), flow breccias and highly fractured sequences of pillow lavas and/or thin flows. The basalt ranges from aphyric to sparsely and highly olivine-plagioclase-clinopyroxene phyric. The association of the first two phenocryst minerals is the most common. Spinel microphenocrysts occur in a few units. Five petrographic types of basalts were distinguished on the basis of the occurrence of the various phenocryst minerals.

The lowermost 347 m of basalts drilled in Hole 504B during Leg 70 exhibit alteration which is slightly different from that of the upper 214 m of basalt drilled during Leg 69. The basic differences are as follows:

1. Calcite occurs below 660 m sub-bottom depth (385 m into basement).

2. Fe-oxyhydroxides are not common between 600 and 760 m and below 800 m sub-bottom depth (that is, between 325-485 m and below 515 m into basement).

3. Vein pyrite was not observed above 540 m sub-bottom depth (260 m into basement) and becomes progressively more abundant with depth. As in the Leg 69 portion of the hole, various types of smectite form the most abundant alteration products (accompanied by minor amounts of zeolites). In addition, analcite and nontronite were identified by XRD. A mixed-layer mineral was tentatively identified as saponite-talc by XRD. Olivine phenocrysts are frequently replaced by various combinations of talc, smectite and red iddingsite (probably an Fe-oxyhydroxide rich smectite mixture). Preliminary reflected light observations indicate that the igneous Fe-Ti oxides are severely altered into mainly non-opaque secondary products (Fe and/or Ti-oxyhydroxides and silicates?) filling up large cracks which separate rather small Ti-magnetite relics. It appears that the basement alterations probably took place in mainly suboxic conditions in the upper portion of the hole (i.e., down to 265 m into basement), and suboxic to anoxic conditions in the lowermost 296 m, or at least as far as the basement was drilled. The alteration processes and the resulting products do not appear to differ, as far as our shipboard observations indicate, from those of basalt-seawater reactions at low temperature.

Paleomagnetic data suggest 15 units with an overall mean stable inclination of -18^{o}. Two of the units, each extending over five cores, have mean stable inclinations of -53^{o} and -63^{o}, respectively, i.e., steeper than would be expected from geomagnetic secular variation alone. Tectonic tilt, geomagnetic excursions, stable secondary remanence, or a combination of these might be responsible for these anomalous inclinations. The overall mean intensity of magnetization is 7×10^{-3} Gauss and the overall mean Q ratio is 10.

The average sonic velocity of these basement rocks measured on-board is significantly higher than the wave velocities derived from site survey data: 5.71 km/s vs. 4 to 5 km/s, respectively. This difference can be attributed to the widespread occurrence of fractures on a scale larger than the cored samples. These fractures are probably responsible for the water flow.

Drilling was followed by an extensive logging and downhole measurements program. Successful logs over the entire basement section include sonic velocity, resistivity, temperature and caliper logs. The Natural gamma and neutron density logs were partially successful; compensated density was unsuccessful. Successful logs show prominent massive basalts at about 325, 590 and 690 m below mudline (50, 315 and 415 m into basement), and otherwise generally fractured/altered basalt. Downhole experiments included the large scale electrical resistivity and oblique seismic experiments, the latter run in cooperation with the R/V GILLIS.

Four borehole temperature profiles and in situ water samples were made during the deepening of Hole 504B on Leg 70; the first was before any disturbance of the re-entered hole, 54 days after the last previous logging during Leg 69. These confirm that the strong downward flow of water to about 350 m sub-bottom observed during Leg 69 is still occurring. The present flow rate down the cored hole was estimated at a few m per hour. The data also suggests that a conductive temperature gradient of about 0.12°C/m exists below about 430 m sub-bottom depth, yielding a heat flow of roughly 200 mW/m^2 (4.8 HFU) which is in good agreement with the measurements of Leg 69. The maximum temperature at the bottom of the hole on the last profile measured 111°C. The estimated equilibrium temperature of the bottom of the hole is about 120°C.

SHIPBOARD SCIENTIFIC STAFFING

Leg 70

J. Honnorez	Co-Chief Scientists	USA	Univ. of Miami
R. Von Herzen		USA	W.H.O.I.
P. Borella	Staff Representative/ Sedimentologist	USA	S.I.O
A. Migdisov	Sedimentologist/ Inorganic Geochemist	U.S S R	U.S.S.R. Academy of Sciences
T. Barrett	Sedimentologist	FRG	Universitat Tubingen
M. Bender	Inorganic Geochemist	USA	Univ. of Rhode Island
A. Moorby	Inorganic Geochemist	UK	Imperial College
H. Hubberten	Igneous Petrologist	FRG	Institut fur Petrographie u. Geochemie der Universitat
C. Laverne	Igneous Petrologist	France	Faculte des Sciences et Techniques
E. Schrader	Igneous Petrologist	USA	University of Alabama
K. Becker	Geophysicist	USA	S.I.O.
S. Karato	Physical Properties Specialist	Japan	Ocean Research Inst.
S. Levi	Paleomagnetist	USA	Oregon State Univ.
S. Jones	Paleontologist (nannofossil)	USA	Florida State Univ.
R. Stephen	Oblique Seismic Experiment	USA	W.H.O.I.

Leg 71

V. Krasheninnikov	Co-Chief Scientists	USSR	Geological Institute
W. Ludwig		USA	L-DGO
J. Usher	DSDP Staff Rep.	USA	S.I.O.
C. Robert	Sedimentologist	France	Centre Universitaire de Luminy
B. Bornhold	Sedimentologist	Canada	Pacific Geoscience Center
E. Goldstein	Sedimentologist	USA	Florida State Univ.
I. Basov	Paleontologist (forams)	USSR	USSR Acad. of Sci.
S. Wise	Paleontologist (nannos)	USA	Florida State Univ.
P. Ciesielski	Paleontologist (diatoms)	USA	Univ. of Georgia
F. Weaver	Paleontologist (radiolaria)	USA	Exxon Prod. Res. Co.
J. Salloway	Paleomagnetist	UK	Univ. of Edinburgh
J. Bloemendal	Paleomagnetist	UK	Univ. of Liverpool
U. Bayer	Physical Properties Specialist	FRG	Universitat Tubingen
H. Von der Dick	Organic Geochemist	FRG	Geologie des Erdoels und der Kohle

IPOD AVAILABLE DATA*

Introduction

The dissemination of geologic data gathered by deep-sea drilling is a primary function of the Deep Sea Drilling Project (DSDP). The Initial Reports of the Deep Sea Drilling Project, a series of volumes published by the U.S. Government Printing Office, is the primary publication of DSDP. Space limitations however prevent the Initial Reports from including all of the observational data. It has been necessary to develop other methods of making this data available to the scientific community. The Information Handling Group (IHG-DSDP) has developed a coordinated, automated Master Data file with associated computer software to process, store, and retrieve DSDP data in a useful form. A series of informal specific memoranda entitled "Data Data" contain more detailed descriptions of the procedures and capabilities of the IHG. They are obtainable by writing to the group at DSDP.

A Sample Distribution Policy has been adopted by DSDP (approved by the National Science Foundation, September, 1976) which restricts the release of scientific data gathered aboard D/V GLOMAR CHALLENGER to those immediate members of the respective shipboard scientific party for a 12-month period following completion of the cruise. This policy excludes the Preliminary Report on Underway Data, containing only track charts and data indexes that has immediate unlimited distribution. (If a data request costs more than $50.00, reimbursement for expenses will be charged.)

Physical Properties and Other Quantitative Core Data

All of the quantitative data are processed through a series of data reduction programs. These programs also convert the standard DSDP labeling notation to a subbottom depth in meters, providing a more readily interpretable sample location. Before a file is declared clean (in an ALGOL-readable format), the data is scanned for points that are clearly in error.

MUDPAK is a flexible graphics program which is used for displaying and comparing sets of coordinated data against a common depth axis. It can make a composite plot of curves from individual data files as well as the superimposition of like parameters measured by different methods. (Requests for quantitative data should be addressed to Barbara Long, Data Resource Coordinator**.)

Aids to Research

In addition to the filling of requests for prime data, the IHG is developing secondary tools to assist researchers in finding materials relevant to their studies. Two of these are discussed below.

The Guide to DSDP Cores summarizes the core material and available information that is published in the Initial Reports. Thirty categories of data have been established in which to select relevant information. A computerized online search system to the Master Guide File, GUIDESEARCH, is available for formulating online searches. The guides are available in microfiche and on magnetic tape. Requests for a list of cores per specific criteria through use of GUIDESEARCH should be addressed to Lillian Musich, Geologist. Inquiries for documentation describing the syntax used in GUIDESEARCH should be addressed to Peter Woodbury, Principal Programmer/Data Manager**.

A computer-generated Keyword Index has been developed to retrieve information relating to current research on core material after an initial shipboard description has been prepared. The Index aids in planning future investigations by enabling scientists to know what studies are currently in progress, and will help in preventing duplication of research. The data base is constructed from the sample request and bibliography files of DSDP, and is updated every six months. (Index requests should be addressed to Trudy Wood**, and requests for core samples should be addressed to the Curator**.)

DSDP Core Photographs

The west and east coast core repositories of D.S.D.P. each maintain a complete collection of black and white and color photographs of all cores retrieved by GLOMAR CHALLENGER. Legs 1 through 44 are archived as prints. Legs 45 onwards are archived as 35 mm slides. They are available for viewing at any time at the repositories.

Individual copies of prints or slides are available upon request to the Associate Chief Scientist, Science Services**.

*This contains information about the availability of DSDP data and how to obtain it. For a detailed discussion of the history and management of DSDP data, see Rosenfeld, M.A. and Davies, T.A., 1978, "Management of Deep Sea Drilling Information," JOIDES Journal, Vol. IV, No. 2, p.67-84.

**Deep Sea Drilling Project, A-031
University of California at San Diego
La Jolla, CA 92093.

DEEP SEA DRILLING PROJECT—DATA BASE STATUS

GENERIC DATA FILE	COMPLETE THROUGH LEG	STORAGE MEDIUM	COMMENTS
CARBON CARBONATE DSDP Shore Lab	59	FT	No carbonate for Leg 46
CHEMISTRY Water content/ Shipboard Lab	68	FT	No chemistry for Leg 41
DEPTHS From underway recording	69	FT	
GRAIN SIZE (Sand/Silt/Clay) DSDP Shore Lab	66	FT	No grain data for Leg 16
G.R.A.P.E. (Gamma Ray Attenuation Porosity Evaluator) Points taken on board. Data processed and edited onshore.	62	FT	G.R.A.P.E. data were not collected on Leg 46; Leg 45 G.R.A.P.E. is not complete.
SCREEN Output from JOIDESSCREEN. Computer-generated lithological classifications. Includes basic composition data, average density, and geologic age of classified layer.	44	T	Leg 38 SCREEN file has not been created yet.
SMEAR SLIDES Shipboard observations	44	FT	
SONIC VELOCITY On board ship-Hamilton Frame method	67	FT	There are no SONIC data for Legs 1 and 2.
VISUAL Shipboard observation	44	FT	

UNDERWAY DATA: Recorded on board between drilling sites. The underway data is processed jointly by DSDP and the SIO Geologic Data Center.

Bathymetry	Legs 07-09 13-56 61-66	FT
Magnetics	Legs 07-09 12-66	FT
Navigation	Legs 03-66	FT
Seismic	Leg 66	

T=magnetic tape
F=microfilm

REPORT FROM IPOD SITE SURVEY MANAGEMENT DATA BANK

The following data have been received:

I. Final Site Survey Report—Walvis Ridge sites from E. Simpson and P. Rabinowitz.

II. Magnetic tape of underway geophysics and microfilm of seismic records, GLOMAR CHALLENGER Legs 54-66.

III. Charts and microfilm of data from Lease Sales 40 and 49, Baltimore Canyon (e.g. bathymetry) structure, hazards, etc.) from NGSDC.

IV. Open File Reports 79-1159 about the COST B-3 well in the Baltimore Canyon, from the conservation division, U.S.G.S.

V. Open File Report 79-948, Mid-Atlantic Seismic reflection . . . ., from the U.S.G.S.

VI. Cruise Report; negatives of seismics; photocopies of digitized records; and track chart, from the R/V THOMAS B. DAVIE, Cruise 397, around SA III-2 area—from Lesley Shackleton, University of Cape Town.

VII. Contoured bathymetry for South Atlantic-Mid-Atlantic Ridge, Site IV-1 through Site IV-7; and final navigation for 3 Angola Basin sites—from Jim. Austin, UTMSI.

VIII. Geological map of Japan Trench and Kuril Trench; geological map of Outer Zone of Southwest Japan (DB 962 and 961)—from Dr. Shozaburo Nagumo, University of Tokyo.

IX. VALDIVIA-West Africa Cruise, 1979, 17.9.79 - 21.1079, DB #963—from Dr. Wilfred Weigel, Germany.

X. Japan Trench Site-IPOD Prospectus for 1981-1983 drilling—from Dr. Shozaburo Nagumo, University of Tokyo.

IPOD DATA BOOKS

At their April meeting the JOIDES EXCOM approved the proposal to prepare site survey information in three documents, a Data Bank Catalogue, Data Bank Books (also called folios), and large-scale reproductions of the original data. The IPOD Data Bank catalogues have been prepared and are continually being updated. These list data that are available for different IPOD drill sites. The IPOD Data Bank Books will contain small-scale (8x10) reproductions of the data available for each site, and summaries of the site survey cruise results written by the chief scientists. Approximately four site survey books are planned, each emphasizing a different geographic location. The Atlantic volume is currently being prepared. It will contain data for 13 Atlantic sites, with approximately 25 pages per site. Data for the sites is being prepared, including drafting and brief summary statements describing how the data was collected. Camera-ready copy for the Atlantic volume should be ready during the spring.

DRAFT REPORT
EXECUTIVE COMMITTEE
26-29 November, 1979—Moscow

CHALLENGER OPERATIONS

I. PERFORMANCE DURING RECENT LEGS

The hydraulic piston coring leg (Leg 68/HPC) and Leg 69 in the Costa Rica Rift area went well. Towards the end of Leg 69 there was a short circuit in the AC switchboard from the main bar to the cabinet. It is speculated that this short circuit migrated causing a surge of power to go through the dynamic positioning part of the computer. Upon shut down several components must have failed, and the dynamic positioning system refused to work. GMI sent several people to fix the computer. About a week's time was lost.

Leg 70 is proceeding well. A pinger has been placed on the drill string and is very useful in locating the exact position on the mounds.

II. INITIAL REPORTS

An index and errata sheet are being prepared for the pre-IPOD volumes (1-44). The index to volumes 1-35 has been finished. The complete (1-44) index will be about 50 pages. DSDP was asked to send a letter to the co-chiefs asking for errata. This has already been done, but may be necessary again.

III. LOGGING

In their deep drilling program in the Kola Peninsula, the USSR has developed a full suite of logging instruments. These instruments are physically and electrically compatible with the Soviet downhole magnetometer, that was successfully operated at Site 501. The Soviets will be ready by February or March to make this equipment available on the GLOMAR CHALLENGER. They would prefer that the equipment be onloaded at a port with Aeroflot connections. An effort will be made to equip the GLOMAR CHALLENGER with Soviet logging tools in Santos, Brazil, prior to Leg 73.

IV. ORGANIC GEOCHEMISTRY HPC FROZEN SAMPLES

A new sampling method will be implemented for frozen organic geochemistry samples. The new method would remove 60 cm of half the core every 30 m for organic geochemistry analysis. The organic geochemistry half would be frozen; half of the organic geochemistry sample (1/4 of the core) would be permanently archieved as a frozen sample. The other half (1/4 of the core), also frozen, would be sampled for organic geochemical analysis. Of the non-organic geochemistry half of the core, half (1/4 of the core) would be sampled, and the other half (1/4 of the core) would be archieved.

STATUS OF EXPLORER PROGRAM*

I. REVIEW OF HISTORY/CURRENT STATUS

The OMD program has been discussed since 1973. It was formally proposed in 1974 but was considered technically premature. It was proposed again, and since the FUSOD meeting has undergone considerable review and reworking. In 1978 the revised program, including engineering costs and budget revisions, was estimated at $560 M.

A Blue Ribbon Panel chaired by H. G. Stever met last spring (1979) to review the Ocean Drilling/EXPLORER program. This panel noted the expense of the program and the mutual science and resource interests. It suggested that funds be sought outside of the NSF and recommended that the Government explore the interest of major U.S. industries in participating in and helping to support such a project.

Industry was approached through the Office of Science and Technology. Since the early fall, several meetings have been held between industry, government, and academic science. These negotiations

*The EXPLORER program has been undergoing continual revision. The information contained in this section is several months out of date.

are reaching a semi-final stage. A draft agreement, expressing the interest of industry and government in participating in an Ocean Drilling/EXPLORER Program has been prepared. It is hoped that the agreement will be signed by 5 December, and be negotiated between NSF and OMB between 5-10 December. This agreement is preliminary; many of the actual details of the science program will be worked out between the signing of this agreement in December and a more final agreement that will be signed sometime next summer before the Systems Integration Contract (SIC) is let.

II. PRELIMINARY AGREEMENT/BUDGET CONSIDERATIONS

The oil industry has been asked to fund half of the program, and in return is expecting to have a considerable influence on the program. They expressed reservations about the estimated total cost of the program. They felt the costs were too low and could run three times the NSF estimates. In addition, the government estimates are only inflated by 7%, when off-shore drilling costs have been increasing at a rate of 15%.

The Santa Fe Engineering Services Company, which has been hired by the NSF as the Systems Support Contractor for the EXPLORER program, reviewed the costs of a hypothetical program, outlined at the 2-3 October Houston meeting. They found that the estimated cost of $560 M was very close to their $600 M estimate (both figures at 7% inflation). Even at these prices, the oil companies considered the program to be too expensive. This was particularly viewed as a problem in 1981 when the NSF budget is still paying for the CHALLENGER program.

To cut costs, it has been proposed to eliminate the 18-month riserless program, saving an estimated $55 M in ship's operations and $20 M in science. In such a shortened program, the ship could be converted on either coast, and begin operations in early (about January) 1984 with a riser. This program allows the conversion of the ship and commencement of operations to proceed at a slower rate. The amount of money needed during the initial phases is decreased.

1981-83 <u>CHALLENGER</u> PROPOSAL

A revised version of a proposal to continue CHALLENGER operations was presented. Several revisions were suggested. Some minor changes in the wording may be made before the final version is submitted. Unfortunately the time available to make the changes is very small.

The proposal will be submitted to the University of California Regents in Januasry for review and to the National Science Foundation shortly thereafter. A letter of intention to submit a proposal will be sent to the National Science Foundation before the proposal arises.

Alternative sources of funding and even a partial style program were discussed.

PLANNING COMMITTEE
23-26 October, 1979—Moscow

REVIEW OF ACTION ITEMS

The cost of producing microfiche masters for I.R. Volumes 1-42 is estimated to be $1,050. DSDP has agreed to fund this and production is underway. When microfiching is completed, announcements of the availability of I.R. microfiche on a cash basis will be made in <u>Geotimes</u> and the <u>JOIDES Journal</u>.

Prior to the meeting a report listing the GLOMAR CHALLENGER work history, from December, 1978 to September, 1979 and the tentative projected work scheduled for 1980 was prepared by DSDP and distributed to the PCOM members. After discussing the report, the PCOM requested that DSDP prepare an additional report, prior to the February PCOM meeting, evaluating the CHALLENGER's performance capability for the 1981-83 time frame. The report should include data on mechanical down time for the ship and drilling equipment (as separate items) by quarter, for the last five years.

DSDP

I. DEVELOPMENTAL ENGINEERING

A. <u>Pressure Core Barrel</u>

The PCB is currently at DSDP undergoing refurbishment. Testing of each of the units will be conducted at the Hydraulic Lab during November, 1979. Two complete PCB units and two additional spare ball valve assemblies will be onboard the CHALLENGER when it is deployed. Sea trials are scheduled for Leg 72 and full operation is planned for Leg 74 or 75.

B. Hydraulic Piston Corer (HPC)

Based on the success of Leg 68/HPC, an HPC Development Program has been detailed to further improve performance. Items considered for design modifications are the core liner, core catchers, and core orientation. Collapse of the liners and failure of the core catchers were the two major problems with core recovery during Leg 68/HPC. Core orientation is available now but it is not very reliable. It is considered to be a long-term development.

Design is also continuing on the non-trip HPC system which will enable piston coring to be followed by rotary drilling without having to trip the pipe. This has been given the highest priority. By Leg 71 it is expected to have a system for dropping the bit. Work is continuing on developing a longer core barrel, but this has been given second priority. During Leg 68/HPC it was found that the work load created by a 4.4 m core was about the maximum that could be handled. Paleomagnetics and GRAPEing were the limiting factors. Preventing even minor bending in the longer cores, which upsets the paleomagnetic stratigraphy, may also be a problem.

A second HPC (HPC-II) is under development. It is anticipated that this will be designed to obtain several different core lengths, depending upon the material being cored. In addition, corrosion resistant materials will be used in the most critical parts. Sea trials for the HPC-II are planned for Leg 74 or 75.

Vessel modifications are also being discussed to minimize the interference when retrieving and handling the cores. The use of heatflow probes in conjunction with the HPC are also being investigated.

Plans for the South Atlantic Program involve extensive utilization of the HPC. DSDP has prepared a developmental schedule to make the HPC as efficient as possible for these legs. As improvements are made, DSDP was asked to keep the co-chiefs in the technical development loop.

C. Extended Core Barrel

A first prototype of the extended core barrel is scheduled for Leg 71, with a more final version planned for September, 1980. The system is being designed to ensure that the landing and latch system are compatible with the HPC. This will allow the extended core barrel to be used when piston coring is terminated without tripping the drill string.

COSTS OF CURATING HPC CORES IN ONE OR TWO REPOSITORIES

The HPC cores recovered during Leg 64 were strip photographed in both black and white, and color. This was considered to be successful. It was suggested that all cores, and particularly HPC cores, be strip photographed. This would allow leg participants to have microfilms of all of the cores on their legs. These photographs can be enlarged and projected onto acetate, printed, and run through an ozalid machine, providing large core photographs.

Continuous strip cameras, however, are very expensive. DSDP is currently using a camera developed and operated by T. Chase, of the U.S.G.S., Menlo Park. DSDP pays his and any technicians' expenses while they are photographing the cores. These expenses would be increased if he had to travel to the east coast core repository. It was suggested that expenses might be cut by using the strip photographs in the I.R.'s. Prior to Leg 45, the cores were individually photographed. The present method of group photography was not considered by some to be adequate.

DSDP is also buying an x-radiograph to use on the cores. The X-rays should be taken at the same time as the photographs. It was considered unwise to photograph and X-ray the samples at DSDP and then ship them to LDGO. The costs of preparing the cores for photographing (e.g. scraping and arranging) were thought to be minimal, and funds could be found at LDGO. In additi-

LDGO already has an x-radiograph, so X-raying the cores would not present a problem. The consensus was that it was important to keep the HPC cores and the rotary drilled cores for each site together, jand therefore two HPC repositories should be maintained.

It was suggested that money for a strip photography camera be included as a high priority in the FY '81 budget. It may be possible to shoot the photographs onboard the ship. This would certainly give the best color reproductions in the I.R.'s. It was suggested that DSDP check with the Dolphin Marine Station which uses color reproductions in its reports.

EXPLORER PLANNING

The representatives from the non-U.S. countries were asked to comment on the status of their countries' interest in, or plans to participate in the EXPLORER program. All of the representatives agreed that it was difficult for their countries to decide whether or not to participate until they knew what the program was going to be, e.g. how much resource evaluation and how much science, the expected role of the non-U.S. countries in the program, and the cost. Discussions are underway in France. Germany is very interested. R. Brett from NSF has been asked to give a presentation about the program in Germany, and a letter of intent to participate in the EXPLORER program has been sent to the U.S. The U.K. is also interested in participating and hopes to be able to formulate a final policy within the next six months. As expressed, their major concern was financial. If the cost per country is high, would it be posssible to increase the number of participating countries, or find a less expensive way to carry out the program. The U.S.S.R. expressed an interest, but is also waiting to learn more about the details of the program. Japan was not represented.

The EXPLORER program has a sense of momentum in the U.S. The Blue Ribbon Committee report is out and was favorable. The National Research Council's engineering review (Hocott) committee plans to have its report out in January. High-level negotiations are underway between the petroleum industry and the NSF. It is hoped that these negotiations will have reached a more final state by the EXCOM meeting.

A new ad hoc EXPLORER planning committee is being established in the U.S. to address the development of the EXPLORER program. Both industry and the government want to be sure that the EXPLORER plans be based on a strong scientific program. NSF is interested in the ultimate participation of the non-U.S. countries.

The EXPLORER Engineering Support Services contract has been let to Santa Fe Engineering Services Company of California. They are reviewing the previous studies and cost estimates. A preliminary review will be ready by early November.

1981-83 CHALLENGER PROPOSAL

The 1981-83 CHALLENGER proposal is being rewritten and will be submitted to EXCOM and SIO. The IPOD representatives were again asked to state their countries' intent. They are waiting until the U.S. makes a clear statement of its intent. They agreed that if there were a program break and funding stopped, that it would be very difficult to regain the funds.

DRAFT REPORT
OCEAN CRUST PANEL
5-7 September, 1979—Albany, N.Y.

FUTURE CHALLENGER DRILLING

I. COSTA RICA RIFT/GALAPAGOS RIDGE

The OCP was distressed that these two legs (69 & 70) were shortened. Such a loss was viewed as deleterious to the well formulated and timely scientific goals of the leg. Decisions such as this seriously comprise good science and violate the fundamental principals of research. Two years of drilling remained and it seemed clear to the OCP that the reduction of drilling time could have easily been absorbed over this interval without significantly perturbing the scientific objectives of the remaining programs.

II. GEOCHEMICAL TRANSECT

The OCP had been asked to prepare a detailed presentation of the data pertinent to formulating a geochemical traverse. It was noted that the CHARCOT cruise that was to obtain more samples to document the patterns of North Atlantic geochemical heterogeneities was postponed until the fall of 1979. Furthermore, Cann, who is the PCOM representative designated to present the information, will be out on Leg 69 and therefore will not be able to attend the PCOM meeting. The OCP will submit a short but detailed document that outlines the scientific rationale behind the geochemical traverse. The CHARCOT data will, however, be available for the PCOM meeting to be held in February in Washington, D. C.

III. CARIBBEAN PROGRAM

Although the OCP agrees that further drilling in the Caribbean would certainly help to better understand aspects of Caribbean geology, it maintains that this program will solve problems local to the Caribbean and will not address problems that will shed light on the fundamental processes that govern the evolution of the ocean basins and margins in time and space. In addition, the success of several of the holes depends on deep penetration (greater than 1000 m) in relatively deep water (3500 m to 5000 m) and into lithologies (cherts, mixed volcanics) that have been difficult in the past to penetrate. Using hindsight as a guide, the OCP suspects that the scientific goals of the program could be compromised by these environmental constraints.

EXPLORER PROGRAM

I. PLANNING ORGANIZATION

The OCP urged that progress be made with regard to deciding how committees were to be organized during the EXPLORER phase of drilling. It was emphasized that subject panels, which identify problems, must be retained. In this regard OCP considered it very important that EXPLORER engineers work closely with scientists as drilling objectives are identified.

II. OCP OBJECTIVES

The Panel reviewed the drilling objectives identified by the OCP at previous meetings and prepared a proposal for "Bare-rock drilling on an active sulfide-producing hydrothermal system." The Panel noted with some concern that EXPLORER plans were still so preliminary that preparatory geological and geophysical surveys could not yet be planned. This survey data is of paramount importance if the scientific potential of drill time is to be maximized. Given the lead time needed to design, implement and interpret the results from a rigorous marine geological and geophysical survey, it is none too soon for PCOM to reach the decisions necessary to begin the initial phases of the EXPLORER program. The panel urged that EXPLORER plans be established for at least the initial phases of the program.

BARE-ROCK DRILLING ON AN ACTIVE SULFIDE-PRODUCING HYDROTHERMAL SYSTEM ON THE EAST PACIFIC RISE AT 21°N

I. INTRODUCTION

The following presents a proposal by the OCP that a bare-rock drilling capability be developed for the GLOMAR EXPLORER. Such a capability has long been advocated by the OCP. The present mode of drilling (requiring a minimum of 25 m of sediments to spud in) only very rarely, and in special cases, allows drilling at the actual zones of plate accretion (zero-age crust). This is unfortunate in view of the excellent resolution of observations and sampling that can be obtained by near-bottom studies of spreading centers (e.g. FAMOUS, CYAMEX, RISE/ROSE, etc.); which need to be complemented by vertical sampling and examination of the crust. Also, we need to investigate the transient properties of plate accretion, such as hydrothermal circulation, heat flow, volcanism, and even structure.

Recent discoveries at 21°N on the East Pacific Rise have reinforced our conviction that bare-rock drilling is urgently needed and moreover is economically as well as scientifically justified. Once such a capability is developed, we envision a wider use of it than that advocated here. This document is preliminary and exploratory in nature, since we will need to develop a more complete statement to incorporate it in a larger proposal concerning the GLOMAR EXPLORER.

II. SULFIDE DEPOSITION AT 21°N ON THE EAST PACIFIC RISE

Recent dives on the East Pacific Rise at 21°N as part of a US-French-Mexican program established that syngenetic sulfide deposition occurs above hydrothermal vents on the sea floor very near the crest of the rise axis (CYAMEX, 1979, SPIESS et al., in preparation). The active vents are arrayed in the zone of axial extrusion along strike paralleling the rise crest, and are of two types.

The first type is characterized by a general low temperature (10°-20°C) fairly dispersed flux between pillows over areas of tens to hundreds of square meters. These areas contain the second more restricted types of vents, which are chimneys 2-10 m high and 1-5 m in diameter from which concentrated, hot solutions are vented. These solutions are rich in small particulate sulfides and sulfates, and are commonly vented at temperatures in the range of 200-500°C with some reaching 400 $\pm$ 10°C. In some cases the fluids vent with high hydraulic pressure.

The chimneys themselves can be chemically zoned, consisting of porous aggregates of oxide, sulfate and sulfide minerals (predominantly Fe, Cu and Zn sulfides). From exterior to interior, a typical zonation is:

1. Iron oxides and oxy-hydroxides (gossan minerals);

2. Sphalerite;

3. Pyrite ($\pm$ sphalerite);

4. Chalcopyrite & sphalerite.

Anhydrite is an accessory mineral. Particulate matter dispersing from the vents includes sphalerite, pyrrhotite and barite. Rare metals (Au, Pt. and especially Ag) are present at unusually high levels.

These deposits occur in an area that has been extensively mapped using deep towed instrumentation (Larson, 1972; Larson and Spiess, 1969; Larson et al., 1974; Normark, 1976, ANGUS) and submersibles (CYANA and ALVIN) and will be investigated again by researchers in November 1979 using ALVIN. The active vents areas occur in an area of very young virtually unfaulted crust near the summit of the East Pacific Rise axis, and are delimited by concentrated colonies of macrobenthos including large clams (up to 40 cm diameter), long tube worms and Galathea crabs. Tube worms cluster near the highest temperature orifices on the chimneys. Inactive chimney vent systems, variability degrated by oxidation and gravitational collapse. have been found away from the rise crest area, where 10-50 meter high normal faults are prevalent.

III. THE PROPOSAL

The OCP proposes that this complex of hydrothermal deposits be considered as a target for bare-rock drilling using GLOMAR EXPLORER following development of a suitable structure to support a bottom-hole assembly while spudding in. The rationale for this drilling would be investigation of the ocean crust beneath and around both active and inactive hydrothermal vent areas. Economic grade ore deposits may be present in these areas. The drilling would be designed to explore in three dimensions the interaction of outflowing hydrothermal solutions containing high concentrations of dissolved metals and sulfur with the oceanic crust, and the downhole thermal and geophysical structure of the crust in the vicinity of the vents. The chemical factors leading to zonation of sulfide minerals on a small scale in the vents may be acting on a larger scale in the crust, and may have a specific relationship to the sea-floor geology and the crust thermal structure.

Detailed exploration of such a system might eventually allow development of strategies for tapping high-temperature submarine aquifers with high concentrations of particular metals. These solutions could be pumped directly to the surface by a drilling ship with reverse circulation. Filtration and precipitation of ore minerals could be carried out on the drilling ship, and collected in tanks for shipment to ore refineries.

The principal advantage of working in the 21°N East Pacific Rise area is that the area has been sufficiently mapped and observed to identify targets where local basement variability is precisely known. This will allow accurate specification of design parameters for the construction of a structure to support a bottom-hole assembly. Presently it appears that many vents could be explored in fairly flat areas, or areas with moderate slopes. Local relief (flow fronts, faults, etc.) can be as little as 5-10 meters. The present and planned detailed surveys will also allow transponder coordinated targeting of drill sites.

IV. DESIGN OF A BOTTOM-HOLE ASSEMBLY SUPPORT SYSTEM

Several alternatives might be considered for bottom-hole assembly sea-floor support structures, depending on the type and depth of penetration desired, the number of holes to be drilled, and the desirability of having a movable and/or retrievable system. Several alternatives are listed below.

1. A permanent re-entry cone and casing structure mounted on the sea-floor in a large cement-inflated bag or net. The original looseness of such a structure would fill in any local basement relief and allow vertical suspension of the re-entry cone while the cement sets.

2. A movable, retrievable re-entry and casing structure which could be hydraulically or mechanically leveled from three or four corners, and perhaps intermediate points. Alternately, a number of legs or struts could be fully extended prior to touching the seafloor, but each would be free to slide upward until all had touched down. Then all could be mechanically locked in place. To move the structure to another location, the lock would first have to be released, either remotely or by divers beneath the tending drill ship.

3. Shorter penetration, high recovery holes could be drilled, not necessarily vertically, by high speed diamond drilling techniques from a similar platform suspended and powered (electrically or hydraulically) from a more conventional drill string. The actual drilling/coring device would be housed in the platform and need not be directly linked to the drill string.

The GLOMAR EXPLORER seems like the logical ship for such a venture, because of its (a) superior uplift, positioning, and heave-compensation capabilities; (b) it will have reverse circulation; and (c) its moon-pool area will be large enough to allow construction and servicing of a large retrievable re-entry structure beneath the rig floor above the vessel's waterline. Such a structure would be designed and tested in the next several years, before acquisition of the GLOMAR EXPLORER for deep sea scientific drilling.

The engineering and scientific planning should proceed simultaneously. The latter could include further submersible mapping and geophysical exploration of the vent areas using site survey funds. The program could be initiated by the Ocean Crust Panel, and planned in coordination with the Ocean Crustal Dynamics program of JOI Inc. It should be of considerable interest to private ocean-floor mining concerns, and ocean-engineering firms developing these types of technologies. These could be approached for both consulting and financial assistance.

Development of bare-rock drilling techniques on the sea-floor has been a long-standing request of the Ocean Crust Panel. The major difficulties this request has faced have been the lack of a clear scientific program for such drilling, uncertainty about whether a drill string could penetrate significantly into zero-age crust even with a bottom-assembly supporting structure and the anticipated cost of developing such a structure. Here, however, the scientific advantage is clear, many important conclusions could be reached even with shallow penetration holes, and the cost of development can be weighed against potential economic gain. The penetration problem in particular will not be as serious with the GLOMAR EXPLORER, especially if it has the flexibility to case and cement unstable zones in the crust.

V. RECOMMENDATIONS

With the approval of the Planning Committee, the OCP would like to prepare a more complete proposal dealing with bare-rock drilling at the East Pacific Rise at 21°N (and/or other rise/ridge crest segments where similar deposits could well exist). This proposal would be incorporated in the larger proposal concerning EXPLORER drilling to be submitted to NSF. To prepare the bare-rock drilling proposal, we will constitute a working group which will also investigate the feasibility and cost of the alternative bare-rock drilling structures suggested here.

DRAFT REPORT
ACTIVE MARGIN PANEL
5-7 September, 1979—La Jolla

FUTURE CHALLENGER DRILLING PLANS

I. BARBADOS RIDGE PROPOSAL

The Active Margin Panel and the Caribbean-Mediterranean Working Group have recommended drilling on the Barbados Ridge to sample the accretionary complex and the shear zone separating the continental from the subducting igneous ocean crust. The water and drill depths are within GLOMAR CHALLENGER capability. The drill hole could be used to emplace downhole instruments as was done off Guatemala where seismic activity, rates of tectonic tilt, and heat flux are being measured. The necessary geophysical site surveys have been done, and in addition, the University of Durham and IFP-CEPM have planned GLORIA, high resolution CDP and single-channel seismic reflection, and SEABEAM surveys in this area. Data are now ready for Safety Panel review.

The reason for drilling the Barbados Ridge is based on some unexpected results from previous drilling. Tectonically accreted sediment, thought to comprise the bulk of a convergent margin, was sampled on only one of 5 active margin legs. Thrust faults were not observed in proximity to zones of subduction as was expected, possibly because most of the thrusting is concentrated in a deep narrow zone with low shear resistance. The tectonic features thought to be most common were not commonly found in drill core data. Perhaps the drilling depths achieved were insufficient to penetrate the anticipated imbricate thrusts and tectonically accreted sediment.

A chance to penetrate the accretionary complex and mega-shear of a subduction zone off Guatemala was inadvertently stifled on Leg 67. As the results of the drilling have become known, increasingly greater importance has been given to drilling on the Barbados Ridge than was given by the AMP during the planning of IPOD-I. Thus the AMP has remained persistant in calling attention to this opportune scientific target that can be achieved in half a leg, at almost any season.

II. GUATEMALA TRANSECT

Leg 67 objectives were only partially met due to the encounter of gas hydrate. The AMP does not consider the Guatemala transect as having successfully met its objectives. There still has been no penetration of a presumed master thrust fault at the base of the accretionary complex. (Only the top of the accretionary complex was penetrated during Leg 66.) The AMP considers that significant penetration of the accretionary complex is a feasible CHALLENGER target off Guatemala.

III. JAPAN AREA DRILLING

Several Japanese scientists (Nasu, Kagami, and Kobayashi) have proposed new active margin sites on the Japan Trench margin, along the Nankai Trough, and on the Amami Plateau. The Nakai Trough is considered to be an interesting target in light of the Leg 31 results from one hole at the base of the trench slope. They will be considered for the 1981-83 Japan Trench proposal once more specific data is received. The Amami Plateau was considered to be a better target for the EXPLORER. Piston coring for tephrastratigraphy and in zones of deformed sediment are appropriate in the 1981-83 program provided the material is soft enough to be cored with this tool.

IV. CHILE TRENCH

A proposal submitted by Cande and Herron to drill at the collision of an active spreading center and the Chile Trench was considered to be an interesting problem, different from the Peru-Chile Trench objectives. This seems to be a singular opportunity to study a phenomenon that must have occurred often in the past. It is included in the proposed EXPLORER program pending more geophysical work in the area.

SITE SELECTION RATIONALE

The AMP agreed that it is more advisable to drill each transect sufficiently to answer most of the major questions there, rather than to partially study many margins. This has been the basic consideration in all IPOD proposals.

Furthermore, the fundamental approach has been to do as much as possible with the CHALLENGER to optimize EXPLORER targets. The additonal work along the Japan Trench transect is consistent with these basic considerations. It seems advantageous to restudy the Guatemalan Trench transect geophysical and drill data and to work out the safety aspects of drilling clathrates before further drilling. Drilling on the Guatemalan transect must therefore be postponed until the EXPLORER program. The area of next priority is along the Peru Trench and since the area has been studied geophysically for about 8 years, it is considered ready for the 1981-83 program.

REVIEW OF PREVIOUS RESULTS

I. LEG 56-57

The history of vertical tectonic changes off Japan shows a surprising net subsidence since upper Miocene time. Current studies in Japan indicate that during the upper Miocene there was a change from tensional to compressional stress. More emphasis is now given to constrain the time/space vertical tectonic history along the Japan Trench transect.

II. LEG 58

A draft report was distributed showing the proposed history of the northern Philippean Sea. The conclusions presented in the Geotimes account apparently have not changed significantly. This report suggested that a hole in the Amami Plateau would test the hypothesis developed as a result of Leg 58, but drilling to basement may be marginal with the GLOMAR CHALLENGER capability.

III. LEG 60

Based on proprietary magnetic data, the south Philippean transect appears to be located in the beginning of a confused magnetic zone. Farther north the anomaly pattern is clear and it indicates spreading; nevertheless, the half rate computed during Leg 60 agrees with the proprietary magnetic data. A comprehensive report on arc and forearc drilling has been prepared. The report outlines some problems regarding the development of arc related igneous rock in arc and forearc regions of the south Phillipine transect. The report emphasizes low temperature metamorphism and the role of interstitial water.

An interesting study by Soviet investigators regarding a possible relation between sediment thickness on the oceanic plate and the amount of subducted sediment was also presented.

IV. LEG 66

On this leg the top of an accretionary complex was penetrated for the first time. Hole conditions were poor below the hemipelagic slope deposits and only the top of the landward dipping section seen in seismic records was recovered prior to hole failure. The oldest sediment recovered is of late Miocene age and the sequence of ages is from youngest near the trench to oldest up slope. This sequence requires reverse or thrust faulting along unspecified faults: most of the reflections in the seismic records are thought to record bedding. Crystalline rocks exposed at the the shore were recovered offshore and the abrupt break between old rocks and young accreted rocks postulated from seismic records was confirmed. A thick hemipelagic sequence was recovered seaward of the trench fill indicating a terrigenous influence far beyond the trench. The accretionary complex is from 7-20 Ma old. At least 50% of the sediment entering the trench appears to have been subducted.

V. LEG 67

The recovery of clathrate prevented drilling at the primary sites selected for this leg. Nonetheless, the section penetrated at the base of the slope consisted of a distal equivalent of the section reported from the edge of the shelf except that the Paleocene section is missing. The recovery of Cretaceous age rock 3 km landward of the trench makes it difficult to interpret the structure of the margin off Guatemala in accord with the simple imbricate accretionary mode.

Sediment recovered from the deep ocean basin 20 km seaward of the trench indicates that considerable hemipelagic sediment accumulates as the ocean plate nears the continent. The same oceanic section was recovered from beneath the trench fill mud and sand turbidite at two sites. Material in the trench, even at the trench landward wall, shows no compressional deformation indicating that accreted and subducted material intercepts the slope without much change during its transect across the trench.

GAS HYDRATES

Legs 66 and 67 definitely confirm the existence of gas hydrates in the deep oceans. Thus, although there has been much drilling at sites in the gas hydrate pressure temperature field, the existence of gas hydrate must be considered in siting future drill holes. In particular, penetration below the gas hydrate zone and into the gas pressure-temperature field must be avoided. In the Leg 66 seismic reflection data there is a clear "base of hydrate" bottom simulating reflection (BSR). In the Leg 67 data there is no BSR, despite the similarities in geology, and the gathering of seismic reflection data by the same organization. Thus it was shown that gas hydrate may occur with, or without, the BSR. Present safety requirements are that no gas hydrate is drilled without a BSR to indicate the base of hydrate and thus the maximum permissible depth of drilling. In the situation encountered on Leg 67, the recovery of gas hydrate and no clear BSR prevented drilling of the primary sites. However, the experienes of Leg 67 may show some alternate procedure for safe operations. These alternate procedure suggestions were presented by the organic geochemist on Leg 67.

With knowledge of the geothermal gradient and gas composition the thickness of a gas hydrate field can be plotted on a PT diagram. Both the Uyeda temperature probe and the HRT log can measure in situ temperature without release of the drill bit. Thus, the position of the bottom of the hole with respect to the base of the gas hydrate can be monitored. Simple plots which could be used in such a situation were presented.

The Organic Chemistry Panel (OGP) was asked to consider the use of such plots. In addition, the AMP advises that the Uyeda heatflow probe and thermal conductivity apparatus be improved. A workable pressure core barrel would aid greatly in monitoring in situ conditions. Perhaps a device that takes only a 6" long small diameter core would be easier to design. It seems that there are procedures by which the thicknesses of the gas hydrate zone can be established without a clear BSR. The Safety Panel will be asked to consider these alternatives once the assessment of the OGP has been made.

DOWNHOLE INSTRUMENTATION

I. PACKER/TELEVIEWER

The packer was used successfully on Leg 68/Site 501, although it suffered some damage. The downhole televiewer gave very interesting results. Fractures and pillows could be identified in the records. After viewing shipboard pictures, the panel felt that this instrument could contribute valuable information about fracture patterns in the deformed sections penetrated in accretionary complexes. The panel endorsed the proposal to put such an instrument aboard the drill ship.

II. HIG DOWNHOLE INSTRUMENT

Preliminary results were given from the HIG downhole instrument emplaced off Guatemala. The tiltmeters and heat flow components gave unexpected results during the first recording period. Change in tilt perpendicular to the regional trend of the trench occurred during the first month. Heat flow required abut 7 days to come to a constant value indicating that the effects of drilling persist for a much longer period than expected. Many earthquakes have been recorded but, due to unresolved difficulties in the digitizing components, noise was superimposed on the seismic records and work is proceeding on correcting this problem.

III. FUTURE DOWNHOLE INSTRUMENTATION

The AMP has been concerned with three types of downhole geophysics:

1. Downhole logging with instrument tools.
2. Intermediate scale geophysical data.
3. Long-term downhole observation.

During the period when there will be no drilling on active margins, the AMP is interested in further developing and optimizing downhole geophysics. The following are suggested improvements that would enhance the data sets from future AMP transects:

I. Downhole Logging with Industrial Tools

A. Update the present suite of tools in use on GLOMAR CHALLENGER which are of a past generation.

B. Experiment further with sonic televiewer, the dipmeter and the magnetometer.

C. Incorporate a heatflow measuring system into the HPC.

II. Intermediate Scale Experiments

Oblique seismic measurements in areas of complex structure to augment seismic reflection data.

III. Long-Term Downhole Observation

Take advantage of the HIG instrument development program, demonstrating that the highest data rate instrumentation (seismic) can be successfully deployed. Suggested improvements include: first, the present instrument should be optimized; second, the satellite data link should be developed; and third, other instruments could be added, such as strain meters, tide gauges, and magnetometers.

Downhole measurements are particularly appropriate in active margin areas because:

1. Recovery of core is often poorest at some of the most interesting sites and the geophysical indication of recovered intervals has been of great value.

2. Complex strucuture often makes it difficult to bridge the gap between the interpretation of seismic reflection records and the interpretation of core data. Detailed refraction information and velocity control become important in bridging the gap.

3. Many questions about modern active margins are related to earth dynamics that is in turn related to earthquakes and rates of tectonism. These parameters are best measured by in-situ instruments. If the Barbados Ridge is drilled it would be most appropriate to obtain the geophysical measurements outlined here. If development of the HIG type of instrument proceeds at a steady pace, an advanced version could be ready for deployment at about the time when the CHALLENGER transits from the South Atlantic to the North Pacific.

<u>EXPLORER</u> PROGRAM

I. AMP SITE OBJECTIVES

The explanation of the EXPLORER program and the statement of objectives were left as previously written. However, the priority of various areas was shifted.

II. CORE DIAMETER

The question of core diameter size was posed by the PCOM. Logging alone could be very advantageous in some circumstances, but coring should remain the prime mode of sampling. Logging alone can be advantageous when the major target is buried beneath "overburden" such as slope deposits over accretionary complexes, or when weather allows only short windows in which to hit the high priority deep target.

In regard to the smallest acceptable core size, small diameter core is acceptable in hard rock where deformation of core is small (down to 2.5 cm). But, coring should always be an option.

SYNTHESIS VOLUME

As noted in the minutes of the last two AMP meetings, the panel recommends compilation of a synthesis volume sponsored by IPOD. IPOD groups of individual member nations plan to produce summary volumes also, each with a different emphasis. The subjects proposed for the IPOD-AMP synthesis volume take this into account to avoid significant duplication.

The AMP thinks such a synthesis is timely because of the lull in active margin drilling (1979 to 1981-83). A comprehensive synthesis of IPOD results will clearly provide a good basis for future active margin investigations.

The preliminary table of contents is as follows:

I. Introduction and overview of IPOD-I geophysical and drilling results.

II. Processes in modern fore-arc areas:

  A. Earthquake and exploration geophysics combined with on land and drill data across the IPOD-I active margin transects.

  B. Sedimentology of fore-arc, trench and ocean basin areas along the IPOD-I active margin transects.

  C. Kinematic models.

III. Some processes active in the development of island arcs:

  A. Geochemical knowledge of island arcs along the IPOD-I active margin transects.

  B. Geophysical observations including crustal structure, heatflow, gravity, and magnetism.

  C. Metamorphic processes.

  D. Time and space history of island arc igneous activity.

IV. Origin of backarc basins.

  A. Geochemistry of dredge and drilled rocks in backarcs along the IPOD-I transects.

  B. Tectonic spreading histories.

  C. Sediment sequences in backarc basins.

V. The status of knowledge along the IPOD transects and definition of problems.

Compilation and structuring of the synthesis volume should involve one to three editors who can solicit contributions and prepare overview chapters. An expensive ($10-$15) paperbound volume is envisaged. Funding will be sought from a U.S. source.

DRAFT REPORT
ORGANIC GEOCHEMISTRY PANEL
24-25 September, 1979--Bristol, England

The panel made several recommendations to DSDP regarding samples, particularly temperature monitoring and sampling frequency. Staffing and other operational matters were also discussed.

Results and the status of sample analyses from recent legs were reviewed.

<u>Leg 64</u>

At Site 478 fluorescence of petroliferous organic matter was used as a measure of the effect of the presence of sills; at Site 479 methane abundances were about the same with depth but ethane increased and higher homologues reach a maximum and then decreased which may be evidence for migration; at Site 481 methane, the main gaseous hydrocarbon, increased in concentration with depth but decreased near sills. At this site evidence was found for hydrothermal activity in the form of cooked-out, amorphous organic carbon with adsorbed gas.

<u>Leg 66</u>

Samples were from the Middle America Trench area. Evidence for gas hydrates was found: frost forming on liner, ice inside liner, and gas expansion 20 times greater than expected. Gas is mainly methane probably of biological origin.

<u>Leg 67</u>

Frozen interstitial water was found in volcanic ash composed of silt and sand-sized particles. Thawing and gas release from this sediment indicated the presence of gas hydrate. An 88cc sediment specimen (assumed to have 20 cc of gas hydrate) was sealed in a 380 cc reaction vessel. After 20 minutes the pressure reached 1.16 kPa (172 psi). During core recovem... sediment...

1. More heat flow measurements;

2. Gas hydrate stability diagrams with reasonable safety factors;

3. Modified pressure core barrel that can close on frozen sediment; and,

4. Stiffer temperature probes for penetration into gas hydrates.

As a result of these summary reports, it was concluded that there is a need for more temperature information at DSDP sites. In addition to more detailed temperature measurements, there is a need to develop better methods and models for temperature considerations. To devise models there is also a need for measurements of porosity, permeability, sedimentation rates, and lithology.

HYDROCARBON MONITORING

The panel reviewed the "Hydrocarbon monitoring as a means to assess safety conditions for DSDP operations," by W. Harrison, shipboard organic geochemist, Leg 67. In addition to discussion specific to that document, the following suggestions were made for hydrocarbon monitoring:

1. Total amount of gas is important. This should be monitored by analysis data and by observations on core expansion.

2. Where C_1/C_2 ratios reach the region of about 400 to 500, greater care must be exercised in the monitoring process.

3. Abrupt changes in the trends of the C_1/C_2 ratios are more important for safety considerations than the trends themselves.

4. Maturity should be compared and monitored by, for example, pyrolysis techniques.

5. Consideration should be given to the overall geology and seismic information.

6. Pressure core barrel should be deployed when high hydrocarbon accumulations are suspected.

New criteria are needed in Safety monitoring. A panel member, Welte, agreed to test a method of C_2-C_8 analysis on Leg 75 in the South Atlantic.

STATUS OF SOUTH ATLANTIC SITES

A change in the proposed location of a site in the Cape Basin (3-1) that cannot reach black shales for a site on the flank of the Walvis Ridge (1-5) was considered essential. The OGP wants to obtain a more or less continuous record of the oxic-anoxic transitions in the South Atlantic. Highest priority is the black shales. The organic geochemistry program should examine Aptian and Albian events with collection of continuous sequences corresponding to these events. To achieve this goal several meters of continuous core are needed.

For sampling it is recommended that, for important intervals, the core be split on shipboard and half the core be frozen and used for organic geochemistry and for the frozen sample archives. Such sampling will have to be approved by OPP and DSDP. The sampling represents a major departure from the way samples have been collected and allocated in the past. It was also recommended that two organic geochemists be on board.

REVISION OF SHIPBOARD ORGANIC GEOCHEMISTRY GUIDE/HANDBOOK

The present document was criticized for emphasizing analytical procedures and problems rather than techniques, approaches, and interpretations. The document should:

1. Delineate the roles of the shipboard organic geochemist and shipboard technicians regarding sampling and analysis.

2. Describe what information the instruments are expected to provide.

3. Provide guidelines for interpretation of analytical data.

The document will be revised, pending panel input.

SHIPBOARD AND DSDP MEASUREMENTS

It was suggested that onboard determination of Eh as soon as cores come on deck would be valuable in assessing early reactions. Such a measurment would be useful in shallow piston cores but less useful in deeper conventional cores. If Eh measurements are to be made routinely in the future, the design, fabrication, and operation must be done by an investigator interested in this problem. A discussion followed about the use of geochemical parameters to distinguish oxic and anoxic environments. It was emphasized that there are a number of organic molecules that potentially can give information on oxic/anoxic conditions, but none of these molecules has been studied in enough detail to provide unambiguous results. Oxoporphyrin compounds offer a good possibility. Oxidation states of iron are also useful.

GAS SAMPLING

Although there was disagreement in OGP about whether or not plastic sacks could be used to contain samples for later C_1 through C_4 gas analyses, there was agreement that canned samples are the most reliable for gas analyses. The project was encouraged to take more canned samples for gas analyses. When No. 2 cans are used, a 50 ml headspace is sufficient. Freezing provides the best method of preservation.

HYDRAULIC PISTON CORE

Organic geochemical programs for hydraulic piston coring were discussed. These studies will consider paleoenvironments including the global carbon budgets, diagenetic processes, both chemical and microbial, and the origin and migration of petroleum. The work will require long cores and frequent sampling in order to detail the relationship between sediment layers and organic geochemistry.

CURRENT AND FUTURE ORGANIC GEOCHEMISTRY IN DSDP/IPOD

Panel members discussed aspects of organic geochemistry relevant to cores obtained by the GLOMAR CHALLENGER. Some of these included:

1. Details of the use of tetrapyrole pigments for diagenesis models and as paleoenvironmental indicators.

2. The role of feed-back mechanisms in petroleum generation. Through material balance calculations the composition of source materials can be determined through compositions of kerogens.

3. The use of isotope fractionation to understand the source of organic matter and its evolution. Isotope fractionation during diagenesis depends on intermolecular isotopic distribution effects and polymerization isotope effects.

4. The diagenetic alteration through microbial and carbonium ion reactions in petroleum formation, of simple distributions of alkanes, alkenes, and arenes and carbonium ion reactions to complex distributions accompanied by decreases in alkenes and arenes and increases in alkanes.

5. The evaluation of the amount of thermally reactive organic matter through pyrolysis-fluorescence and pyrolysis-FID methods. Measurements of C_{eff} can be related to the van Krevlin diagram and there is a parallelism between C_{eff}/C_{org} and Iron Index.

6. Possible inputs to marine sediments were summarized. Gas and lipids are minor, humates are variable and kerogen is the major form of organic matter. The lipids act as molecular markers to fingerprint metabolic, diagenetic, and catagenetic processes in recent and ancient sediments. Aeolian transport forms an important input mechanism in marine sediments.

7. The kinetics of the production of hydrocarbons upon pyrolysis follow first-order reaction kinetics. Activation energies (Ea) can be calculated that relate to the timing and origin of petroleum. It should be possible to relate Ea to T_{max} of pyrolysis.

8. Organic matter in sediments recovered thus far in DSDP is generally of low maturity. Vitrinite reflectance is not of great use at these levels of maturity, and more information is needed on the onset of petroleum generation. This information may reside in low molecular weight hydrocarbons.

   There is a problem distinguishing migrated from indigenous hydrocarbons. To relate maturation with temperature there is a need for good temperature data that can be used with lithology, sedimentation rate, porosity, permeability, and vitrinite reflectance to construct heat flow models and thermal history.

DRAFT REPORT
OCEAN PALEOENVIRONMENT
PANEL MEETING
5-6 September, 1979--Barbados

HPC AD HOC WORKING GROUP MEETING

The HPC ad hoc working group meeting was discussed (See JOIDES Journal, Vol. 5, No. III, p. 50-52). A telegram from the ship to DSDP was read giving the latest results at CR-1 (Site 502). It was noted there are presently 3 to 4 U.S. ships and 3 non-U.S. ships capable of HPC operation; daily costs are about $50,000. The Health memo for second generation long (200 m) piston coring was briefly discussed.

SOUTH ATLANTIC PROGRAM

Various factors (delays, ship repairs, mini-leg, etc.) have caused rescheduling of the South Atlantic drilling program. It will now begin in the SW Atlantic (Falkland Plateau). The latest ship schedules for the GLOMAR CHALLENGER and the recommendations of the South Atlantic and Southern Ocean Working Group meeting, held in April, were reviewed.

The information about the South Atlantic Program will be presented on the next three pages as a continuation of this report, but in table form.

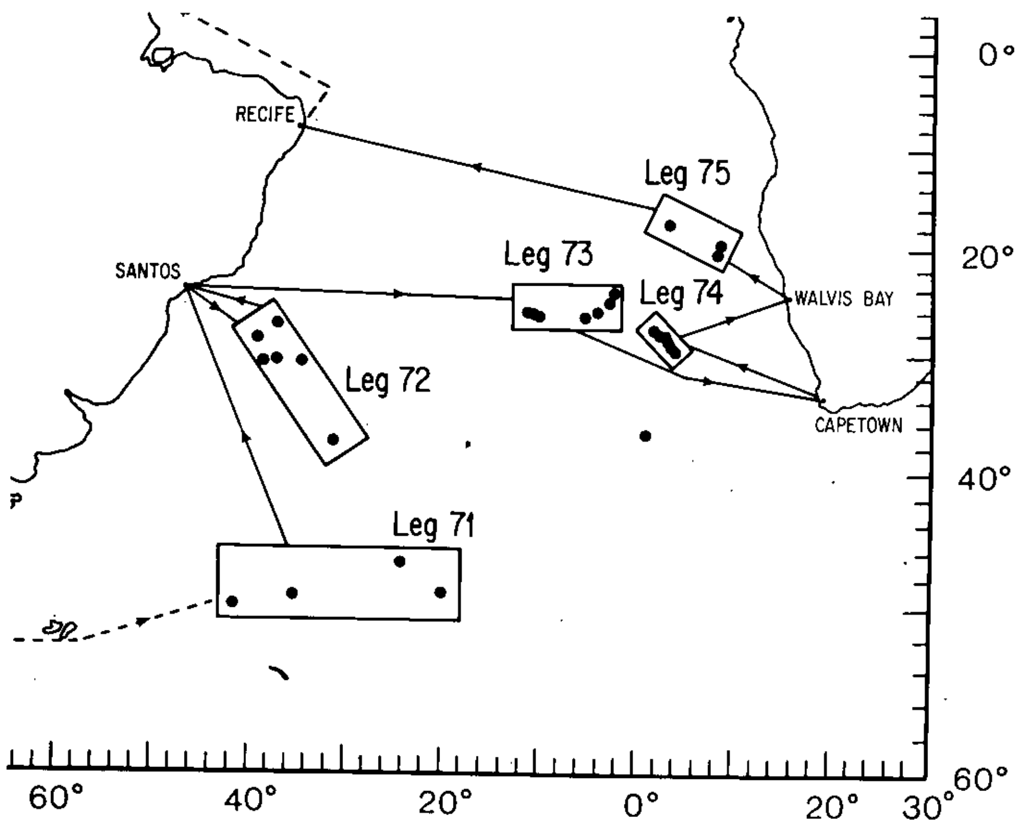

FIGURE 10

South Atlantic Leg Locations

TABLE I

I. LEG 71 SITES (FALKLAND PLATEAU)

A. First-Priority Sites

Site/Location	Objective
AB-1/N. Falkland Plateau	High latitude record of CCD fluctuations in Cenozoic and Mesozoic; opening of Drake Passage; high latitude biostratigraphy record.
AB-3/SE Argentine Basin	Test Cenozoic latitudinal oscillations and development of polar front; biogenic productivity history.
AB-4A/SE Argentine Basin	Together with AB-3, provides transect of the polar front; Eocene-Oligocene boundary.
AB-6A/Rio Grande Rise	Paleodepth Transect (with AB-6B, 7, 8, & 9) to investigate history of water-mass development in the South Atlantic; complete biostrat record for late Cretaceous & K/T boundary.
AB-6B/Rio Grande Rise	Cenozoic record to go with AB-6A.
AB-10/Brazilian Slope	Paleoclimatic history of Brazilian Current.

B. Second-Priority Sites

Site/Location	Objective
AB-2/Ridge between Agulhas and Falkland Plateaus	OP of the S. Atlantic and Indian Basin.
AB-2A/Ridge between Agulhas and Falkland Plateaus	OP events and sediment changes related to break in Agulhas-Falkland fracture zones.
AB-5/Hunter Channel (Back-up Site)	Examine history of AABW in S. Atl.

C. Leg 71—Proposed Schedule

Site	Drilling Days	HPC	Drill
AB-1	8	Yes	Yes
AB-3	7	Yes	Yes
AB-4A	3	Yes	—
AB-6A	10	Yes	Yes
AB-6B			
AB-10	3	Yes	—
SUBTOTAL	31		
No. Days Steaming	9		
TOTAL	40 Days		

II. LEG 72 SITES (RIO GRANDE RISE)

A. Site Selection

Sites AB-7, 8, and 9 will be drilled. These sites together with AB-6 are designed to examine the history and development of bottom water-mass in the South Atlantic.

B. Leg 72—Proposed Schedule

Site	Drilling Days	HPC	Drill
AB-7	10	Yes	Yes
AB-8A, 8B	28	Yes	Yes
AB-9	12	Yes	Yes
SUBTOTAL	36		
Days Steaming	4		
TOTAL	40 Days		

Back-Up Site: AB-10—Drill to basement

III. LEG 73 (MID-ATLANTIC RIDGE)

The revised site selections (following recommendations made at the Toronto OPP meeting) were presented. Leg 73 is a ridge transect designed to examine Tertiary Oceanography; seven primary sites were selected (several alternates discussed), each located on a magnetic anomaly as part of a designed age-depth traverse. In addition to the proposed sites, another site will be added to the SA-II, 1-6 transect. This site will be in water less than 2 km deep.

A. First-Priority Sites

Site/Location	Objective
SAII-1/Anomaly 5/5A 10 Ma	Miocene record.
SAII-2/Anomaly 5B 14 Ma	Miocene record.
SAII-3/Anomaly 5C/D 17 Ma	Miocene; mid-Miocene event.
SAII-4/Anomaly 14-15	Late Tertiary
SAII-5/Anomaly 16-17	Late Tertiary
SAII-6/Anomaly 20 45.5 Ma	Eo-Oligocene
SAII-7/Anomaly 21-22 50 Ma	Mid-Tertiary

B. Second-Priority Sites

The Cape and Angola Basin sites were given lower priority because of the additional travel time required.

Sites/Location	Objective
SAIII-2/Cape Basin Anomaly 31 (lowest priority)	Cretaceous and Tertiary
SAII-6/Angola Basin	Mid-Cretaceous events

C. Leg 73 Schedule

It is estimated that the seven first-priority sites will each require 4 to 6 days of drilling time.

37 days operation (sites SAIV 1 to 7)
10 days steaming time

TOTAL 47 days

IV. LEG 74 (WALVIS RIDGE)

The major objective of this leg is an ocean gradient study across the Walvis Ridge.

A. Leg 74 Sites

Sites/Location	Objective
SAII-1 to 6/Walvis Ridge	Tertiary and late Cretaceous
SAII-7/Walvis Ridge; North of SAII-1 in 1800 m.	Shallow water site

B. Leg 74—Schedule

HPC and drilling of SAII 1 to 6 is estimated to require 6 days per site and 1 day per site to log. If logging is reduced, SAII-7 can be included.

	42 days operation
	8 days steaming
TOTAL	50 days

(Scheduled 44 days)

V. LEG 75 (ANGOLA BASIN)

A. First-Priority Sites

Sites/Location	Objectives
SAI-1/Angola margin, located at 200 mile limit; 4900 m water depth re-entry.	Examine history of Cretaceous anoxic events; 1200 m section.
SAI-2/Central Angola Basin	North end of Walvis Ridge Transect, anomaly 31; Cret.-Tertiary boundary; HPC
SAI-5/Flank Walvis Ridge	Cretaceous Anoxic history; intermed. site between DSDP 363 and basin; Albian basement.

B. Second-Priority Sites

Sites/Location	Objectives
SAIII-1/Cape Basin	Cretaceous

C. Leg 75—Schedule

On Site	
SAI-2	4
SAI-1	16
SAI-5	12
SUB-TOTAL	32 days
STEAMING	13 days*
TOTAL	45

(Scheduled 42 days)

*Assumes Walvis Bay as port of call.

VII. LOGGING RECOMMENDATION

A. Legs 71 & 72

Because of the reduced number of operational days on Legs 71 & 72, OPP requests that the sites be prioritized with respect to their logging potential and recommends that logging be restricted to the deeper holes at sites AB-6, 7, 8, and possibly 10.

B. Leg 74

OPP recommends that logging be reduced to sites SAII-1, 3, and 5, and that sites SAII-2, 4, 6, and 7 be omitted because of the reduced number of operational days available on Leg 74 and the close spacing of the sites.

REVIEW OF OPP RESULTS IN THE PACIFIC

The results obtained for the Tertiary phase of the recent ocean paleoenvironment drilling in the Pacific were summarized. Some of the succeses included:

1. The recovery of excellent late Neogene siliceous record for the Kuroshio Current System.
2. A complete Cretaceous-Tertiary boundary on Rise.

Failures included:

1. The poor recovery of the sites in the California Current System.
2. Loss of sites GA 1, 2, & 3 in the Gulf of Alaska and EP-1 in the Mid-America Trench area due to weather, scheduling and logistical problems.

The Chairman of the Mesozoic WG reviewed the failure of Legs 61 and 62 to achieve stated OPP objectives—recovery of early Cretaceous and Jurassic sediments. He re-iterated that the most important Mesozoic goals are drilling in the NW Pacific, the south end of the Japanese lineations and in the Mariana and Nauru Basins.

DRAFT REPORT
POLLUTION PREVENTION
AND SAFETY PANEL
19-20 November, 1979—Woods Hole

During the first day of the meeting the Safety Panel reviewed the sites for Legs 71 and 72. The second day was spent in a review and discussion of gas hydrates and the safety problems they present.

Leg 71

AB-1 Disapproved. Inadequate data. Poor seismic record left open the possibility that an angular unconformity underlies the area, and that a major fault nearby could have provided a migration route for hydrocarbons into the section to be penetrated.

AB-1b Approved if drill site moved to avoid penetration of lower beds where truncation and possible trapping could be encountered. New location at 1700 hours on CONRAD seismic line 2106, 21 March, 1978. Penetration approved to a depth equivalent to 4.1 sec on that record.

AB-1c Dropped.

AB-1c' To avoid penetration of the apparent unconformity at the site proposed, it was recommended that AB-1c' be drilled at two separate sites as follows:

AB-1c'(a) Approved at 0730 position on Vema 3103 (17 March, 1978), with penetration only to the prominent reflector at 2.9 sec at this location.

AB-1c'(b) Approved at the 0930 position on Vema 3103, also with penetration only to the prominent reflector at 2.9 sec at this location.

It was further recommended that a serious attempt be made to resolve seismic velocities in this area before drilling, in order that reliable predictions of depth to the 2.9 sec reflectors are available at these two locations. If the velocity problem cannot be satisfactorily resolved, it is recommended that Site AB-1c'(a) be drilled first in order to test the older beds nearest their outcrop position.

AB-1D Approved for hydraulic piston coring to 150 m.

AB-2 Approved as proposed.

AB-2A Approved as proposed.

AB-3 Approved as proposed.

AB-4A Approved to basement.

AB-4B Approved to basement.

Leg 72

AB-5 Approved as proposed.

AB-6A Dropped.

AB-6B Approved to basement. Extra precaution should be exercised to avoid drilling into or near the crest of one of the mid-section domes shown in the processed record. An adequate site survey by CHALLENGER and a complete analysis of available processed records should be made to insure the penetration of the mid-section in a synclinal position with respect to the domes.

AB-7 Approved as proposed.

AB-8A Approved as proposed.

AB-8B Approved as proposed.

AB-9 Approved as proposed.

AB-10 Approved for hydraulic piston coring to 200 m.

AB-10A Dropped.

Gas Hydrates

During the morning invited guests presented brief talks about various aspects of the gas hydrate problem.

The safety review of Legs 71 and 72 was completed on 19 November, and the day following was spent in a review and discussion of gas hydrates and the safety problems they presnt.

John Hunt explained the formation of gas hydrates and discussed their properties.

Tom Shipley talked about the BSR in the continental margin region off Oaxaca, and the gas hydrates encountered there during Leg 66.

Bill Harrison discussed the absence of an obvious BSR in the Guatemalan margin, and the encountering of gas hydrates there during Leg 67.

Roland Von Huene talked about the geologic setting of the Guatemalan margin, and the estimated P-T conditions under which the Leg 67 hydrates were found. He suggested that a very faint BSR may appear in the seismic records at the levels predicted under these P-T conditions.

Alfred Mayer-Gurr presented a brief case history of a blow out at an offshore drilling site.

Brian Tucholke discussed the character and occurrence of BSR's in geophysical records and showed some examples. He also presented a map showing the distribution of BSR's in the Atlantic margin of North America.

Bill Dillon and Charlie Paull expanded the Atlantic margin BSR discussion and showed geophysical records and maps of the supposed gas hydrate region in the Blake Outer Ridge.

Tom Shipley talked about the geophysical signature of gas hydrates and BSR's as the base of clathrate.

The day closed with a general discussion of the present state of knowledge of gas hydrate occurrence in continental margin settings, and the degree of risk incurred by CHALLENGER-type drilling in these regions. No clear-cut guidelines for future decisions emerged, but it was generally conceded that the P-T field for hydrate formation, although experimentally well established, is not known well enough in nature to accurately predict the position of its lower boundary. Furthermore, state-of-the-art in downhole temperature measurement for CHALLENGER drilling is not sufficiently accurate, and indeed, in many places, the geothermal gradient may not be well enough known, to form the basis for predicting a lower clathrate boundary below which drilling should not be continued. It was agreed that the pressure field could be satisfactorily represented by hydrostatic pressure, but the uncertainties involving other factors placed the accurate location of a base-of-clathrate beyond present capabilities unless a clear BSR is present.

Where a BSR is present, and is taken to be the reflector of a hydrate/gas interface, there still seems to be no complete assurance of the absence of high pressure above that marker. The published electric-log-interpretation of free gas occurrence within the hydrate zone in the McKenzie delta leaves open the possibility that zones of hydrates and zones of free gas can interfinger under some conditions, and that the hydrate/gas contact may not always be a clearly definable, and avoidable, stratum. Until more can be learned about the relationship in nature of clathrate and free gas, open hole drilling where clathrates are suspected will continue to present a high risk.

In summary, the Safety Panel concluded that, although a policy of strict avoidance of drilling in areas where gas hydrates might exist is not justified, each drillsite proposed in such areas will be critically reviewed, and very thorough site surveys and extensive regional background information should be provided for safety review. In the present program of open hole drilling, a very conservative attitude toward site approvals in possible gas hydrate areas will be the rule.

DRAFT REPORT
SEDIMENTARY PETROLOGY AND PHYSICAL PROPERTIES PANEL
2-3 November, 1979—SIO

CORE QUALITY

The reporting of core quality aboard the drillship was discussed. Staff scientists, recently aboard the CHALLENGER, indicate that sufficient documentation of relative disturbance is made on a routine basis for both the hydraulic piston corer (HPC) and rotary cores. For cores that are semi-indurated core splitting may be a problem. In these cases cutting with the standard wire knife is impossible and alternate methods of cutting the core with saws introduces water to the samples rendering the samples suspect with regard to physical properties. The SP4 recommended that the DSDP investigate how to avoid changing the physical properties of semi-indurated cores when they are split by saw in the shipboard laboratory.

REVIEW OF ACTIONS TAKEN ON THE 1978 SP4 REQUESTS

I. TECHNICAL MANUAL STATUS

Initial Reports Volume 44 is out and the ad hoc Technical Manual chairman Ross Heath is pushing all Manual authors to revise previously submitted papers or to prepare papers to complete this project.

II. DRILLSHIP STAFFING (IN SP and PP)

Efforts to date for SP4 members to suggest names have not been very successful. The SP4 has proposed to establish a working group to help the SP and PP staffing.

III. REVIEW OF STATUS OF OBTAINING ORIENTATED CORES

Apparently a prototype orientated coring system was developed and tested on Legs 32(?) and 37(?). The tests were unsuccessful, which is attributed to lack of unfractured basalt that would hold together during coring. DSDP management, according to old records, recommended against further funding and development.

The HPC can be relatively oriented with respect to a mark to within about 5° about 70% of the time. Geodetic orientation is feasible, but initiation would cost about $5000/leg. Because of the cost, and lack of clamor for true orientation, this method is held in abeyance. It was the consensus of the Panel that orientated cores should be collected. The status of orientating soft and indurated sediment and rock cores will be reviewed.

REVIEW OF RELEVANT DSDP INFORMATION

I. FUEL AND LOGGING

The CHALLENGER's fuel costs have risen over budget by about 0.5 M$. Logging is a package that may be susceptable to being eliminated to provide these unbudgeted funds, although a number of other alternatives are being explored. The panel restated that logging is on a par with full-hole coring. To delete logging from the DSDP diminishes critical components from the main body of data. All reasonable attempts should be made to preserve the logging budget even at the expense of other items such as additional holes drilled.

II. INSTRUMENT DEVELOPMENT

A. Pressure Core Barrel (PCB)

The PCB did not work on Leg 62 because of seating problems. It is hoped to run it on Leg 72 for tests and on Legs 71 and 75 for operations.

B. Bit Sensor

This devise is to detect bit motion when coring; it will be tested on Legs 72 and 73.

C. Hydraulic Piston Corer

A new version is being designed that is capable of collecting a full-length core. A prototype should be ready in February, 1980, for testing on leg 71. Plans call for the tool to be operational in the fall of 1980.

D. Other Items

It was mentioned that on a recent leg some tests were made using the needle penetrometer. The SP4 feels that needle penetrometer is an obsolete piece of equipment. It should be removed from the CHALLENGER and not be permitted to be used on any future sediment core at sea or in the laboratory.

PCOM-RELATED INFORMATION

The SP4 was asked to consider, what if any, special procedures should be considered relative to the new hydraulic piston corer. The Panel made the following recommendations:

1. Sonic probing ("ultra-scan") should be considered by the DSDP as an alternative to X-ray, for rapid indication of major structures or inclusions prior to splitting. This method is both safer and quicker. The screen can be photographed if a permanent record is desired.

2. Color photographs would be better if made sooner than the present practice, onboard the CHALLENGER, of photographing batches of sections at one time.

3. Plastic films are being applied to cut surfaces before storage. To prevent drying and the efflorescence and loss of detail that accompanies drying, the plastic covering should be applied to the working section as soon as possible.

DOWNHOLE MEASUREMENTS PANEL REPORT

A brief summary was made of the logging improvements; the DMP mini-leg proposals; the past, present, and proposed downhole experiments; and the soon-to-be released DMP report listing logging tools. During the discussion no one was certain if a dipmeter had been proposed. The 3 arm or 4 arm Dipmeter is a sophisticated logging device that measures rock resistivities and hence enables the accurate measurement of bedding and fracture orientation in situ. This logging tool should be acquired, rented, or designed for DSDP drilled holes.

REPORT OF THE AD HOC COMMITTEE TO REVIEW SEDIMENTARY PETROLOGY PROCEDURES ABOUT THE CHALLENGER

This review was requested of the ad hoc committee. The review was summarized and the SP4 made the following recommendations:

1. Update and fill out the reference slide collection.

2. Make a new set of posters of instructional materials giving details of both counting and sample preparation techniques. Common problems and pitfalls should be summarized.

3. Construct a new and realistic set of visual estimation charts designed specifically for smear slide analysis.

4. Institute a detailed standardized program of initial instruction in the technique plus a system of replication and operator checks. A system of periodic shipboard operator checks should be instituted preferably through occasional duplication of analyses by different operators.

5. Make frequent shipboard carbonate bombe analyses at horizons where smear slide samples are taken.

PHYSICAL PROPERTIES REPORT TO THE PCOM

With regard to the SP4-DMP report, "Undisturbed Sampling and Physical Property Testing," previously submitted to the PCOM, the SP4 members have reviewed the written comments and recommend the following action plan.

I. FOR DSDP IMMEDIATE IMPLEMENTATION ON A ROUTINE BASIS

A. Aboard the CHALLENGER:

1. velocity—as specified in the report;

2. report layer interval velocities measured to 0.001's;

3. all Table I*, priority 1 shipboard items.

B. In the shore laboratory:

1. measure grain densities (previously mandated by PCOM);

2. all Table 1, priority 1, laboratory items.

II. FOR DSDP IMPLEMENTATION AS SOON AS POSSIBLE OR WHENEVER POSSIBLE

A. Sonobuoy wide-angle reflection measurements;

B. Routinely measure heat conductivities using the thermal conductivity meter;

C. Use compressed velocity and compensated density logs in semi-lithified sediments and rocks;

D. All Table 1, priority 2, shipboard items.

III. FOR NON-DSDP SCIENTIST OR ENGINEER PRIORITY IMPLEMENTATION AS SOON AS POSSIBLE

A. Shear wave velocity and attenuation and compressional wave measurement in oblique experiments;

B. All report items for igneous and metamorphic rocks and indurated sediments (listed in section III of report); some may be done by the DSDP whenever possible;

C. All other Table I, priority 1, ship and laboratory items.

NEW BUSINESS

I. GRAPE SPEED

It has been proposed that the core translation speed in the GRAPE be increased. The SP4 has requested that before this is done that representative cores be analyzed by both the new and the old method and a report be made to the Panel regarding the actual difference measured.

II. REVISED SHIPBOARD MASS PHYSICAL PROPERTY HANDBOOK

As previously requested by the SP4, an "executive summary" to the shipboard manual has been prepared to assist the physical property specialists who may not have the time to read through the voluminous detail on physical property measurements. Panel members were asked to review, add or delete information, and return the manual and the summary to the Chairman as soon as possible.

IV AD HOC COMMITTEE ON LONG-RANGE PLANNING

An ad hoc committee was formed to look at long-range planning. This committee met at DSDP prior to the SP4 meeting. Two areas were addressed:

1. Technical developments; and,

2. Research proposals for the CHALLENGER and the EXPLORER.

The list of recommended technical developments proposed by the long-range planning committee, in decreasing priority, is:

1. Hydraulic piston core sampling capability in sands.

2. In hole, in situ penetrometer for the measurement of core resistance.

3. In hole, in situ vane shear strength device.

4. In hole, in situ piezometer for the measurements of pore pressure.

5. In situ hydrofracturing device.

6. In situ permeability device, suitable for sediments and rocks.

7. Stress-strain meter, to measure tectonic strains.

TABLE II. GEOTECHNICAL TESTING OF SOFT SEDIMENTS

	Priority	Methods, Equipments, and Notes	Present and Next 2 Years	Future (Riser-drilling)	Staffing Tech.(T) Prof.(P)	Ship(S) Shore-Lab(L)	Relevance Sci.	Relevance Eng.
CLASSIFICATION								
Description			x	x	P	S	x	x
Core quality (disturbance)			x	x	P	S	x	x
Water content	1	ASTM	x	x	T or P	L	x	x
Bulk density	1	GRAPE	x	x	T or P	S	x	x
Grain density	1	ASTM	x	x	T or P	L	x	x
Grain size	1	% sand, silt clay only	x	x	T or P	L	x	x
Atterberg limits	1	ASTM-modified	x	x	T or P	L	x	x
$CaCO_3$	2		x	x	T or P	L	x	x
Pore-water salinity								
continental margin	2		x	x	T or P	S	x	?
ocean basin	3		x	x	T or P	S	x	?
Mineral composition	3		x	x	T or P	L?	x	?
Organic carbon	3		x	x	T or P	L?	x	?
MECHANICAL PROPERTIES								
Vane shear strength	x	Lab vane; Undisturbed & remolded	x	x	T or P	S	x	x
Unconfined compression	1		x	x	T or P	S	x	x
Triaxial								
static	2		x	x	P	L	?	x
dynamic	3	Where needed	x	x	P	L	?	x
Consolidation-permeability	2		x	x	P	L	x	x
IN SITU TESTS								
FCone resistance	1	Quasistatic penetromer		x	P	S	x	x
Shear strength	1	Vane		x	P	S	x	x
Excess pore pressure	1	Differential piezometer	x		P	S	x	x
Stress-strain	1	Pressuremeter-type tests		x	P	S	?	x

NEWS ITEMS AND ERRATUM

"Paleoceanic Reconstructions" by Fristbrook, Funnell, Hurley, and Smith is based on DSDP drilling results through Leg 59. It consists of paleoceanic maps reconstructing continental and oceanic positions, on 10 Ma time slices that correspond to stages from the present to the Cellovian. It is available at no cost on request to:

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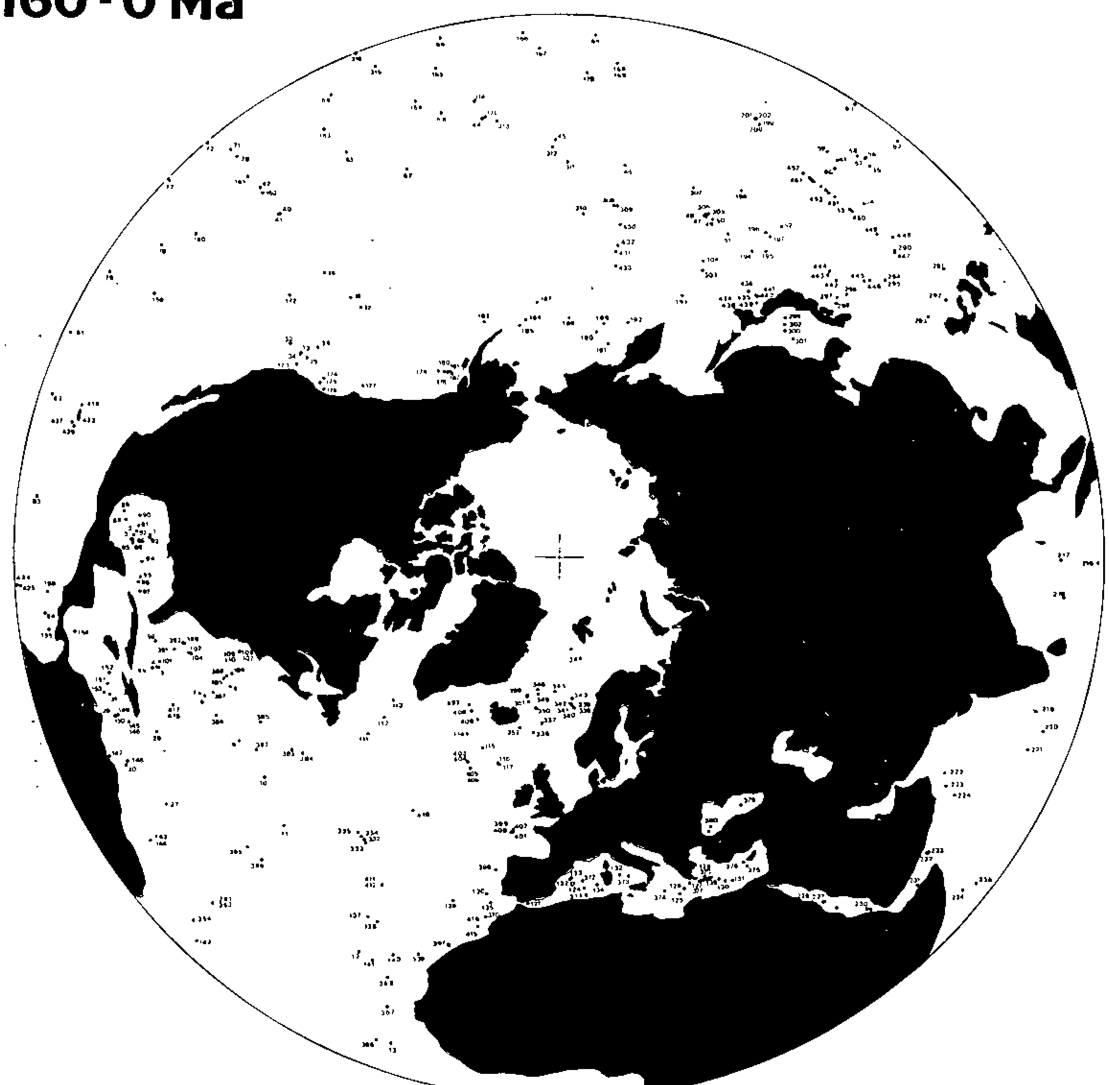
PALEOCEANIC RECONSTRUCTIONS

160 - 0 Ma



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PCOM.		25-29 Wash, DC					2-4 Paris			15-17 URI			
DMP					20-21 LDGO								
IHP	9-11 SIO												
IGP													
OCP		20-22 Djibouti											
AMP													
PMP	7-9 PMP												
OPP		18-19 SIO											
OGP								23-25 N.H.					
PPSP		13 SIO											
SP4													
SSP													
SCP					7-9 SIO								
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September, 1977	Vol. III, No. 2		
October, 1977	Vol. III, No. 3	Special Issue:	Initial Site Prospectus
February, 1978	Vol. IV, No. 1		
April, 1978	Supplement Number One (For Special Issue published October, 1977; Volume III, No. 3)		
June, 1978	Vol. IV, No. 2		
October, 1978	Vol. IV, No. 3		
February, 1979	Vol. V, No. 1		
June, 1979	Vol. V, No. 2		
October, 1979	Vol. V No. 3		
February, 1980	Vol. VI No. 1		