# OCEAN DRILLING PROGRAM

# LEG 108 PRELIMINARY REPORT

# NORTHWEST AFRICA

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## INTRODUCTION

The eastern equatorial Atlantic is a critical boundary zone of surface- and deep-water oceanography that includes the Intertropical Convergence Zone (ITCZ), the thermal equator, and the east-west trending topographic barrier of the Sierra Leone Rise. Changes in these first two major boundaries are tightly linked to global climate history. The seasonal and mean annual positions of the ITCZ and the thermal equator in part reflect 1) local forcing by trade winds from both the northeast and southeast, 2) monsoonal winds from the southwest during the northern summer, 3) the configuration of the African coastal outlines versus the geographical equator resulting in differential Coriolis influence, and 4) low-latitude insolation. One feature of the modern equatorial Atlantic is unique in the world's oceans: the net flow of heat across the equator from the southern to the northern hemisphere.

This large number of climatic controls results in a complicated response of the equatorial Atlantic Ocean to climatic change. However, the first spectral analyses of time series of Quaternary sea-surface temperature fluctuations (McIntyre et al., 1982) show that a 23,000-year periodicity, i.e., the low-latitude signal of orbital precession, is dominant in the equatorial sediment record.

Monitoring the variations of the ITCZ is vital for understanding the evolution of the tropical Hadley Cell during the past. In the eastern equatorial Atlantic, the development of the Hadley Cell can be documented by a variety of windblown sediment components which are supplied late in northern winter by a combination of mid-tropospheric zonal and meridional surface winds. These components record the history of both atmospheric circulation and of continental aridity in Africa (Hooghiemstra et al., 1986; Pokras & Mix, 1985; Sarnthein et al., 1981 and 1982; Stein, 1985; Tetzlaff & Wolter, 1980).

Surface ocean circulation in the equatorial and eastern subtropical North Atlantic is dominated by the North and South Equatorial Currents which flow from east to west and are fed by the eastern boundary currents (Canary and Benguela) along the western coast of Africa. This equatorial circulation also responds to remote forcing from higher latitudes, particularly the relative strengths of the Arctic and Antarctic polar cells and the subpolar westerly circulation in each hemisphere. Over geologic time scales, equatorial changes are thus in part directly related to the amount of land and sea ice in each polar hemisphere.

Near-shore and equatorial upwelling cells are a characteristic feature of the eastern Atlantic ocean. The biological productivity in these cells is controlled by climatic change, but also largely contributes to the carbon transfer from the sea surface and atmosphere to the deep ocean waters and sediments. This transfer has large implications for the global $CO_2$ budget and climate. A number of Leg 108 sites were positioned to monitor the variations of this chemical transfer and the diagenesis of sediments rich in organic carbon. In addition, upwelling causes cooling of the sea surface, reducing evaporation and, thereby, moisture in the atmosphere available for monsoonal rains in Africa.

The tectonically inactive Sierra Leone Rise acts as a barrier separating bottom-waters of the northeast Atlantic from those of the southeast Atlantic. These waters are a mixture of North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW). The latter originates in the western Atlantic and enters the eastern basins north and south of the Sierra Leone Rise through two low-latitude fracture zones, the Vema and the Romanche, respectively (Mantyla & Reid, 1983). In both places, the AABW flows eastward, driven in part by the Coriolis force in low latitudes of the northern hemisphere. Subsequently, it flows around the eastern end of the Sierra Leone Rise in a northerly direction through a passage with a sill depth of 4570 m, the Kane Gap (Mienert, 1985; Sarnthein et al., 1983). The upper boundary of this mixed bottom water lies near 4000-4350 meters water depth.

Differences in the bathymetric distribution of both calcium carbonate dissolution and $S^{13}C$ (Curry & Lohmann, 1983 and 1984) indicate that there were dramatic short-term changes in the exchange of deep water and oxygen between the western and eastern Atlantic from glacial to interglacial times. Furthermore, a number of erosional reflectors, various echo characters, and differential growth rates of manganese nodules in the Kane Gap (Mienert, 1985) suggest that the exchange of bottom water between the northeastern and southeastern Atlantic was subject to substantial long-term changes, on which the short-term fluctuations during late Neogene times were superimposed. However, these events have remained largely undated and their paleoclimatic context unexplained.

The primary objectives of Leg 108 were these:

1. To investigate the history of upwelling intensity including the seasonal vertical movement of the thermocline in the eastern equatorial and subtropical Atlantic, based on changes in the abundance of the opaline plankton. The goals of this effort are to define the latitudinal persistence of the upwelling cells during varying climates and to assess their importance in the broader climatic context of: (i) Atlantic-wide changes in paleo-productivity; (ii) variations in the global $CO_2$ budget; and (iii) deposition of sediments rich in organic carbon.

2. To trace the late Neogene latitudinal stability of the thermal equator by examining the geologic record in (i) the southern equatorial divergence zone along the equator, and (ii) the eastern boundary current and upwelling regions between 22°N and 2°S offshore from west Africa. In particular, studies from Leg 108 intend to document the response of this oceanic region to major gateway changes in Atlantic circulation, including closure of the Tethyan seaway, the Messinian salinity crisis, and closure of the Pan-American isthmus.

3. To clarify whether the tropical SST signals are driven by polar ice volume or by low-latitude factors (such as changes in insolation and $CO_2$-related effects). Of particular interest is the tempo of tropical ocean variability prior and subsequent to the prominent changes in Northern Hemisphere ice-volume variability at 0.9 and 2.5 Ma, and in Southern Hemisphere ice-sheet changes at 6-5 Ma.

4. To document the abundance of wind-blown particles in order to record the timing of changes in atmospheric circulation as part of the Hadley Cell and to gain a better understanding of the fluctuating cycles in continental aridity and monsoon in west Africa.

5. To determine the Neogene history of deep-water exchange through the fracture zones between the western and eastern Atlantic basins and through the Kane Gap and to investigate the cause of incursions of Antarctic-source bottom-water into the northeastern Atlantic.

6. To monitor changes in global ice volume vs. changes in deep-water temperatures during the Tertiary based on the comparison of oxygen isotope signals from planktonic and benthic foraminifers.

Leg 108 of the Ocean Drilling Program, which began on February 21, 1986 in Marseille, France and ended on April 17, 1986 in Dakar, Senegal drilled 12 sites in the eastern Equatorial Atlantic and along the northwest African margin. The geographic positions of these sites (Table 1; Fig. 1) provide a transect spanning about 24 degrees of latitude designed to answer the objectives listed above. The majority of the holes were cored continuously with double or triple-APC coring to refusal at all sites. XCB-drilling was used when further penetration was required. In excess of 3.8 km of sediment was recovered during Leg 108.

During Leg 108, continuous curves of magnetic susceptibility and P-wave velocity data allowed continuous high-resolution correlations between holes and even sites for the first time in the history of ocean drilling. Downhole logging was unsuccessfully attempted at two sites.

## DRILLING RESULTS

### SITES 657 - 659

Sites 657 through 659 were selected to investigate the late Neogene paleoceanography of the Canary Current and the paleo-productivity history of the upwelling region offshore from Cape Blanc. Sites 657 and 659 were positioned to document the "non-upwelling" paleoceanography and paleo-productivity record. They allow for comparisons of these records to that at Site 658, which is situated below the permanent oceanic upwelling cell west of Cape Blanc. Site 658 is also positioned to study the amounts and composition of dust recording the history of longshore meridional trade winds the velocity of which controls the upwelling intensity. On the other hand, Sites 657 and 659 receive dust mostly from the Saharan Air Layer paralleling the Intertropical Convergence Zone and thus aid in determining the patterns of zonal winds and in documenting the long-term history of south Saharan aridity and humidity. They are also recorded by the pollen flux and by eolian-sand and fluvial-mud turbidites.

### SITE 657

Site 657 lies on the lower continental rise 380 km west of Cape Blanc (Table 1; Fig. 1) and was drilled on a smooth plain of a distal turbidite fan into a well-layered, thick seismic sequence that appears relatively undisturbed. The recovered 178 m thick sequence consists of two major, mainly pelagic lithostratigraphic units. Excellent biostratigraphic control combined with the careful correlation of distinct units indicates that a nearly complete uppermost Miocene to Holocene sequence was obtained.

The lower Pliocene through Holocene sedimentological record of lithologic Unit 1 (0-145 m BSF) was dominated by the deposition of pelagic nannofossil ooze cycles which vary from light to dark grey in color and alternate in bearing foraminifers and wind-blown silt and clay. The amplitude of the sediment cycles has markedly increased during the last 2 m.y. The influence of the Canary Current at this site is registered by planktonic foraminifers characteristic of cool water which occur in the sediment record as far back as the early Pliocene. Including the several small turbidites that occur throughout the section, the average sedimentation rates vary from 20 to 28 m/m.y. for the interval representing the last 4.6 m.y., and indicate an ongoing regime of low oceanic productivity.

The record of pelagic sedimentation is broken twice at about 0.7 Ma and about 3.8 Ma by episodes of gravitational sedimentation (Fig. 2). Based on the high organic carbon content, the source of the greenish gray mudflow that comprises the upper layer is a high-productivity area at the nearby continental slope of northwest Africa such as that sampled at Site 658. The slump fold of the lower layer is most likely locally derived based on its similar composition to the underlying and overlying sediments.

A hiatus of 1.5 m.y. representing most of the Messinian (4.6 to 6.0 Ma) occurs at 145 m BSF in Hole 657B, at the top of lithologic Unit 2. This hiatus corresponds in time to a major lowering of the CCD, possibly associated with a major event of bottom-water circulation at about 4200 m water depth. The upper Miocene sediment cycles present in Unit 2 are brownish nannofossil bearing clay and non-fossiliferous silty clay. Similar to the low carbonate content, the low sedimentation rates which decrease downhole from 7 m/m.y. (6 to 6.6 Ma) to 2.5 m/m.y. (until 8.4 Ma), indicate a sedimentation regime near or below the CCD, in a low oceanic productivity region dominated by the deposition of little wind blown silty clay. In addition, occasional deposition of sand and silt by turbidity and/or contour currents continued into the Miocene.

## SITE 658

Site 658 is located on the continental slope 160 km west from Cape Blanc, at 2263 m water depth (Table 1; Fig. 1). Site 658 cored, for the first time in the history of DSDP and ODP drilling, hemipelagic sediments lying directly underneath one of the major nearshore cells of permanent oceanic upwelling in the world ocean. Also, these sediments were deposited in the central region of dust supply from the northern trade winds which control upwelling intensity. At Site 658, 3 holes were cored to a total penetration depth of 300.4 m BSF into a largely undisturbed, pillow-shaped seismic sediment section near the outer margin of a protruding terrace on the slope, a position which should restrict lateral sediment input from near-bottom down-slope transport. The eight cores recovered from Hole 658C were dedicated to shorebased special organo-chemical analysis.

The lower Pliocene to Holocene sediment section comprises three major hemipelagic lithologic units (Fig. 2). Unit 1 (0-91.2 m BSF) consists of gray to olive-gray nannofossil ooze grading into a diatom-nannofossil ooze deposited during the last 0.7 m.y. The sediments include minor amounts of quartz silt and foraminifers. Cyclic variations of the measured carbonate content (28-69%) and of organic carbon (up to 2.3%) occur through the unit. Unit 2 (91.2-233.9 m BSF) consists of olive to olive-gray cyclic nannofossil ooze interbedded with mixtures of calcareous, siliceous, and siliciclastic sediments and is late Pliocene to early Pleistocene in age. This unit contains the highest contents of biogenic opal at the site and up to 3.3% organic carbon, while carbonate decreased to 19-50%. Unit 3 (233.9-300.4 m BSF) contains lower and upper Pliocene cycles of gray to dark gray nannofossil-bearing mud to nannofossil ooze with up to 3% organic carbon, but only minor amounts of siliceous biogenic debris.

Good paleomagnetic and biostratigraphic time control indicate exceedingly high sedimentation rates of 146 m/m.y. for the last 0.7 m.y., a hiatus from 0.7-1.5 Ma, medium high rates of 68 m/m.y. from 1.5-2.5 Ma and again, very high rates of 112 m/m.y. from 2.5-3.7 Ma.

Continuous hemipelagic deposition during the last 3.7 m.y., combined with the very high sedimentation rates, provided an excellent record of the history of the Cape Blanc upwelling cell and documented its exceptionally high organic productivity. After 0.7 Ma, the upwelling cell fluctuated in cycles of approximately 100 Ky depicted by the varying contents of organic carbon and diatomaceous silica. Both variables were particularly abundant prior to 1.5 Ma. The change in sedimentation rates occurring at 2.5 Ma and a uniform increase in both $CaCO_3$ and biogenic opal subsequent to 3.1 Ma may signify important changes in productivity. They may be related to thresholds of the major climatic deterioration during late Neogene times, perhaps with cause and effect relationships between upwelling productivity and climatic change. However, shorebased estimates of mass accumulation rates and time series analyses will be necessary to provide insight into the actual variations of upwelling productivity and its implications for the climate. In addition, the low-temperature regime of the upwelling cell may have caused the first and last-occurrence datums of some planktonic species to occur at times similar to those found in transitional and higher latitudes of the Atlantic.

The varying nearshore input of wind-borne and possibly river-borne fine-grained siliciclastic sediment was most abundant prior to 3.1 Ma and scarcest from 3.1-1.5 Ma. The detection of the actual trade-wind signal and the proportions of fluvial mud indicating Saharan humidity in this fraction will require detailed shorebased laboratory work.

The major hiatus spanning from about 0.7 to 1.5 Ma corresponds to two adjoining slump-style pinch-out structures on the seismic record from near the site (Fig. 3). The resulting mass flow is considered similar in composition and age to a slump deposit found at companion Site 657 on the continental rise.

Below the hiatus, lithologic Unit 2 is correlated with the transparent portion of the seismic section shown in Figure 3. This correlation assumes seismic velocities near 900-950 m/s indicating the presence of free gas in the sediment. This assumption is supported by the large amounts of biogenic gas recovered in the sediment cores, particularly below 90 m BSF. The methane:ethane ratio increased downhole from 5000-6000 at 60 m to 1250 at 300 m BSF.

Magnetic susceptibility data enabled us to establish a detailed composite depth section of Holes 658A and 658B down to 90 m BSF, despite numerous artificial voids in the core recovery because of extensive degassing in the core liners.

## SITE 659

Site 659, one of the two "non-upwelling" reference sites, is located near DSDP Site 368 on top of the smooth Cape Verde Plateau near the east Atlantic continental margin (Table 1; Fig. 1), a plateau which was formed during the early Miocene (Lancelot, Seibold, et al., 1978). The upper portion of the seismic record at Site 659 is finely laminated and almost transparent, with a thick series of strong seismic reflectors underneath.

The Neogene sediment section recovered at Site 659 is 273.8 m thick and comprises two major lithologic units with good magnetic stratigraphy for the last 3 m.y. and good biostratigraphic time control until the Oligocene/Miocene boundary (Fig. 2). Thus, one of the few continuous and complete pelagic sediment sections for calcareous biostratigraphy of the middle and late Miocene was recovered at this site. Lithologic Unit 1 consists of 166 m of Pleistocene to upper Miocene pelagic sediment cycles of light gray foraminifer-nannofossil ooze interbedded with whitish nannofossil ooze, including minor amounts of silt and clay. The sediment cycles during the last 2 m.y. have large amplitudes and are distinguished from the underlying cycles formed 4.6 to 2.0 Ma by their uniformly lower carbonate content and more moderate foraminifer preservation, which again decreased between 4.6 and 7.0 Ma. Lithologic Unit 2 (166-273.8 m BSF) consists of Miocene nannofossil ooze in cycles interbedded with silty nannofossil ooze. In the upper portion formed 11.2 to 7.0 Ma, the ooze is grey to yellowish brown. The lower portion of Unit 2 is bluish green, shows stronger variations of $CaCO_3$ and was deposited between 24 and 11.2 Ma. It contains a volcanic ash layer at 233 m BSF that parallels ash layers at the nearby Site 368 which were ascribed to the early Miocene maximum of volcanic activity on the Cape Verde Islands (Lancelot, Seibold, et al., 1978).

Sedimentation rates varied from 30 m/m.y. during the last 4.6 m.y. to 13 m/m.y. from 4.6-9.0 Ma. They were 4 m/m.y. from 9.0-14.4 Ma and 6 or 8 m/m.y. from 14.4 Ma to a long-lasting hiatus from ?18.5-23.5 Ma. These rates can be applied to the thickness of the sediment cycles, which varies from 30-140 cm in Unit 1 to 15-90 cm in Unit 2. As a result, the cycles represent time intervals of about 10,000 to 90,000 yrs, which are in the order of Milankovitch-type climatic cycles. The sediment cycles may be largely a product of fluctuating carbonate dissolution, but in part may be also caused by a fluctuating supply of wind-borne siliciclastic sediment, particularly during the last two m.y. when more abundant clay and silt particles indicate an increased dust flux from the Sahara. Low-amplitude sediment cycles already changed to high-amplitude cycles near 3.2 Ma, i.e., at an age clearly preceding the time of onset of major northern hemisphere glaciation at about 2.5 Ma.

Planktonic foraminifers (common *N. pachyderma*) record a very early onset of enhanced cold-water advection by the Canary eastern boundary current to the Site 659 region, as early as about 2.9 Ma. On the other hand, *N. pachyderma* was common at the more northerly Site 657 throughout the Pliocene since 4.6 Ma. This difference may imply that the anticlockwise warm-water eddy east of the Cape Verde Islands was much more active prior to about 2.9 Ma than later. This eddy is driven by monsoonal winds from the southwest during summer and carries warm water to as far as about 21° N and also to Site 659. The change suggests a decrease of the monsoon winds as well.

Finally, the striking change of sediment color during ongoing sedimentation near 11 Ma and the change in sedimentation rates and $CaCO_3$ dissolution at 4.6 Ma may signify major events of deep-water paleoceanography. The younger event is also observed at some neighboring sites in greater water depths (Sites 657, 660, and 661).

## SITES 660 and 661

Companion Sites 660 and 661 lie on a depth transect directly east of the Kane Gap deep-water passage through the Sierra Leone Rise, at 4328 m and 4006 m water depth, respectively. Both sites were selected near the upper boundary of a bottom water mass mixed with North Atlantic Deep Water and Antarctic Bottom Water to investigate sedimentary signals of bottom-current action and deep-water stagnation. Thereby, we also expected to identify and date any seismic reflectors which may document major events of bottom-water circulation between the southern and the northern east Atlantic.

Other important objectives were to analyze accumulation rates of organic carbon and other sediment components in order to monitor the Cenozoic history of north equatorial surface-water oceanography, particularly the organic productivity within the "Guinea Dome" upwelling cell in the North Equatorial Divergence Zone, and the advection of dust during northern winter recording the history of aridity in the African Sahel zone.

## SITE 660

Site 660 is located on the lower slope about 80 km northeast of the northern end of the Kane Gap (Table 1; Fig. 1). The seismic record at this site contains a layered unit of standing sediment waves overlying a rather transparent horizon and then another layered seismic unit, the top of which pinches out in the Kane Gap.

Holes 660A and 660B cored three lithologic units to a maximum penetration depth of about 165 m BSF. There is good biostratigraphic time control for Units 1 and 3, and good magnetostratigraphy for the last 4 m.y., but very little time control for Unit 2. As a result, sedimentation rates varied from about 28 m/m.y. during the last 0.7 m.y. to about 17 m/m.y. from 0.7 to 3.9 Ma, and 3.3 m/m.y. from 3.9 to about 6.0 Ma.

A complete uppermost Miocene to Recent section forms Lithologic Unit 1 (0-75.0 m BSF) spanning the last 6.0 m.y. Similar to previous sites, it consists of sedimentary cycles. Light olive-gray nannofossil ooze is interbedded with dark gray silty clay containing up to 1.6% organic carbon in the uppermost 21 m BSF. Below this depth (i.e., prior to 0.73 Ma), the carbonate and foraminifer preservation markedly increased, but again gradually decreased prior to 3.9 Ma. From the enhanced sedimentation rates and increased abundance of biogenic opal and organic carbon in the uppermost 21 m BSF, we infer increased oceanic upwelling and organic productivity at the Northern Equatorial Divergence combined with phases of enhanced bottom-water stagnation during the last 0.7 m.y.

Lithologic Unit 2 (75.0-115.8 m BSF) is composed of cyclic yellowish brown clay which in most parts is fossil-barren and compares well with similar units found at Sites 657 and 659. Lithologic Unit 3 (115.8-164.9 m BSF) consists of middle Eocene yellowish radiolarian ooze with chips of chert near the base. The almost pure radiolarian ooze from about 149 to 130 m BSF (and probably up to a manganese-rich layer at 126 m BSF) possibly formed during a single radiolarian zone, that of Podocyrtis mitra which spans less than 1 m.y. at about 43 Ma. The relatively rapid deposition, the laminated fabric free of bioturbation, the lack of clay and organic matter, and the mound-like seismic structure associated with this facies suggest that the ooze is a displaced sediment unit, e.g., a sediment dune reflecting a regime of cyclic bottom-current activity.

Similar to Sites 657 and 659, the drastic change in the carbonate content and in sedimentation rates between 3.9 and 4.6 Ma indicates a major event of deep-water paleoceanography in the east Atlantic.

## SITE 661

Site 661 is the shallower end member of the two-site transect selected to investigate Cenozoic deep-water paleoceanography and paleoclimate near the northern end of the Kane Gap deep-water passage. The site is located at 4006 m water depth on a plateau east of the Kane Gap, and lies almost 600 m above the floor of this passage (Table 1; Fig. 1). The upper portion of the seismic record at this site is nearly transparent with few faint reflectors. The lower portion contains a layered and then another transparent seismic unit on top of a thick layered unit draping middle Cretaceous basement. Holes 661A and 661B cored a 296.1 m thick section consisting of 3 different lithologic units which are Late Cretaceous to Pleistocene in age. Biostratigraphic age control is good in Unit 1 and in the upper parts of Unit 3, magnetostratigraphy is good for the last 3.2 m.y. Unit 2 was fossil-barren except for its uppermost part, and the lower part of Unit 3 was completely non-fossiliferous (Fig. 2).

Lithologic Unit 1 (0-72.55 m BSF) consists of uppermost Miocene to Recent sediment cycles which comprise light gray foram-nannofossil ooze interbedded with gray muddy nannofossil ooze or clay. Sedimentation rates averaged 15 m/m.y. during the last 4.2 m.y. and 4.1 m/m.y. prior to this time. The upper part of Unit 1, which formed during the last 1.4 m.y., displays high-amplitude carbonate cycles which are distinguished from those below by a uniformly lower carbonate content and higher proportions of organic carbon (up to 0.65%) and biogenic opal. Both variables may imply increased ocean productivity for most of the Pleistocene, as found at Site 660. Differing from Sites 657-659, the planktonic foraminifer fauna at

Site 661 maintains a tropical aspect throughout the Pleistocene. The lower portion of Unit 1 consists of smaller-amplitude sediment cycles with only minor amounts of clay, and decreasing contents of carbonate prior to 4.0 Ma. This lithostratigraphy closely matches that of the neighboring Site 660 to the level of precision of susceptibility curve cycles, but with more carbonate and less organic carbon. The marked changes in $CaCO_3$ and in sedimentation rate at about 4.0 to 4.2 Ma compare to similar rate changes at Sites 657, 659, and 660 and likewise indicate a major event of deep-water oceanography in the earliest Pliocene.

Olive brownish to brownish red cycles of silty clay interbedded with rare nannofossil ooze near the top form the 18 m thick Unit 2 (72.55-90.8 m BSF), which is early late Miocene and older in age. At its base, we encountered three distinctly weathered bedding planes with manganese nodules and clay (20 cm thick), or yellowish dolomite clay between 92.5 and 93.75 m BSF. Undoubtedly, these horizons signify extended hiatuses. Possibly, they may be contemporaneous with the thick radiolarian ooze and manganese horizon at Site 660, dated at about 43 Ma and younger.

Below, lithologic Unit 3 (90.8-296.1 m BSF) is composed of about 200 m thick Upper Cretaceous and younger bluish-greenish zeolite clay and claystone cycles. In the upper 60 m, it is interbedded with nannofossil ooze representing almost the entire Maestrichtian (76-66.5 Ma). Based on the most conservative estimates of sedimentation rates, the K/T boundary could occur 0.8 m (= 0.13 m.y.), or less, above the uppermost nannofossil ooze bed ending at 105.3 m BSF. Further work is required to pin down this possible boundary more exactly.

## SITES 662 - 664

Sites 662 through 664 were selected to retrieve a late Neogene record of climatic variability from the equator. Reconstructions of sea-surface temperatures at the last glacial maximum 18,000 years ago show that the surface ocean was chilled as much as 6-8°C relative to today in a band along and just south of the equator in the eastern half of the Atlantic Ocean (CLIMAP, 1981). Studies of the last 250,000 years of the Pleistocene by McIntyre et al. (in press) show that the relative abundance of the cool-indicator planktonic foraminifers varied mostly with the 23,000-year period of orbital precession. This signal requires a large cooling of the sea surface or of the shallow subsurface layers, either by increased advection of colder waters from high southern latitudes (Benguela Current), or by wind-driven changes in subsurface isotherm structure due to increased divergence and/or shallowing of the thermocline in general. The primary objective at these sites was to trace several paleoceanographic signals back through the late Neogene to distinguish the paleoceanographic and paleoclimatic history of this region. The critical indicator signals are: estimated sea-surface temperature, and the fluxes of opaline silica, $CaCO_3$, and organic carbon. Sites 662 and 663 should have a larger Benguela Current influence while Site 664 primarily monitors equatorial divergence.

A secondary primary objective at Sites 662, 663 and 664 was to monitor late Neogene variations in African aridity, as indicated by clay and biogenic material contained in wind-blown terrigenous dust from the continent. Pokras & Mix (1985) proposed that the abundance of freshwater diatoms (genus Melosira) can be used in this region to monitor periodic drying out of lakes in north equatorial Africa at the 23,000-year cycle. Because of the prominence of southern trade winds at this site, eolian deposition may also include a significant contribution from southern African source areas.

Other important objectives include obtaining a continuous late-Neogene sequence for high-resolution paleomagnetic, biostratigraphic, and stable isotopic analysis and obtaining a calcareous sequence to monitor late-Neogene carbonate dissolution.

## SITE 662

Site 662 is located in the eastern equatorial Atlantic (Table 1; Fig. 1) on the upper eastern flank of the mid-Atlantic Ridge just south of the Romanche Fracture Zone. The site position was selected in order to detect both the near-equatorial divergence signal as well as the advective southern-hemisphere contribution from the Benguela Current.

The upper Pliocene and Pleistocene section recovered from Holes 662A and 662B is 200 m thick and comprises one major lithologic unit consisting of nannofossil and foraminifer-nannofossil ooze (Fig. 2). Secondary components include clay, diatoms and radiolarians.

Although a useable paleomagnetic stratigraphy could not be obtained at Site 662, the nannofossil and planktonic foraminiferal biostratigraphy provided several well-dated datums. The depositional rates of the pelagic sediments average 42 m/m.y. Preservation of calcareous fossils is good to moderate; preservation of diatoms is moderate to fair.

The pelagic layers are interbedded with several slumps, debris flows and turbidites; these appear to have originated from topographic highs and flowed over the pelagic beds, in some cases tilting the pelagic beds slightly, but not deforming them extensively. It appears that the slumps were added with little loss of the pelagic units to erosion. Using carbonate layering in core photographs, we succeeded in correlating between Holes 662A and 662B and verifying the continuity of recovered section over intervals between 0-0.5 Ma and 1.3-3.6 Ma.

A trend toward higher-amplitude $CaCO_3$ variations and deeper $CaCO_3$ minima began in the late Pliocene at 2.65 Ma and continued into the latest Pleistocene. This prominent change slightly precedes the initiation of significant-scale northern hemisphere glaciation at 2.5 Ma. It may reflect: (1) increased dilution of $CaCO_3$ by opaline silica, (2) increased dilution by eolian dust; (3) increased dissolution of $CaCO_3$, or (4) decreased productivity of $CaCO_3$. Because the mean sedimentation rates do not change, it seems likely that explanations 4 (and possibly 3) must be balanced by explanations 1 and 2.

## SITE 663

Site 663 was added to the Leg 108 plan because of the numerous turbidites and slumps encountered in the upper 100 m at Site 662. The objectives at this site were identical to those at Site 662, but with the major focus on the upper 100 m in order to provide a complementary record to Site 662. Site 663 is located in the eastern equatorial Atlantic (Table 1; Fig. 1) on the upper eastern flank of the mid-Atlantic Ridge just south of the Romanche Fracture Zone.

The entire 152 m section cored is one lithologic unit consisting of nannofossil and foraminifer-nannofossil ooze of Pleistocene and late Pliocene age (Fig. 2). The lithologic unit includes five slump layers, as well as layers with less deformation (minor tilting). Although a useable paleomagnetic stratigraphy could not be obtained at Site 663, the nannofossil and planktonic foraminiferal biostratigraphy provided several well-dated datums. Preservation of calcareous fossils is generally good; preservation of diatoms is moderate to poor.

The depositional rate of pelagic sediments ranges from about 33 m/m.y. in the uppermost (upper Pleistocene) pelagic section to 38 m/m.y. in the lower two (upper Pliocene) pelagic units. As at Site 662, it appears that the slumps at Site 663 were added as extra sediment to rapidly deposited pelagic sections, with little loss to erosion.

Again using carbonate layering in core photographs to correlate between holes, we found that a continuous composite record was obtained in pelagic layers representing time intervals of roughly 0-0.95 and 1.75-2.6 Ma. Combined with Site 662, it appears that we have recovered a continuous record of the last 3.6 Ma, except possibly for a brief interval around 1.2 Ma disturbed by slumps at both sites. As at Site 662, the amplitude of $CaCO_3$ cycles intensified from the upper Pliocene to the uppermost Pleistocene, with larger percentages of clay and silica and organic carbon and lower proportions of $CaCO_3$.

## SITE 664

Site 664 is located in the central equatorial Atlantic on the upper-middle flank of the east side of the mid-Atlantic Ridge just north of the Romanche Fracture Zone (Table 1; Fig. 1). The entire 296.8 m section cored is one lithologic unit consisting of nannofossil ooze and foraminifer-nannofossil ooze of Pleistocene, Pliocene, and late Miocene age (Fig. 2). Secondary components are clay, zeolitic clay, diatoms, and radiolarians. The two deeper holes (664B and 664D) contain many slump units, as well as several other partially deformed layers.

Paleomagnetic reversal boundaries provided a useful stratigraphy down to the Jaramillo subchron. The nannofossil and planktonic foraminiferal biostratigraphy also provided numerous datums. Preservation of calcareous fossils is generally good, although it deteriorates below 200 m BSF (4.4 Ma). This change in $CaCO_3$ preservation agrees with evidence in previous Leg 108 sites of a major change in bottom-water chemistry in the early Pliocene. Preservation of diatoms is moderate to poor in the upper 200 m BSF, and the sediments are barren of diatoms below this depth. This suggests a much lower supply of biogenic silica from surface waters due to lower productivity, or poor preservation of silica on the sea floor before 4.4 Ma.

The Pleistocene and upper Pliocene (0-4.4 Ma) pelagic sequence was deposited at average rates of 43-46 m/m.y. Early Pliocene and late Miocene rates averaged about 21 m/m.y. Using carbonate layering in core photographs for between-hole correlations, we verified the continuity of the section for the upper Pleistocene pelagic unit (0-1.2 Ma). The high recovery and undisturbed condition of the sections below 200 m BSF in Hole 664D indicate a valuable upper Miocene sequence deposited at high rates.

The slumps in Holes 664B and 664D show surprising variability in the degree of deformation and age over small lateral scales (1000 m) within the same sediment pond. The slump at about 1.25 Ma appears to correspond to similar deformation at Sites 662 and 663 at that time. All three sites are located adjacent to the active transform-fault section of the Romanche Fracture Zone, suggesting that a major seismic event associated with this feature may have dislodged pelagic sediments over a broad region of the upper flanks of the mid-Atlantic Ridge.

As at Sites 662 and 663, $CaCO_3$ cycles intensified from the upper Pliocene to the upper Pleistocene. This occurred because of stronger $CaCO_3$ minima, accompanied by increased silica and clay contents in gray-green sediment layers.

SITES 665 - 668

Sites 665 through 668 compose four sites in a transect taken at different water depths down the southern margin of the Sierra Leone Rise. Studies by Curry & Lohmann (1983) of upper Pleistocene sediments in conventional piston cores have shown that water below about 4000 m depth in the eastern Atlantic probably was more isolated from water at the same depths in the western Atlantic than is the case today. This isolation is suggested by a 0.7 $^{o}/_{oo}$ depletion of $S^{13}C$ values in benthic foraminifers in the eastern basin, and by the higher organic carbon content in the deeper cores.

Our primary objective in the Sierra Leone Rise transect was thus to retrieve a suite of cores located close together in space, but spanning a large depth range. The sediment recovered should allow tracing these intervals of increased isolation back into the Neogene and to separate this signal from that of local productivity.

A secondary depth-related objective was to use this close-spaced group of cores to assess the long-term fluxes of $CaCO_3$ (both bulk calcareous nannofossils and planktonic foraminifers (as well as individual species of planktonic foraminifers)) from the surface waters, the dissolution of $CaCO_3$ by deep waters, and the redistribution of all sediment components by bottom currents. This followed a strategy applied to gravity cores spanning the last 160,000 years by Curry & Lohmann (1984).

Dean et al. (1981) found strong cyclicity in records of $\%CaCO_3$ from Sierra Leone Rise DSDP Site 366, with periods of 30,000-50,000 yrs. dominant from the Oligocene to middle Miocene, and periods of 7,000 to 21,000 yrs. during the Eocene. We planned to determine any periodicity in the $CaCO_3$ record of the late Miocene to Recent, an interval thoroughly deformed by rotary drilling at Site 366. In addition, we planned to refine the early Miocene and late Paleogene $CaCO_3$ signals, based on improved stratigraphy.

Broader paleoenvironmental objectives were: (1) to measure fluxes of eolian dust and freshwater diatoms as indicators of continental source-area aridity and of wind strength during the Neogene and late Paleogene, (2) to monitor late Neogene changes in surface-water temperature using assemblages of planktonic foraminifers and other indicators, (3) to obtain a high-quality Neogene and upper Paleogene reference section of $CaCO_3$-rich equatorial sediments for detailed biostratigraphic and paleomagnetic studies, and (4) to monitor the late Paleogene and Neogene deposition of opaline silica to see whether the decrease in opaline silica deposition after the middle Miocene at Site 366 was also recorded here, interpreted as indicating a northward plate-tectonic drift of this site out of the equatorial high-productivity area (Stein, 1985).

## SITE 665

Site 665 is located in the eastern equatorial Atlantic in relatively flat terrain along the base of the southeastern margin of the Sierra Leone Rise. Site 665 was critical to the depth transect, because it lies well below the 4000-m water depth at which evidence of relative isolation of the eastern Atlantic deep circulation may become evident.

In Holes 665A and 665B, we recovered a total of 20 APC cores to depths of 97.9 and 82.0 m BSF, respectively. The sedimentary sequence at Site 665 is divided into two lithologic units (Fig. 2). From 0-73 m BSF, lithologic Unit 1 is cyclical nannofossil ooze and clay-bearing nannofossil ooze of Pleistocene and late Pliocene age (0-4.6 Ma). Carbonate contents vary between 0% and 80%, with most values between 20% and 80%, and a trend toward deeper $CaCO_3$ minima toward the top of the unit. From 73-97.9 m BSF, lithologic Unit 2 is red clay of early Pliocene (4.6-5.0 Ma) age and probably older in the non-fossiliferous lower section. There is no $CaCO_3$ in this layer, except in a few turbidite beds brought in from shallower depths.

Opaline silica is a secondary component of both units, except for some 10-cm thick diatom ooze layers in the uppermost 20 m of Unit 1 (0-1 Ma). Organic carbon is less than 1% of the sediment, but is slightly more abundant in the upper 50 m of the upper lithologic unit. Several sharp unburrowed contacts were observed in each unit; these are probably indicative of erosion by bottom currents. Several intervals toward the bottom of lithologic Unit 1 (about 60-70 m BSF) had increased manganese contents, suggesting significant periods of non-deposition or slow deposition.

Depositional rates average 15-21 m/m.y. from 0-3.0 Ma in the upper Pliocene and Pleistocene nannofossil ooze cycles of the upper lithologic unit, but only 4 m/m.y. in the red clay. Between-hole correlations based on paleomagnetic susceptibility data verify the continuity of the composite section to a depth of 68 m BSF (about 3.5 Ma).

The increasing amplitude of the Pliocene-Pleistocene $CaCO_3$ cycles at Site 665, accompanied by increasing organic carbon and opaline silica, is similar to trends observed at other sites on Leg 108. The Sierra Leone Rise is located in an area marked today by relatively low productivity, with higher productivity both toward the north (the north equatorial divergence zone) and the south (the south equatorial divergence zone). Nevertheless, the climatic indicators available in shipboard analysis of Site 665 sediment suggest a trend toward higher productivity, higher terrigenous dilution, and possibly stronger dissolution through the late Pliocene and Pleistocene similar to that observed at the southern sites.

At Site 665, the large early Pliocene shift in the $CaCO_3$ compensation depth marked by the onset of $CaCO_3$ sedimentation occurs between 4.1 and 3.8 Ma. This age is comparable to the late stages of a similar shift observed at other Leg 108 sites.

The stratigraphic sequence at Site 665 records large changes in the depth of the CCD and changes in the productivity of equatorial surface waters. Prior to 4.1 Ma, this site was below the CCD and was characterized by slow deposition of pelagic clays. Carbonate deposition in this interval occurred only by the rapid deposition of two thin carbonate-rich turbidites. At approximately 4.1 Ma, the lowering of the CCD resulted in the deposition of a sequence of nannofossil and foraminifer-nannofossil ooze. Little or no siliceous material and organic carbon were deposited from 4.1 to 2.5 Ma. Organic carbon preservation increased at about 2.5 Ma, while biogenic opal preservation increased at about 1.5 Ma. The increase in organic carbon preservation was the result of increased productivity in the surface waters or increased preservation because of reduced oxygen conditions in the deep water. The increase in biogenic opal preservation indicates an increase in surface-water productivity that resulted in generally increased deposition rates for the interval 1.5 Ma through present.

## SITE 666

Site 666 is located in the eastern equatorial Atlantic in relatively level terrain along the base of the southeastern margin of the Sierra Leone Rise. This site lies below the 4000-meter water depth at which evidence of relative isolation of the eastern Atlantic deep circulation becomes evident. Together with Site 665 at a deeper water depth, Site 666 should provide control on past depth gradients in $S^{13}C$.

Two major lithologic units are recognized at Site 666. Unit 1 (0-140 m BSF) is composed of nannofossil, foraminifer-nannofossil and siliceous nannofossil pelagic oozes of Pleistocene and early Pliocene age (0-4.1 Ma) interbedded with numerous small and large foraminifer sand turbidites. Mud-bearing, clay-bearing and muddy nannofossil oozes are less common. Biogenic opal is restricted to the upper 27 m BSF. The unit varies in color from pale brown to very pale brown, light yellowish brown and reddish yellow. Nannofossil oozes and siliceous oozes that are rich in organic carbon are generally dark gray in color. Below 27 m BSF, the colors are generally light gray, olive gray and white. Numerous turbidites interrupt the pelagic deposits throughout this unit. Large turbidites (up to 12 meters) were also observed and comprise approximately 50% of the total section.

The carbonate content of this unit varies from near to 0 to greater than 80%. Low carbonate values are found in the upper 27 m of the section and coincide with high percentages of biogenic silica. Diatoms are the primary biogenic opal component, although radiolarians are also present. The primary terrigenous components are clay (up to 35%), accessory minerals and quartz. Organic carbon increases above 10 m BSF from negligible values to greater than 1% by weight.

Lithologic Unit 2 (140-150.5 m BSF) is composed of white to pale yellow clay-bearing nannofossil ooze and pale brown, light yellowish brown to yellowish brown silt-bearing clayey-nannofossil ooze. Graded bedding and sharp lower contacts are common. Foraminifers are generally absent or rare in the pelagic deposits, but are quite common in the turbidites. Accessory minerals are an important component of the terrigenous fraction, while clay concentrations reach 25%. This unit appears to correlate with the top of Unit 2 at Site 665.

The depositional history at Site 666 reflects the complex interactions of pelagic deposition interrupted by turbidite deposition. Prior to 4.1 Ma, this site was located near the CCD. Clay with occasional nannofossil ooze layers in the uppermost portion of the clay interval were deposited by pelagic processes. These deposits were interbedded with rapidly deposited foraminifer turbidites. Between 4.1 Ma and approximately 1.5 Ma, the pelagic deposits were generally foraminifer-nannofossil ooze and nannofossil ooze with variations in clay concentrations. After that time, biogenic opal productivity in the surface water increased, and deposition of the biogenic opal fraction has continued throughout the late Pleistocene. Organic carbon preservation in the sediments increased at approximately 2.5 Ma, correlating with the similar increase at Site 665. Throughout the entire record at Site 666, turbidite deposition dominated the sedimentary processes. Based on a rough correlation of lithologic Unit 2 at this site and Unit 2 at Site 665, approximately 75 m of additional sediments (mostly foraminifer sand) was delivered to Site 666 by gravity processes.

## SITE 667

Site 667 was the third site in the Sierra Leone Rise depth transect (Sites 665-668). This site lies well above the approximate 4000 m depth at which partial isolation of the eastern basins becomes apparent, but it may record unusually shallow upward penetrations of this phenomenon.

The 381.3 m section recovered at this site contains six lithologic units (Fig. 2). Lithologic Unit 1 (0-20.3 m BSF) consists of alternating layers of Pleistocene foraminifer-nannofossil ooze and clay-bearing foraminifer-nannofossil ooze which vary in color from dark brown to light yellowish brown. The carbonate content of this unit varies from 20 to 80%. Quartz and clay are the principal non-carbonate component, while biogenic opal occurs usually in trace amounts (<10%). Lithologic Unit 2 (20.3-68.8 m BSF) consists of a coarser-grained foraminifer-nannofossil ooze interbedded with foraminifer sands of early Pliocene to early Pleistocene age. The foraminifer-nannofossil ooze and nannofossil ooze are generally light gray to white in color and exhibit both graded and reverse graded bedding. The sand is generally white in color and has sharp contacts.

Lithologic Unit 3 (68.8-124.3 m BSF) consists of upper Miocene to lower Pliocene cycles of white to light gray foraminifer-nannofossil ooze and nannofossil ooze interbedded with very pale brown to light yellowish brown muddy nannofossil ooze. The carbonate content of this unit varies from 70 to 80%. Unit 4 (124.3-148.3 m BSF) is an upper Miocene slump deposit about 10 m thick with mixtures of lithologic units 3 and 6.

Lithologic Unit 5 (148.3-198.8 m BSF) consists of middle Miocene cycles (60-70 cm thick) of white to very pale brown mud-bearing nannofossil ooze and clayey nannofossil ooze interbedded with yellow and brownish yellow nannofossil-bearing silty clay. The carbonate content varies from less than 20% to greater than 80%. Clay concentrations increase to 85% and quartz composes up to 10% of the sediment, while biogenic opal occurs only in trace amounts. Unit 6 (198.8-376.5 m BSF) consists of upper Oligocene to middle Miocene light greenish gray muddy-nannofossil ooze and clayey-nannofossil chalk interbedded with grayish-green siliceous-bearing nannofossil ooze and claystone. The carbonate content of this unit varies from near 0% to greater than 80%. Biogenic opal composes up to 45% of the sediment.

Sedimentation rates are based on paleomagnetic, nannofossil and foraminiferal datums in the middle Miocene to Pleistocene interval. These groups as well as diatoms also provide stratigraphic datums for the Oligocene and lower Miocene interval. Sedimentation rates are 14.7 to 12.4 m/m.y. from 0 to about 2.4 Ma. Stratigraphic uncertainties between 2.4 and 14.0 Ma did not allow reliable sedimentation rates to be calculated for this time interval; however, the available resolution does indicate rates ranging from 7.7 to 19.6 m/m.y. Between 14.0 and 16.0 Ma, sedimentation rates averaged 19.7 m/m.y. and then decreased to 12.5 m/m.y. throughout the lower Miocene and upper Oligocene.

The history of sedimentation at this site reflects changes in geographic position relative to the equatorial high-productivity zone and changes in the reworking of sediments because of bottom current scouring. During the late Oligocene through middle Miocene, high concentrations of biogenic opal in these sediments indicate that the productivity in the surface water above this site was generally high. Continuous pelagic deposition continued throughout the middle Miocene, but the concentration of biogenic opal decreases significantly. At this time the sedimentation was cyclic with sediment cycles attaining a thickness of 60-70 cm. Pelagic deposition was interrupted in the late Miocene by a slump that mixed the older, more siliceous material with clay-rich deposits. Cyclic deposition of clay-rich and clay-poor nannofossil ooze resumed in the late Miocene and continued until the early Pliocene (about 4.0 Ma). From the early Pliocene to the early Pleistocene (about 4.0-1.5 Ma), the sediments at this site have significantly higher concentrations of foraminifers. Foraminifer sand is common and may be a result of either winnowing or turbidite deposition. Bottom scouring may have also removed significant portions of the finer material during this time. Normal pelagic sedimentation resumed at about 1.5 Ma and continued throughout the Quaternary. Throughout this time, increased clay concentration suggests that eolian material became a significant component in the sediments deposited at this site.

## SITE 668

Site 668 is located near Site 366 in the eastern equatorial Atlantic on the relatively flat crest of the Sierra Leone Rise and is the shallowest of the sites comprising the depth transect on the southern margin of the Sierra Leone Rise. Operational problems, followed by the illness of a crew member, denied our reaching most of the objectives at this site.

One core was retrieved from Hole 668A and a total of four cores were recovered from Hole 668B. The sediments recovered are all nannofossil ooze, varying from muddy nannofossil ooze to muddy foraminifer-nannofossil ooze to mud-bearing, foraminifer-bearing nannofossil ooze. Secondary components include clay, quartz, and biogenic opal. Paleomagnetic stratigraphy defined the Matuyama/Brunhes boundary and the Olduvai subchron. Nannofossils and planktonic foraminifers provide several biostratigraphic datums. Preservation of calcareous fossils was very good, but few siliceous fossils were observed. Deposition rates averaged 12 to 18 m/m.y. in the upper Pliocene to upper Pleistocene sequence (0-2.0 Ma). Too few shipboard analyses were made to detect significant trends at Site 668. Both from the lithology and the state of preservation, the overall sequence is characteristic of a low-productivity surface-water environment and a deep-water regime not heavily undersaturated with $CaCO_3$.

## CONCLUSION

Leg 108 shipboard results indicate that the Pliocene depositional regime prior to about 2.5-3.0 Ma resulted in low-amplitude sediment cycles rich in calcium carbonate, mainly foraminifer-nannofossil ooze. Biogenic opal, land-derived silt, and clay and freshwater diatoms are rare in these sediments. During the last 2 to 3 m.y., most sediment sequences show a change in the sedimentation regime to sediments consisting of high amplitude sediment cycles ranging from foraminifer-bearing nannofossil ooze to nannofossil clay. Increased concentrations of biogenic opal and organic carbon during these times indicate increased oceanic productivity.

Further shorebased analysis is required to ascertain whether these changes developed slowly over the the last 3 Ma or with abrupt step like changes in amplitude. Regardless, a clear first order correlation exists between this equatorial trend and that seen in polar climates.

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# TABLE AND FIGURE CAPTIONS

Table 1. Summary of location, water depth, sub-bottom penetration, and age and lithology of oldest sediment recovered from each hole cored during Leg 108.

Figure 1. Geographic position of Leg 108 sites. Arrows mark major current systems; dotted areas indicate regions of strong Plio-Pleistocene upwelling and divergence.

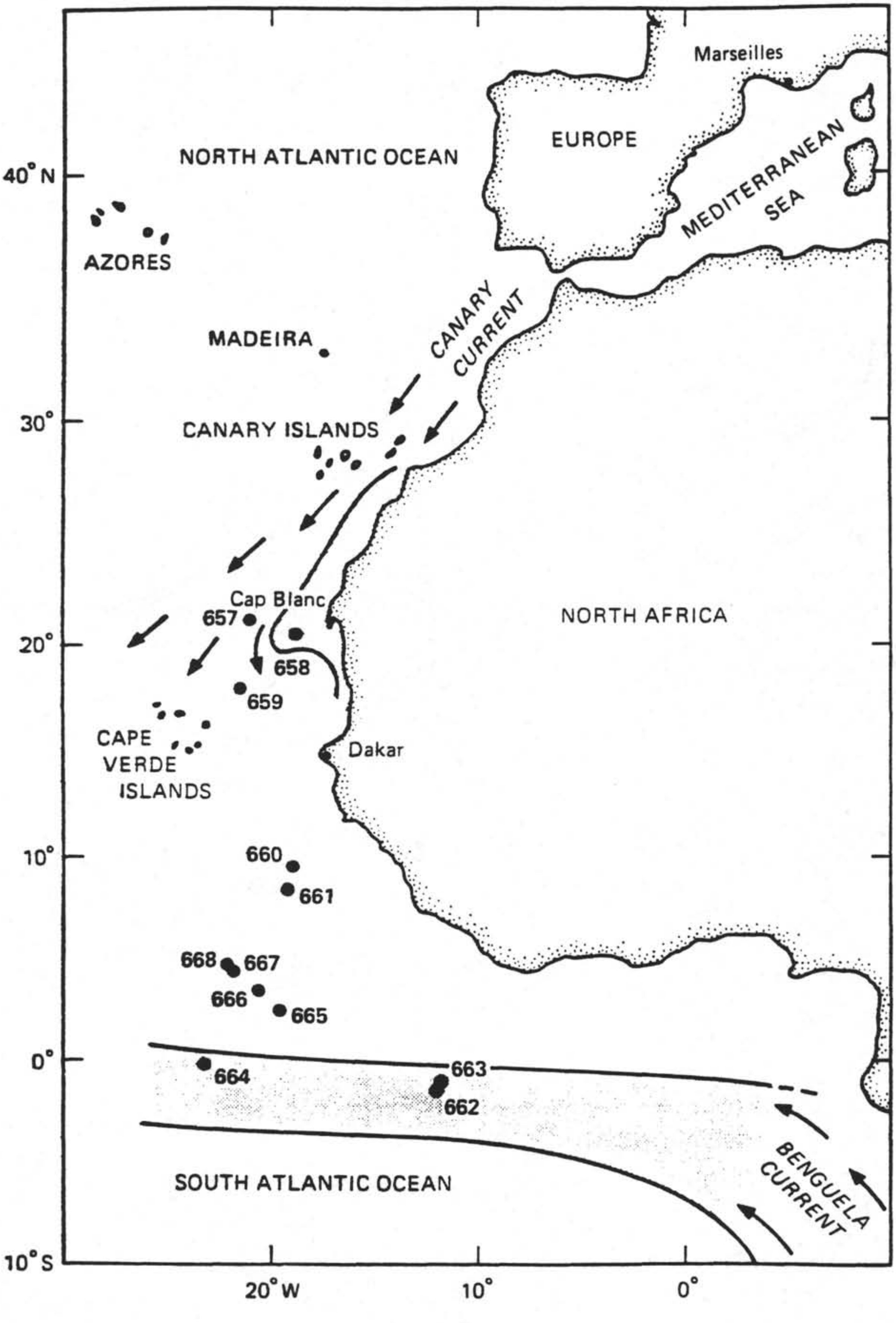
Figure 2. Schematic log of lithologic sequences obtained in and near northwest African margin upwelling area (Sites 657-659), Kane Gap area (Sites 660-661), equatorial divergence area (Sites 662-664), and Sierra Leone Rise (Sites 665-668). $CaCO_3$ cycles increase in amplitude progressively from 3.0-2.5 Ma until present, with non-carbonate lithology consisting of silty clay and opaline (diatom) silica, with minor amounts of organic carbon. The actual cyclicity of these changes could not be determined from shipboard analyses, but is presumably of orbital origin (20,000-40,000 years). Lithologic change in the range 4.6-3.8 Ma marks deepening of carbonate compensation depth.

Figure 3. Portion of watergun seismic line showing location of Site 658 near buried slide escarpment and a crevasse further upslope possibly signifying the initiation of mass flow of the sediment pile cored at Site 658. Region of the transparent seismic reflector (0.47 secs.) corresponds to interval of high biogenic gas content in the sediment.

TABLE 1.

| SITE | HOLE | LATITUDE | LONGITUDE | WATER DEPTH (m) | SUB-BOTTOM DEPTH (m) | OLDEST | |
|---|---|---|---|---|---|---|---|
| | | | | | | SEDIMENT (Ma) | LITHOLOGY (type) |
| 657 | A | 21°19.89'N | 20°56.93'W | 4221.1 | 178.2 | about 8.0 | zeol. clay |
| 657 | B | 21°19.89'N | 20°56.93'W | 4221.1 | 166.1 | about 9-10 | red clay |
| 658 | A | 20°44.95'N | 18°34.85'W | 2263.6 | 300.4 | 3.5-3.8 | nanno-ooze |
| 658 | B | 20°44.95'N | 18°34.85'W | 2264.2 | 163.8 | about 2.4 | silic-ooze |
| 658 | C | 20°44.95'N | 18°34.85'W | 2262.9 | 72.9 | 0.5 | nanno-ooze |
| 659 | A | 18°04.63'N | 21°01.57'W | 3071.2 | 273.8 | about 24 | clay |
| 659 | B | 18°04.63'N | 21°01.57'W | 3073.4 | 202.0 | about 11.0 | clay |
| 659 | C | 18°04.63'N | 21°01.57'W | 3070.5 | 196.0 | <9.0 | nanno-ooze |
| 660 | A | 10°00.81'N | 19°14.74'W | 4332.2 | 163.7 | mid. Eocene | rad-ooze |
| 660 | B | 10°00.81'N | 19°14.74'W | 4332.3 | 148.8 | mid. Eocene | rad-ooze |
| 661 | A | 09°26.81'N | 19°23.17'W | 4012.7 | 296.1 | mid-upp. Cret. | clay |
| 661 | B | 09°26.81'N | 19°23.17'W | 4013.1 | 81.7 | about 8.0 | clay |
| 662 | A | 01°23.41'S | 11°44.35'W | 3813.8 | 200.0 | about 3.6 | nanno-ooze |
| 662 | B | 01°23.41'S | 11°44.35'W | 3813.8 | 188.2 | about 3.6 | nanno-ooze |
| 663 | A | 01°11.87'S | 11°52.71'W | 3697.6 | 147.2 | <2.7 | nanno-ooze |
| 663 | B | 01°11.87'S | 11°52.71'W | 3697.4 | 152.0 | <2.7 | nanno-ooze |
| 664 | A | 0°06.44'N | 23°13.65'W | 3806.0 | 28.9 | about 0.7 | nanno-ooze |
| 664 | B | 0°06.44'N | 23°13.65'W | 3806.3 | 247.0 | about 4.5 | nanno-ooze |
| 664 | C | 0°06.44'N | 23°16.5'W | 3806.8 | 61.2 | about 1.4 | nanno-ooze |
| 664 | D | 0°06.44'N | 23°16.5'W | 3801.7 | 296.8 | about 9.0 | nanno-ooze |

| SITE | HOLE | LATITUDE | LONGITUDE | WATER DEPTH (m) | SUB-BOTTOM DEPTH (m) | OLDEST | |
|---|---|---|---|---|---|---|---|
| | | | | | | SEDIMENT (Ma) | LITHOLOGY (type) |
| 665 | A | 2°57.07'N | 19°40.07'W | 4740.4 | 97.9 | >4.6 | clay |
| 665 | B | 2°57.07'N | 19°40.07'w | 4741.8 | 82.0 | >4.6 | clay |
| 666 | A | 3°29.84'N | 20°10.03'W | 4516.8 | 150.5 | about 5.0 | nanno-ooze |
| 667 | A | 4°34.15'N | 21°54.68'W | 3535.5 | 381.3 | Olig. | nanno-chalk |
| 667 | B | 4°34.15'N | 21°54.68'W | 3535.5 | 139.1 | about 9-10 | nanno-clay |
| 668 | A | 4°46.12'N | 20°55.62'W | 2690.0 | 8.8 | <1.6 | nanno-ooze |
| 668 | B | 4°46.12'N | 20°55.62'W | 2693.1 | 31.2 | <3.4 | nanno-ooze |



NORTH ATLANTIC OCEAN
EUROPE
Marseilles
MEDITERRANEAN SEA
40° N
AZORES
MADEIRA
CANARY CURRENT
30°
CANARY ISLANDS
Cap Blanc
657
658
659
NORTH AFRICA
20°
CAPE VERDE ISLANDS
Dakar
10°
660
661
668
667
666
665
0°
664
663
662
SOUTH ATLANTIC OCEAN
BENGUELA CURRENT
10° S
20° W
10°
0°

FIGURE 1.

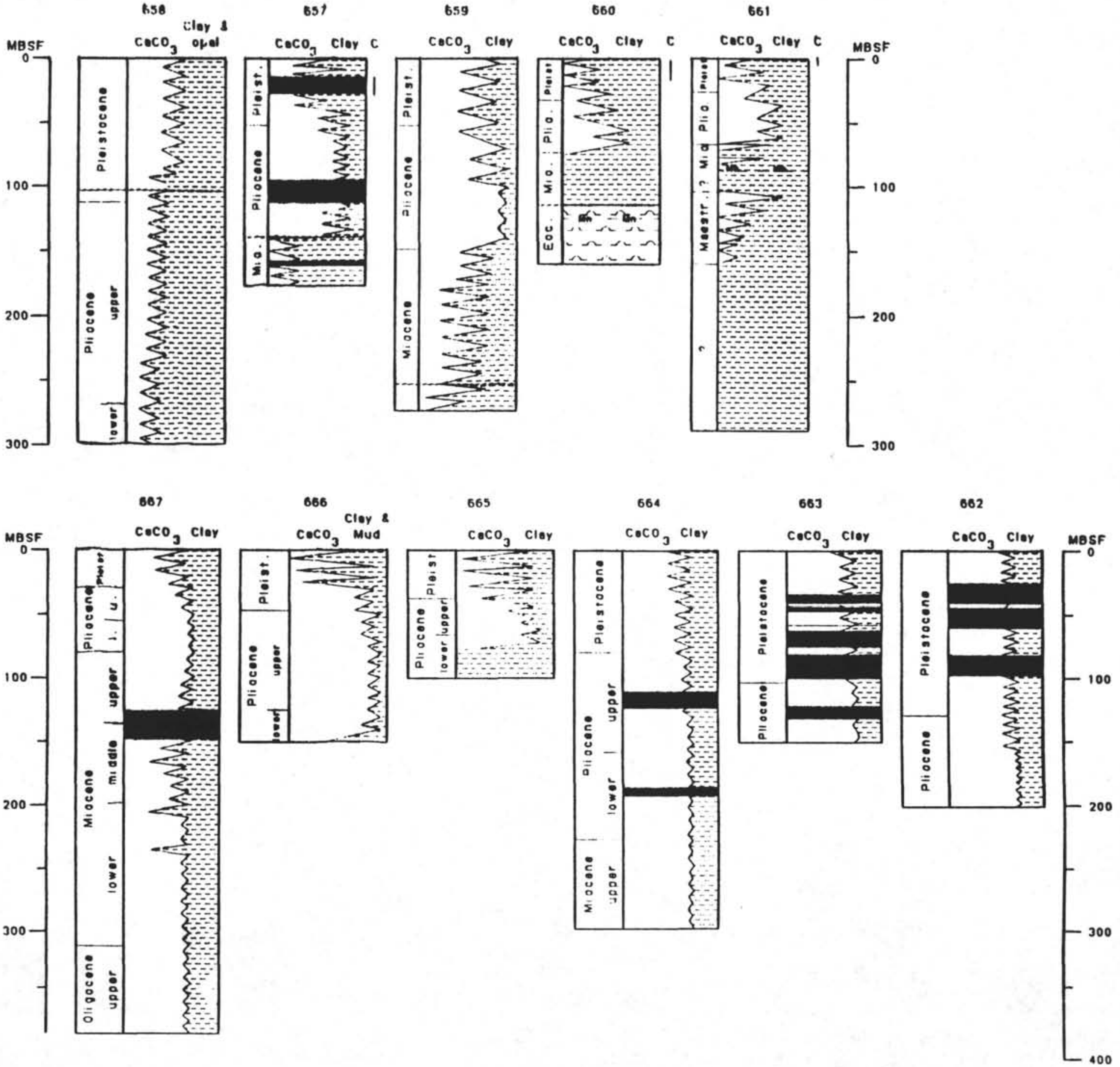

658
CaCO3
Clay & opal
657
CaCO3
Clay
C
659
CaCO3
Clay
660
CaCO3
Clay
C
661
CaCO3
Clay
C
MBSF
0
100
200
300
Pleistocene
Pliocene
upper
lower
Pleist.
Pliocene
Mio.
Miocene
Plio.
Eoc.
Maestr.
667
CaCO3
Clay
666
CaCO3
Clay & Mud
665
CaCO3
Clay
664
CaCO3
Clay
663
CaCO3
Clay
662
CaCO3
Clay
400
middle
Oligocene
upper

FIGURE 2.

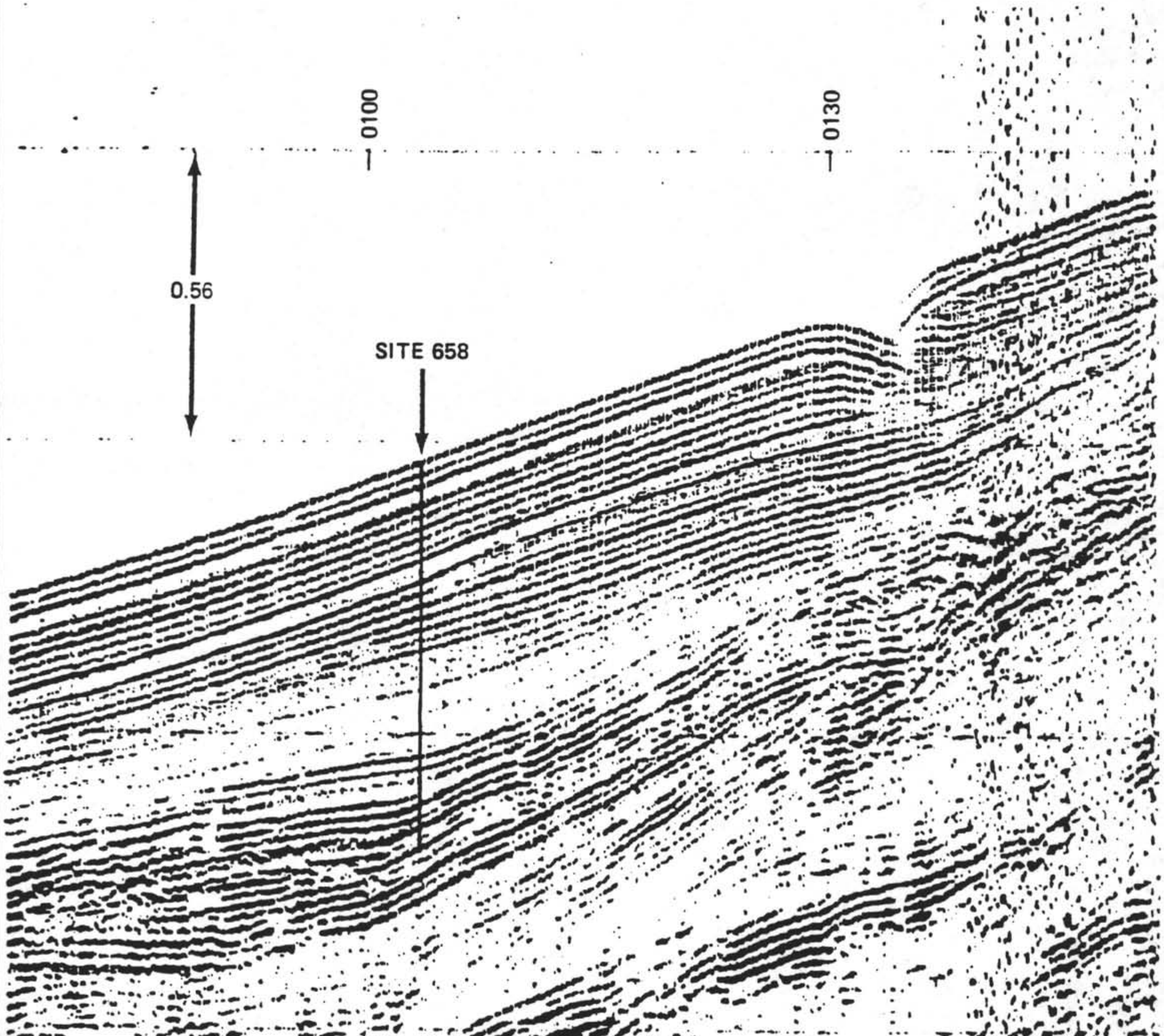


FIGURE 3.

# OPERATIONS REPORT

## INTRODUCTION

Leg 108 of the Ocean Drilling Program was devoted to the coring of shallow sites off the West African coast for purposes of high-resolution stratigraphy. Operational challenges included the requirement for a high rate of core recovery with a minimum of core disturbance, occupation of numerous sites over a wide geographic area and operation under hot equatorial conditions.

The voyage commenced on February 21, 1986 at Marseille, France and ended on April 17, 1986 at Dakar, Senegal. A total of 27 holes were drilled at 12 sites (Figure 1), with a total cored interval of 4437 m (Tables 1 and 2). Some of the operational highlights of Leg 108 are the following:

1. The 3841 meters of core recovered (Figure 2) established a new core recovery record for a single voyage, exceeding the mark set by DSDP Leg 90.
2. The hydraulic piston corer (APC system) was used to recover 3396 m of core with a 94.2% recovery rate (Figure 3).
3. A prototype "free-fall re-entry cone" was deployed and re-entered successfully.
4. Logging tools were successfully deployed through a side entry sub to permit vertical movement of the drill string in the borehole.
5. Only one bit (a rerun) was used on Leg 108.
6. The 5607 nautical miles logged between Marseille and Dakar was the greatest distance traveled between ports by JOIDES Resolution since launch in 1978.

Total length of the voyage was 58.0 days, with 35.7 days spent on site, 18.8 days under way and 3.5 days in port.

## MARSEILLE PORT CALL

Leg 108 started 0645 hours on February 18, 1986 when the first line came ashore in Port Marseille, Marseille, France. Crews were changed out and started loading ODP and SEDCO supplies. While loading supplies, 362,223 gallons of fuel and 190 tons of drill were was pumped on board. The bulk mud system was topped off with 80.5 tons of barite, and 64.6 tons of barite. Four knobby joints of drill pipe were off-loaded to have new boxes and pins cut.

Numerous tour groups from the oil industry and scientific community visited JOIDES Resolution during the 3.4-day port call. Tests were conducted on the XCB coring system during the night hours.

When the last critical freight item was on board, clearance from the port authorities was requested and granted. The port call was officially completed when JOIDES Resolution departed her berth at 1815 hours, 21 February 1986.

## UNDERWAY OPERATIONS

### MARSEILLE TO SITE 657

During the 6.2-day cruise to Site 657, a new swage-type sandline was installed on core winch No. 2; a new Cavins/Saunders oil saver (line wiper) was installed on core winch No. 1. Oil was changed in the top drive and rotary table; the top drive shaft, drill pipe elevators, etc. were magnafluxed. Survey gear was deployed at 1715 hours, 27 February 1986.

### SITE 657

#### Hole 657A

A Datasonics beacon was deployed at 2215 hours, 27 February 1986 (Table 3). The bottomhole assembly (BHA) (Table 4) selected for the first drill site for Leg 108 consisted of an 11-7/16 RBI, type C4 bit, long bit sub with float valve, one seal bore drill collar, landing sub, head sub, 5 each 8-1/4" drill collars, McCullough jars, 2 each 8-1/4" drill collars, crossover sub, one 7-1/4" drill collar, and one stand of 5-1/2" drill pipe.

The trip in with the drill string continued to 4229 meters, which would position the bit three meters above the mudline at a PDR depth of 4232 m. The mudline was established at 4231.6 m below the rig floor (m BRF) (4221.1 m water depth).

The APC (Advanced Piston Corer) was used for 16 cores from the mudline to 4381.3 m (149.7 m below sea floor: m BSF), with the maximum overpull of 55,000 pounds occurring on Core 657A-16. Cores 657A-15 and 16 contained only traces of core that had lodged in the core catcher. On Core 657A-18, the core catcher consisted of a flapper with a soft formation 10-finger catcher and recovered 4 m of very coarse sand.

The only problems encountered while coring the first hole on Leg 108 were the inconsistent shearing of the APC shear pins and the problem of shattered, broken, split and collapsed core liners that affected core recovery as well as core quality.

Experimental seal subs were installed on both of the APC core barrels that were in use. These prototype subs had a bonded rubber pack-off that was designed to replace the easily dislodged O-ring seals previously used to minimize the core liner failure that was a problem on Legs 101, 103, 104 and 105; but the failure rate continued at about 30%.

While retrieving Core 657A-3, the No. 2 sandline parted at the rope socket and two wireline trips with an overshot were required to recover the core barrel.

## Hole 657B

The ship was offset 15 m south and the mudline was established at 4231.6 m BRF (4221.1 m water depth). Hole 657B was cored with the APC to 4397.7 m BRF (166.1 m BSF) and 18 cores were recovered. The XCB was used on the final core, and recovered only a trace of coarse sand.

After recovering Core 657B-5 with a shattered core liner, it was noticed that most of the liner failures were occurring with one particular core barrel. The suspect barrel was disassembled for inspection. The barrel appeared to be OK and was reassembled and was used again on Core 657B-7. When the core was recovered, the liner was cracked/shattered with only 5 m of recovery. Determined to find the problem with this particular core barrel, we decided to pressure test the core barrel on the rig floor with 1000 psi. Only 300 psi was needed to find a leak in a threaded connection in the lower end of the core barrel. For the following ten cores there were no failures of the plastic core liners. The last two APC cores were shot with 4200 psi and resulted in both liners being partially cracked.

The No. 2 sandline had two partial failures and required new terminations. The hole was abandoned when Core 657B-19 was recovered with a core catcher of loose, coarse sand. No gas was encountered. The hole was left open with seawater.

## SITE 658

On the approach to Site 658, the survey gear was deployed at 2210 hours, 3 March 1986. While working in these low latitudes, there was a window from 1800 to 0700 hours with no satellite fixes from GPS or SATNAV. The five-hour survey at Site 658 was completed by dead reckoning. The beacon was deployed at 0300 hours, 4 March 1986. The drill pipe was tripped in to the mudline as indicated by PDR. The first GPS position indicated that the ship was positioned 2 miles south of the target location.

## Hole 658A

The bit was raised 300 m above the mudline and knobby joints were positioned from the rotary table through the keel. The ship was moved two miles due north in thruster mode while the PDR was constantly monitored for changes in water depth. A beacon was deployed at 0400 hours, March 4 in 2274.1 m BRF (2263.6 m water depth). The bit was lowered to 3 m above the mudline to shoot the first core. Two point two meters of firm nannofossil ooze was recovered. The hole was cored with the APC through Core 658A-18 (2432 m BRF (157.9 m BSF)) with an excellent recovery of 95.7%. During this cored interval, there were only four core liners that had short longitudinal cracks. However, in each case the core recovery was 100%. Beyond a doubt the new seal subs and the elimination of leaks in the core barrel have improved recovery by 10 to 15%.

Traces of methane gas were evident in Core 658A-12 with some core expansion caused by gas intrusion. Coring continued with the APC, and each core was checked for changes in gas ratios. The ratios remained above 1000:1 C1/C2. After shooting APC 658A-18 with only a partial stroke and requiring 70,000 overpull to retrieve the core barrel, the XCB was deployed on Core 658A-21. The XCB was used to the total depth of 300.4 m BSF. Recovery was excellent due to the gas expansion of the recovered cores. On three different occasions the gas samples were analyzed before drilling the next core. The methane peaks were too high to measure, but the gas ratio remained above 1000:1 C1/C2.

The bit was positioned at 151.9 m BSF, then 117 cu ft of cement was mixed and placed to plug across the methane zone between 2368 m BRF (93.9 m BSF) and 2426 m BRF (151.9 m BSF). The bit was raised above the cement plug and the drill string was flushed out with seawater. A prototype free-fall re-entry cone was prepared for testing (Figure 4).

## Free-Fall Re-entry Cone Test

The upper drill pipe guide was raised above the rig floor and the VIT was secured around the drill string. The moonpool doors were opened and the TV camera was lowered to observe the wellbore at the mudline. The hole became visible when the camera was approximately 12 m above the mudline. After viewing the wellbore for a few minutes, the camera was lowered to within 5 m of the seafloor. The wellbore was surrounded by a mound of drill cuttings that had been circulated out while drilling. Using the diameter of the 5-1/2" drill pipe at the mudline, it was easy to calculate that the wellbore at the mudline was about 20" (50 cm) in diameter and approximately 60" (150 cm) in diameter across the top of the mound. The mound seemed perfectly shaped to receive the free-fall re-entry cone. The VIT was retrieved and removed from the drill string. Prior to testing, the two halves of the cone were bolted together. For conductor casing, a seven-foot section of 13-3/8" casing with a 5/8" wall was welded into the cone throat, then the 13-3/8" casing was split in half for ease of installation. The bolts were removed and the two sections were ready to be installed around the drill pipe. Only 1-1/2 hour was required to complete the installation of the cone and the welding of the 13-3/8" casing. Three flotation balls were tethered from the top rim of the cone with six feet of polypropylene rope. A pinger that was intended to quit sending signals on impact with the mudline was attached to the outer edge of the cone.

The cone was lowered into the water, the handling ropes were cut and the cone began its fall to the mudline. The VIT was attached around the drill string and the TV camera was lowered to scan the position of the re-entry cone. The black and white circles that were painted inside the re-entry cone were very visible from 12 m above. As the camera was lowered for a closer view, it was apparent that the 6-ft diameter cone had seated perfectly within the mound around the wellbore.

With the VIT positioned 9 m above the mudline, the BHA was pulled up until the bit cleared the re-entry cone. The 8-1/4" drill collars appeared to be 10" due to a mud ball over the entire length of the BHA.

The ship was offset 30 m to the south purposely to lose sight of the beacon. Due to the muddy BHA forming an opaque cloud around the BHA and over the cone, 55 minutes were required to return to the beacon and to successfully re-enter the prototype cone. Without the opaque cloud over the target, re-entry would have been achieved within 30 or 35 minutes.

With a successful conclusion of the free-fall re-entry cone test, the VIT was retrieved, and the upper drill pipe guide was secured. The ship was offset 15 m south to Hole 658B.

## Hole 658B

Hole 658B was cored from the mudline, which was confirmed at 2274.7 m BRF (2264.2 m water depth). Core recovery was excellent through the last core from a total depth of 2438.5 m BRF (163.8 m BSF). Core 658B-9 contained methane gas, which caused some core expansion. However, Hole 658B had less gas and less core expansion than Hole 658A. Apparently the initial hole depleted the gas that was embedded in the stiff clay. The hole was terminated after recovering Core 658B-18 when 65,000 lbs of overpull was required to retrieve the APC.

The bit was positioned at 2363 m BRF (89 m BSF) and 99 sacks of class G cement were mixed to place a cement plug across the methane gas bearing clays between 2313 m BRF (39 m BSF) and 2363 m BRF (89 m BSF), then the drill pipe was tripped out until the bit cleared the mudline. The drill string was flushed with sea water.

## Hole 658C

The ship was offset 15 m northwest of Hole 658B and the mudline was established at 2273.4 m BRF (2262.9 m water depth. The hole was cored with the APC to a total depth of 2346.3 m BRF (72.9 m BSF). The maximum overpull of 2000 lbs occurred on Cores 658C-7 and -8 and no core liner failures were experienced. The hole was filled with 11.8 ppg drilling mud since only a trace of gas was detected in Core 658C-8. The drill pipe was tripped out and the ship was under way at 1600 hours, 8 March 1986.

## SITE 659

## Hole 659A

A Datasonics beacon was deployed at 0845 hours, 9 March 1986 in 3083 meters of water as indicated by PDR. We used the same BHA and the RBI-C4 rerun core bit that had been used since Site 657. The pipe was tripped to 3080 meters. The first APC core established the mudline at 3081.7 m BRF (3071.2 m water depth).

The APC was used for 20 cores to 3270 m BRF (188.3 m BSF) through this sequence of foraminifer ooze. Cores 659A-6, -18, and -19 had no recovery. Two ten-finger core catchers were used on these cores, but apparently, the springs are too weak for the long finger catcher, and sticky clay seems to slide out while the catcher's fingers remain stuck open.

The XCB was deployed on Core 659A-21 at 3270 m BRF (188.7 m BSF). Recovery was disappointing. Nine cores were attempted to a total depth of 3354.8 m BRF (273.8 m BSF). The silty nannofossil ooze proved to be difficult to recover. Pump pressure, bit weight and RPM were all adjusted in attempts to improve recovery, but with the same disappointing results.

After achieving our objectives in this hole, the hole was filled with 11.8 ppg drilling mud. The pipe was tripped out until the bit cleared the mudline. While coring at Site 659, the rig mechanics discovered that the forward rod of the Western Gear heave compensator was badly scored and that it would need to be locked in an inactive mode for the remainder of Leg 108. The heave compensator was operable, but would be used only in an emergency. With the ideal sea conditions that Leg 108 had enjoyed through the first three sites, the heave compensator had been used only five hours.

## Hole 659B

The ship was offset 15 m south of Hole 659A. The first APC core established the mudline at 3083.9 m BRF (3073.4 m water depth). Cores 659B-2 and -3 were retrieved with no recovery. The two 10-finger catchers were replaced with one clamshell catcher and one 10-finger, and the core recovery was 9.5 m on Core 659B-4. Good recovery continued until the two soft-formation catchers were used again on Core 659B-9 and the recovery was only 3.5 m.

The hole was terminated after recovering Core 659B-22 from a total depth of 3286 m BRF (202.1 m BSF). The last core recovered required 50,000 lbs overpull to unseat the core barrel: the hole conditions were becoming sticky, due to either swelling clay or a mud ball on the BHA. The hole was filled with 11.8 ppg drilling mud and the drill pipe was tripped out to clear the mudline and begin coring Hole 659C.

## Hole 659C

The ship was offset 15 m south of Hole 659B and Hole 659C was selectively cored and washed from the mudline at 3081.0 m BRF (3070.5 m water depth) to a total depth of 3277 m BRF (196 m BSF). Using the clamshell and one 10-finger catcher, APC coring continued to 3119 m BRF (38 m BSF) with 98% recovery. An XCB without the coil spring was used to wash two intervals, 3119-3181 m BRF (38-100 m BSF) and 3200-3258 m BRF (119-177 m BSF). A total of eight cores were recovered with 95.3% recovery from the 76 m cored. The hole was left with seawater, since total penetration was less than 200 meters and no trace of gas was observed. The pipe was tripped out and the ship was under way at 0600 hours, 13 March 1986.

## SITE 660

The final five hours of survey were completed by dead reckoning. The last GPS position was received at 1930 hours, 14 March 1986. The beacon was deployed at 0030 hours, 15 March 1986. The trip-in started at beacon drop. The no. 1 thruster pod was down by the time the survey gear was retrieved, and the ship turned almost on its own axis with the forward thrusters pushing the bow around. The ship returned to the beacon in DP mode at one knot, so tripping-in could continue.

## Hole 660A

Hole 660A was officially spudded at 0830 hours and the first APC core established the mudline at 4342.7 m BRF (4332.2 m water depth). Piston coring continued with excellent recovery rate through Core 660A-16 when the maximum overpull of 80,000 lbs occurred. Only two liners had cracks of 4-6" long. Every core recovered during this sequence was virtually undisturbed.

The XCB was deployed on Core 660A-17. Cores 660A-17 and 18 had 95% recovery. After coring 1.9 m on Core 660A-19, the pipe started torquing severely. It was decided to retrieve the core barrel to determine the cause of the slow rate of penetration (ROP) and excessive torque in the drill string. As we expected, the core catcher was full of chert fragments. The hole was terminated with the recovery of Core 660A-19 from 163.7 m BSF. Since no gas was encountered, the hole was left open with sea water. The bit was pulled clear of the mudline at 1030 hours to prepare to spud Hole 660B.

## Hole 660B

The ship was offset 15 m south of Hole 660A. A 4.5-meter pup joint was added to the drill string to change the connection depths by 4.5 meters between Holes 660A and 660B. APC Core 660B-1 confirmed the mudline to be 4342.8 m BRF (4332.3 m water depth). Coring was done routinely through Core 660B-14 to 129.8 m BSF with 100.8% recovery and no core liner failure.

The XCB was deployed for Cores 660B-15 and 16 with recovery of 92.6%. Coring was terminated at the request of the scientists. As no traces of hydrocarbons were encountered, the hole was left open with seawater. The drill pipe was tripped out and the ship was under way at 1215 hours, 17 March 1986.

## SITE 661

## Hole 661A

A Datasonics beacon was deployed in 4018 m (PDR) of water. The first piston core established a medium firm mudline at 4023.2 m BRF (4012.7 m water depth). Fifteen APC cores were taken in gradually stiffening silty nannofossil ooze. The first ten cores had 85% recovery. Cores 661A-12 through 15 recovered stiff brown clay. The brown clay that was recovered in Core 661A-12 through 15 was determined to be Cretaceous and of the oldest formation cored with the APC.

The maximum overpull of 70,000 lbs occurred on Core 661A-16. The XCB was used for the last 17 cores to a total depth of 4319.3 m BRF (296.1 m BSF). From 4205 m BRF (182 m BSF), the ROP changed from 18 minutes per core to 70 minutes per core, and the drill string started overtorquing. To help control the drill string torque, each joint was reamed down after retrieving a core barrel. This procedure was continued until the final core (661A-32) was retrieved. Recovery through this section was about 71%. Apparently the stiff gray clay was forming a mud ball over the entire BHA and causing the hole to become very sticky.

To prepare the hole for logging, the hole was circulated with sea water for half an hour. Since the hole was less than desirable for running logs, it was decided to make a wiper trip prior to logging. The pipe became stuck once and required 125,000 lbs of overpull to free the drill string.

Thirty to forty thousand pounds of overpull was required at various depths to complete the short trip out. The short trip back to bottom was not much better. The bit had to be spudded through several tight spots.

The hole was circulated for half an hour. Then the bit was positioned at 4100 m BRF (76.8 m BSF). The following logging runs were attempted:

Run 1. Dual induction, sonic gamma ray. Log stopped at firm bridge at 196 m BSF.
Run 2. LDT, CNT, NGT. The log stopped just below the bit. No logging was attempted.

The logging tools were retrieved and the equipment was rigged down. The drill string was tripped into the hole to fill the hole with mud. A firm bridge was encountered at 160 m BSF. The hole was displaced with 11.8 ppg mud. No gas was encountered in this hole. The drill pipe was tripped out to clear the bit of the mudline to spud Hole 661B.

### Hole 661B

The ship was offset 15 m south of Hole 661A. The second hole was cored with the APC from the mudline at 4023.6 m BRF (4013.1 m water depth) to 4105.3 m BRF (81.7 m BSF). During this nine-core sequence, the overpull never exceeded 25,000 pounds. Cores 661B-8 and -9 had cracked liners. (A leaking thread on the core barrel caused both failures.) Recovery was an excellent 99.6%. No gas was detected, so the hole was left open with seawater. The drill string was tripped out and the ship was under way to Site 662 at 1145 hours, 21 March 1986.

## SITE 661 TO SITE 662

During the 39-hour trip to Site 662, the rig crews serviced drilling and coring equipment, magnafluxed the drill pipe elevators, elevator links, top drive shaft and connector link ears.

## SITE 662

No satellite fixes were received between 1900 and 0700 hours, as we were working close to the equator. Fortunately the ship was following an old seismic line when the last GPS position was received and the beacon was deployed at 0300 hours. The last eight hours of the survey were completed by dead reckoning, the survey record was very good, and we had no trouble locating the middle of a large sediment pond.

### Hole 662A

The ship positioned over the beacon, and the trip-in with the drill pipe commenced without delay. The bit was positioned 3 m above the PDR water depth of 3821 m, to shoot the mudline.

Three water cores were taken before a 60-m mistake in the length of the BHA was discovered. To correct this error, 60 m of pipe were added to the string. The bit was positioned at 3821 meters and the mudline was defined at 3821.3 meters by DPM on the first core.

Twenty-two APC cores were taken while coring to total depth of 4024.3 m BRF (200 m BSF). Recovery was excellent in the foraminifer-nannofossil ooze. The overpull to unset the core barrel did not exceed 20,000 lbs. The pipe was tripped out to clear the mudline. Since the hole did not exceed 200 m and no gas was encountered, the hole was left open with seawater.

## Hole 662B

The ship was offset 15 m south of Hole 662A. A 4.5-m pup joint was added to the string so that the core depths would overlap Hole 662A by 4.5 m. Twelve cores were taken in the following sequence: Cores 662B-1 and 2 from the mudline at 3824.3 m BRF (3813.8 m water depth) to 19 m BSF, Core 662B-3 from 36-45 m BSF, Core 662B-4 from 75-84 m BSF, Core 662B-5 from 93-102 m BSF, and Cores 662B-6 through 12 from 122-188.2 m BSF. The uncored intervals were washed with an XCB barrel in place. As on Hole 662A, the recovery was excellent and only one core liner collapsed over a two-foot section in the lower seal sub area. The only mechanical problem experienced on Hole 662B happened while lowering the APC for Core 662B-10 when a strand in sandline no. 1 (old line) broke with the barrel 240 m below the rig floor. The ball of stranded cable was cleared away and sandline no. 2 was used to take Cores 662B-10 and 11 while the old line was reterminated.

No gas was encountered. The drill pipe was tripped and the ship was under way to Site 663 at 1215 hours, 26 March 1986.

## SITE 663

Site 663 is located 19 km northeast of Site 662. The survey gear was streamed as the ship departed Site 662, and the beacon was dropped at 1730 hours on the initial pass over the proposed site.

## Hole 663A

The pipe was tripped in with the same BHA as used on the previous site. The bit was positioned at 3704 m to shoot the mudline at 3706 m as indicated by the PDR. Sixteen APC cores were recovered to a total depth of 3855.3 m BRF (147.2 m BSF). Only one liner was reported to be cracked. The drill pipe was tripped out to clear the mudline for the move to Hole 663B.

## Hole 663B

The ship was offset 15 m south of Hole 663A and the mudline was established at 3707.9 m BRF (3697.4 m water depth). Hole 663B was cored with the APC to a total depth of 152 m BSF. Heat flow measurements were taken on Cores 663B-4, -6, -9 and -12. The foraminifer-nannofossil ooze with turbidites and slumps proved to be a perfect formation for coring with the APC. Recovery was 101%. The turbidites, a loosely cemented sand, were 3-9 m thick, but hole conditions remained good throughout Site 663. The hole was terminated with the recovery of Core 663B-16 from 3859.9 m BRF (152 m BSF). With the completion of the double APC site, the drill pipe was tripped out and the ship was under way at 0945 hours, 28 March 1986.

## SITE 663 TO SITE 664

During the 54-hour trip, the new sandline was transferred from the forward (no. 1) coring winch to the aft (no. 2) coring winch to provide the operator with better vision of the line receiving the greater usage. The line was spooled onto the core winch drum with 7,000 lbs of tension. The old sandline was spooled onto the forward coring winch under 9,000 lbs of tension.

## SITE 664

### Hole 664A

A beacon was deployed at 1615 hours, 30 March 1986. The drill pipe was tripped in with the standard BHA. The bit was positioned 3 m above PDR bottom at 3806 m, to shoot the mudline. The first core retrieved was a full 9.5-m core. On re-counting the pipe in the pipe racker, it was dicovered that one extra stand of drill pipe (28 m) was in the drill string (Core 664A-1 was actually shot considerably below the seafloor). Hole 664A consisted of this one core only.

### Hole 664B

The ship was repositioned 15 m south of the first hole. Core 664B-1 established the mudline at 3816.8 m BRF (3806.3 m water depth). Twenty-six APC cores were taken to a total depth of 4063.8 m BRF (247 m BSF), with the maximum overpull of 70,000 lbs occurring on the final core.

The site was located in a large sediment pond. The recovered sediments are foraminifer-nannofossil ooze, a sediment that is ideal for piston coring. Recovery was 99.1%.

A new Cavins/Saunders (field modified) line wiper was installed on the aft coring winch before arriving on Site 664. By closing the line wiper and using 40 strokes of pump, the APC core barrel was pumped down the drill pipe at 300 m per minute.

No gas was encountered, but to comply with ODP safety regulations the hole was filled with 11.8 ppg drilling mud. The drill pipe was tripped out to clear the mudline and spud Hole 664C.

### Hole 664C

The ship was offset 15 m north. Core 664C-1 established the mudline at 3817.3 m BRF (3806.8 m water depth). Seven cores were taken while coring to total depth at 3878.5 m BRF (61.2 m BSF). Cores 664C-3, -4, -5 and -6 were oriented. The cored formation was the same as at the previous hole, but recovery was less. Cores with flow or orientation measurements normally had a lower percentage of recovery. Apparently, the 5-10 minutes that is required to record the measurements cause the loss of core that is normally recovered in the shoe.

No gas was encountered. The hole was left open with seawater and the drill pipe was tripped out to clear the mudline.

## Hole 664D

The ship was offset to the north as far as possible for positioning with the same beacon. Hole 664D was 1000 m north of Hole 664C and the mudline was established at 3812.2 m BRF (3801.7 m water depth). Thirty-two piston cores were taken while coring to refusal depth at 4109 m BRF (296.8 m BSF). The type of sediment recovered from this hole down to Core 664D-24 was foraminifer-nannofossil ooze similar to that recovered from the two previous holes. The formation changed to a clay-bearing nannofossil ooze and 30,000 lbs of overpull was required to unseat the core barrel. As APC Core 664D-33 was on its way down, the scientists advised operations that we were very close to basement. We decided to take one last core. The pins sheared at 2700 psi, and full stroke was indicated. The core barrel was firmly stuck in the formation, and the core barrel parted with 145,000 lbs of overpull.

By pumping the core barrels down and continuing to fine-tune the core handling procedures, the drill crews had recovered 32 cores from 4000 m below the rig floor in 24.75 hours, an average of 45 minutes per core.

No gas was encountered, but to comply with safety regulations the hole was filled with 11.8 ppg drilling mud. The drill pipe was tripped out and the ship was under way to Site 665 at 1945 hours, 4 April 1986.

## SITE 665

The last three hours of the site survey were completed by dead reckoning because there were no SATNAV or GPS fixes received during the night hours.

## Hole 665A

A beacon was deployed at 2100 hours, 3 April 1986. The survey gear was retrieved while the no. 1 thruster was being lowered. At the same time, the drill crews were making up the drilling BHA. The ship positioned over the beacon and the trip-in continued until the bit was positioned 3 m above bottom at 4748 m as indicated by PDR. Core 665A-1 was retrieved and the mudline was established at 4750.9 m BRF (4740.4 m water depth). Eleven APC cores were taken while coring to total depth at 4848.8 m BRF (97.9 m BSF). The hole remained very stable and the core recovery was an outstanding 102.1%. The maximum overpull of 30,000 lbs occurred on Cores 665A-9, -10 and -11. Only Core 665A-10 had a cracked liner.

As no gas was encountered and the hole was less than 200 m penetration, the hole was left open with seawater. The drill pipe was tripped to clear the mudline to spud Hole 665B.

## Hole 665B

The ship was offset 15 m and the mudline was established at 4752.3 m BRF (4741.8 m water depth). The hole was cored to total depth at 4834.3 m BRF (82 m BSF) and nine cores were recovered. Cores 665B-2 through -9 were oriented.

On the last two wireline trips, each sandline was coated with CCX-77.

No gas was encountered and the hole was left open with seawater. The drill pipe was tripped out and the ship was under way to Site 666 at 1715 hours, 5 April 1986.

## SITE 666

### Hole 666A

The site survey was completed by dead reckoning, and the beacon was deployed at 0830 hours, 6 April 1986. As the beacon hit the water, thruster no. 1 was lowered while the survey gear was being retrieved and the drill crew was making up the BHA. The PDR water depth was 4519 m. The mudline was shot with the bit positioned at 4517 m BRF (4506.5 m water depth). Before this first core could be retrieved, one hour of mechanical downtime was required to cool down the electrical components in the coring winch controls. The ambient temperature of 90°F had caused the panel to overheat.

The first two cores were "water cores." The bit was lowered another 9.5 meters and the mudline was determined to be at 4527.3 m BRF (4516.8 m water depth). Sixteen APC cores were recovered to total depth of 4677 m BRF (150.5 m BSF). The upper part of the section consisted of foraminifer-nannofossil ooze; the last five cores contained sandy turbidites. Hole conditions were good and recovery was 100%. No gas was encountered and the hole was left open with seawater. The trip out was completed and the ship was under way at 2115 hours, 7 April 1986.

## SITE 667

### Hole 667A

Site 667, in a sediment pond, was located about 16 km north of the proposed site location. A spar buoy was deployed on the first pass. ODP was contacted by phone for permission to drill the relocated site. Authorization was received before the ship returned to the spar buoy. A beacon was deployed at 1330 hours, 8 April in 3529 m of water as indicated by PDR.

The upper drill pipe guide (UGH) was laid aside for this site, and the flapper was left out of the float valve. The plan was to log Hole 667A, and the UGH was not compatible with the side entry sub (SES) that would be used for the first time in deep water riserless logging. The drill pipe was tripped in, and the bit was positioned at 3227 m. The first core established the mudline at 3535.5 m BRF (3525 m water depth). Twenty APC cores were taken, 17 of which were oriented. Recovered sediments consisted of nannofossil ooze and turbidites for the first 14 cores. Core 667A-15 required 45,000 lbs of overpull, and by Core 667A-23 hard chalky nannofossil ooze caused a 60,000-lb overpull.

The XCB was deployed on Core 667A-24 and recovered 13 more cores. The XCB coring results had only 66.5% recovery. An experimental cutting shoe was used on Core 667A-40 and recovered 8.8 m of core. The standard type cutting shoe was used on Cores 667A-39 and 41 with only 4.5-m recovery on each attempt.

The hole was flushed with 40 barrels of drilling mud, and the pipe was tripped out to position the bit at 82 m BSF. The logging line was passed through six sheaves to get the end of the logging line in position under the rig floor and into the SES.

## Logging Operations

Run 1: A dummy tool was rigged through the SES. While the dummy tool was being lowered on the logging line, the drill pipe was lowered to position the bit at 140 m BSF. After proving that the logging line would pass through the six sheaves and the SES without problems, the dummy tool was retrieved.

Run 2: The logging tool DIL-LSS-GR-CAL was rigged through the SES. The drill pipe was lowered from 95 m BSF to 155 m BSF while the logging tool was being lowered through the drill pipe. The logging tool lost all functions at 600 m below the rig floor. The logging tool was retrieved and the bit was positioned at 95 m BSF; the logging tool was laid out and a faulty swivel removed.

Run 3: The same tool as used on Run 2 (less swivel) was rigged through the SES; the logging tool checked out OK. The logging tool was run in and the bit was repositioned at 155 m BSF. Again, the logging tool failed as the tool passed through the bit into open hole. The tool was retrieved and the logging equipment was rigged down. The tool failed due to short in the cable head.

Before one last try at logging Hole 667A, it was necessary to condition the hole. Rather than spend time circulating and conditioning the hole, it was decided to take five more XCB cores, to a total depth of 381.3 m BSF. After the cores were recovered, the hole was flushed with 40 barrels of mud. The pipe was tripped out to position the bit for logging, then rigged to log without the SES.

Run 4: The same logging tool as used on Runs 2 and 3 was lowered down the drill pipe. The tool was checked at several depths while running in. The logging tool malfunctioned in open hole at 198 m BSF. The logging tool was retrieved and the logging equipment was rigged down. After three consecutive logging tool failures, it seemed useless to waste any more rig time logging.

The bit was run back to 198 m BSF and the hole was displaced with 11.8 ppg drilling mud to comply with ODP safety procedures even though no gas was encountered. The drill pipe was tripped out to clear the mudline.

## Hole 667B

The ship was offset 15 km to the south. The first piston core indicated no change in the water depth. Fifteen APC cores were taken from the mudline to a total depth of 3764.3 m BRF (139 m BSF). Heat-flow measurements were run on Cores 667B-6, 8, 11 and 14. The hole was cored exactly the same as the previous hole. It was suggested by the co-chief scientist that we continue coring with the XCB. With the ship starting to roll 2° in a cross swell, it was decided that we would not rotate the drill pipe any more without making a trip to install the UGH. With the short time remaining on Leg 108, it was decided to move to Site 668. The drill pipe was tripped and the ship was under way at 0300, 14 April 1986.

## SITE 668

### Hole 668A

The ship arrived in the vicinity of the site at about 1300 hours and surveyed for three hours before locating an area without obvious sediment slumps. The beacon was dropped at 1600 hours, and the drill pipe was tripped to within 3 m of the mudline at 2693 m (as indicated by PDR). The first core was a water core. The bit was lowered 9.5 m and the APC was shot again. The sandline (old line) parted while retrieving the core barrel, and the core barrel fell from 368 m below the rig floor back to the mudline. A cable spear was installed on the sinker bars of sandline no. 1. On the first fishing attempt, a long piece of stranded sandline was retrieved. We made three more runs with various fishing tools to catch the top of the sinker bars. Apparently a piece of cable was fouled around the fishing neck of the sinker bars.

The pipe was tripped out to recover the sinker bars and the core barrel with the mudline core. The core barrel was found stuck in the seal bore drill collar and required three hours to work it free. A 10-inch piece of cable was still in the rope socket, and was wrapped around the fishing neck of the sinker bars, thus eliminating any chance of successfully fishing out the sinker bars. After the stuck core barrel was removed, the pipe was tripped back to the mudline to core Hole 668B.

### Hole 668B

The ship was offset 15 m south of Hole 668A and the mudline was established at 2703.6 m BRF (2693.1 m water depth). The hole had been cored to 31.2 m BSF when the ship's doctor advised the Captain and ODP operations that he was recommending a medical evacuation for a member of the scientific staff. The drill pipe was tripped out and the ship was under way for Dakar at 0345 hours, 15 April 1986.

## SITE 668 TO DAKAR

The transit to Dakar required just 51 hours at a speed of over 13 kts. Leg 108 ended officially with the first mooring line at the port of Dakar, Senegal at 0645 hours, 17 April 1986.

## SPECIAL REPORTS

### FREE FALL RE-ENTRY CONE

On Site 658 a prototype free fall re-entry cone (Figure 4) was deployed and successfully re-entered. The cone is secured around the drill string, then permitted to slide down the drill string to the sea floor. The 72"-diameter cone has no mud skirt: a 7' section of 13-3/8" casing welded to the cone penetrates the mud line and helps maintain the cone in a vertical position. With the cone in place the drill string is tripped out and re-entry is possible. The advantages of a free fall re-entry cone are as follows:

1. It provides an inexpensive means of "salvaging" planned single-bit holes that develop problems short of target depth.
2. It allows re-entry for running a packer test.
3. It provides a means to re-enter the well bore for fishing for a broken or parted BHA.
4. It will provide a way to re-enter the well bore for logging if the release mechanism fails to release the bit.

## SIDE ENTRY SUB (SES)

On Site 667, a logging side entry sub (SES) was introduced for the first time in deep ocean riserless logging. For installation of the SES, the drill string is tripped out until the top of the BHA is positioned at the mud line. Six logging sheaves are arranged to pass the logging line into the SES at the moonpool doors, leaving the drill string open so drill pipe can be added to the drill string as the logging tool is being lowered to the bottom. The drill bit remains close to the bottom until the logging tool passes through the bit, then the drill string is tripped out until the BHA is far enough off bottom to minimize the risk of sticking. The hole is logged from the bottom up. If the logging tool becomes stuck the drill string can be tripped in to free the stuck tool. Another distinct advantage of logging with the SES is the capability of circulating through the drill pipe while logging or washing down to free a stuck logging tool.

Operationally the side entry sub test was a complete success and has established the procedure for future logging on JOIDES Resolution.

## PERSONNEL

Leg 108 success can be attributed to complete cooperation and professionalism that has become standard on JOIDES Resolution. The SEDCO crews continued to fine-tune coring procedures that resulted in a record core recovery. The ODP technical crew dispatched their duties with enthusiasm and efficiency. All the scientific objectives were achieved despite the four days that were lost due to a medical evacuation.

# APPENDIX I: ENGINEERING REPORT

## LINER SEAL SUB

The new style liner seal sub was tested during Leg 108. This sub (see drawing SK 0084) has molded rubber seals. Before sending the seven new subs to the ship, they were slightly machined to increase the rubber seal inside diameter. It was impossible before this machining to slide the liner in the subs. Each liner was beveled and greased with Dow Corning III silicone grease before sliding it in the APC core barrel.

On the first holes (Figure 5) the new liner seal subs did not help to decrease the liner splitting problem. Obviously the liner splitting cause was elsewhere. No liner collapse was noted until the end of Site 661. At that point 182 cores had been taken with the APC and each sub had been used roughly 50 times. A close examination of the subs after this site showed that the rubber was worn to the point that the inside diameter became closer to the sub inside diameter.

After Site 661 a few collapsed liners were spotted. The collapsed part is generally 2 feet long and just above or across the bottom liner seal sub. Recovery was never affected when the liner collapsed. The collapse appears to happen while pulling out the core barrel, most likely during the initial pull-out.

There is no firm correlation between collapsed liners and heat flow measurements (or core orientation); however, the liner collapsed more often after a heat flow measurement. While making a heat flow measurement, the APC stays longer in the formation which closes around the barrel. When starting to pull out, the suction effect at the cutting shoe may be greater and the liner is more likely to collapse.

The collapse rate was kept low by cautiously cleaning the sub with a pressurized jet. If the silicone grease is not cleaned out of the seal sub, it has a tendency to pack in the sub. This packed grease prevents a good seal. The top seal sub does not need to be cleaned so often. The top section of the liner is less subject to collapse.

At the end of the leg the liner seal subs were completely worn out but still effective. Each sub had been used about 110 times.

The new liner seal subs are a must, because without the subs, the recovery with the APC would not have been as good. The final seal sub design must take into account the machined modification. A flat sealing surface is certainly better, as it will help to reduce the wear.

Care must be taken to prevent overconsumption of the liner seal subs. It is easy at the first slightly collapsed liner to throw away the faulty seal sub, but Leg 108 experience has shown that, with proper care, the subs can be used a long time even when looking worn out.

## LINER

The liner failure problem has been a common topic since the beginning of ODP (and certainly during DSDP). But during Leg 108 this problem was solved. When all minor cracks, one inch long splits and slightly deformed liners were counted, the percentage of non faulty liners was nearly 80% (see Figure 6).

How was such a result achieved? No space age technology or clever-minded modifications were needed. Only a careful observation of the core barrel when the liner failed was necessary. On the first site we had a lot of liner failure (Figure 5). After a liner split badly, a close inspection of the core barrel showed a faulty connection. There was a gap between the two connection shoulders that prevented this connection from being pressure tight. The upper 12-1/8 inch long inner barrel box thread was defective. The component was exchanged for a new one and the next liner came back without any failure.

Later, each time a liner was found split in the middle (split and cracked liners are all called "split" in this report), the core barrel was pressure-tested and very often a leaking connection was found. A close relation between split liners and leaking connections was established.

A leaking connection will certainly crack the liner, but not all the splits are caused by it. Most of the splits during leg 108 were issued at the lower seal sub and were the consequence of wear in these subs.

The core barrel pressure test is very easy to perform. A plug is screwed on at the lower seal sub pin connection, the core barrel is filled with water and a plug screwed on the top seal sub box connection. One of the plugs has a side entry port to be connected to a pump. Pressure is made up to 1000-1500 psi and all the connections are checked for leaks.

As shown in Figure 5, this procedure helped us to keep the liner split rate very low (less than 15% on the last six sites). The first site being the exception (where badly split liners were common), nearly all the split liners on the other holes had a split only a few feet long and sometimes shorter. Core recovery and quality were never affected by a split liner.

A small leak in a core barrel could not be stopped by making up the thread. A Teflon based compound was used to seal the connection and the next liners were not split in that area.

Three or four heavy core liner failures were encountered. In most of these cases the liner failed in compression when the core barrel hit a harder formation. The failure point is usually located at the core liner bottom. Even in these cases the core was only disturbed in the broken section and the recovery remained excellent.

Pressure testing the core barrel when the liner is split or cracked must become a standard ODP policy. Thicker liners have been suggested to reduce the liner failure problem, but they must be tried with care. A thicker liner will perhaps withstand higher stress, but once the split has generated the liner might be more damaged. The structural strength of the butyrate is not enough to stop a split once started. Making the APC barrel connections pressure tight with a compound is a solution which must be investigated.

## SHEAR PINS

At the first sites the shear pressure was inconsistent. As an example, at Hole 657A with two hard pins and one soft pin, the shearing pressure was between 1400 psi and 3200 psi. Later in the leg only two hard shear pins were used. With this disposition the shear pressure became more constant at around 2700 psi.

The problem may come from the shear pin steel quality. Outer and inner shear pin subs that do not fit together perfectly can also make the shear pressure inconsistent. Only good quality control can prevent it.

A system to control the shear pin quality is needed on shore. This system must be able to check a pin in a configuration close to the APC one. A systematic test of a pin for each one hundred built should be enough to check the good quality of the shear pins.

## SOFT FORMATION CORE CATCHER

Each time that two soft formation core catchers were used, rigged up with ten long fingers, the core barrel came back empty. The finger shape is such that the fingers are pushed back in their slots by the core and the spring is not strong enough to bring them back to the closed position.

The fingers must be designed so that the finger edge stays slightly in the core way and will be caught by the core on its way down. The fingers will be forced in the closed position by the core.

During Leg 108 a combination of a flapper type core catcher and a ten-finger combination-type core catcher was used (four long fingers and four short ones). But this solution is not always effective. In some sticky formations the flapper and the long fingers stayed glued to the core catcher and the four short fingers were not enough to catch the core.

The ten-finger core catcher is a useful link between the flapper and the 8-finger one. Its design must be modified as suggested.

## FREE-FALL RE-ENTRY CONE

The free-fall re-entry cone was successfully tested at Site 657. A full report can be found in the Operations report. Only some topics will be developed here.

The cone was very easy to handle. One and a half hours were enough to pick up the cone, make the mounting around the drill pipe, weld the two halves of the 13-3/8 inch casing and drop the cone. Of this one and a half hours, three quarters of an hour was spent in welding the two halves of the casing. This could be reduced by previously mounting on the casing some brackets for bolting together the two casing halves. But the brackets can be damaged during the setting up and may be not strong enough to hold the two casing halves during the fall with the expected heavy bounces on the drill string tool joints.

A pinger had been fastened to the cone to monitor the fall speed. Unfortunately, thruster noise prevented the pick up of the pinger signal and the cone speed is unknown. Two flotation balls were tied by seven foot long ropes to the cone edge, but no trace of the ball could be found on the bottom when viewing with the TV camera. It is believed that the balls, caught by the cone turbulence, made a turn around the pipes, breaking the rope at once. The cone design has been modified to increase by two feet the distance between the ball fastening point and the cone axis.

On the bottom the cone fit perfectly with the mud cone made by the drill pipes. A rough measurement of the mud cone gives an opening at the top equal to five feet. The free-fall cone width is six feet. To prevent having the cone disappear into the mud cone, the cone width will be increased by two feet.

The re-entry into the cone was slowed down by a "smoking bit." The mud coming out of the bit decreases visibility. But once the bit was clean, the re-entry was very easy. When the drillstring was pulled out of the hole, the cone did not move at all.

One remark is not related directly to the cone but to the TV system: it would be very advantageous to know the orientation of the TV camera relative to north when making a re-entry. The system used on Leg 106 (a magnetic compass suspended under the TV frame that is read by zooming the TV camera) is not easy to use. A digital compass reading on the TV screen would be much simpler and more useful.

The free-fall cone is certainly a very useful component. It will save time needed to redrill the hole in single-bit holes when the bit fails earlier than expected or when the formations are harder than expected. It can also take the place of some full-size re-entry cones where a casing string is unnecessary.

## SIDE ENTRY SUB

The side entry sub (or side door stuffing box) was tested at Site 667. A full report can be found in the Operations report. Only some topics will be developed here.

The test has shown that the side entry sub idea does work. It takes roughly one hour more to rig up the sub than in conventional logging. Three runs were performed with the side entry sub, but defective logging tools prevented any logging. With two extra sheaves, the two small sheaves in the side entry sub and the rubber packing around the logging cable, some extra drag was expected, but no extra drag was noticed. The logging cable ran smoothly through the side entry sub.

The test showed one flaw in the sub design: the cable clamp was not strong enough to hold the logging tool weight. This is certainly either a design or machining flaw, as this kind of clamp should be able to hold many tons.

The slot at the top of the side entry sub must be longer by one foot to help make the "torpedo" connection. It would be better if the "torpedo" connection could be changed to a plug-in type connection. The "torpedo" has never been easy to connect. Great care must be taken not to smash a cable or a boot when closing the two shells together. With the side entry sub, this connection must be done over the lower guide shoe.

The use of this sub, after some design modifications, must become standard procedure. Though more time is needed for the setup, the sub can save a lot of time if bridges prevent the logging tool from going to the bottom of the hole.

## EXTENDED CORE BARREL

### Vent Sub

During Leg 104B a prototype vent sub was successfully tested, showing that the pressure at the top of the core can be reduced by two thirds and core recovery may be increased. This prototype, with a larger Q/R nut to force the water in the vent sub, was tried during Leg 107 with very good core recovery as a result. There are some mechanical weak points, however.

A new design was made and tested during Leg 108. The main differences between the prototype and the new vent sub are in a thicker vent sub body just above the lower pin connection, a larger outside diameter in the upper part, and only two inside components (a venturi and a diverter) instead of three (see drawings OP5520, -22, -24, -26). When the first mounting was made with the new vent sub, two small design mistakes became evident. The diverter lower o-ring can be damaged by the outlet holes in the vent sub body and the diverter and body outlet holes are not aligned very well. But the new vent sub can still be used.

The XCB was used in six holes (Figure 7). Only the results from Holes 659A, 661A and 667A are of interest. Loose sands in Hole 657A, gas in Hole 658A and few cores in Hole 660A prevent any XCB comportment study in these holes.

During Hole 659A (9 XCB cores) the prototype vent sub and the new one were used in alternation, both with a 3/4" diameter venturi (Table 5). The new vent sub seems to give a much better result than the prototype one. The recovery is 75% with the new vent sub and only 26% with the prototype. But the prototype results are badly diminished by an empty barrel (the core catchers stayed glued in the open position) and by a new cutting shoe test.

During Hole 661A (17 XCB cores) the new vent sub was exclusively used for the first eight cores either with a 5/8" or 3/4" diameter venturi (Table 5). Then the old vent sub was used in alternation with a prototype or a new vent sub. The formations cored were a very sticky clay. Neither the prototype nor the new vent sub improved core recovery. A new phenomenon appears that reduces the core recovery: the vent sub plugging. Only on this site we noticed the vent sub plugging.

On the first XCB cores the vent sub was found very often plugged from the ball seat to the venturi. In two or three circumstances, a two foot long core piece was found sticking to the vent sub. In the core barrel a large void separated this piece from the rest of the core. One explanation may be a too strong vent effect. A piece of core is sucked by the vent sub and plugs it. The water in the core barrel below that core piece is trapped and the core cannot fill the core barrel any more, reducing the recovery. Once the vent sub plugged it has to be completely dismantled and cleaned. In the new vent sub the communication holes are too small (3/16"), easy to plug and hard to clean.

During Hole 667A (18 XCB cores) the prototype and the old vent sub were used in alternation (Table 6). The recovery was the same with both vent subs. When increasing the flow rate, we seemed to have a better recovery with the prototype vent sub.

One concern when designing the new vent sub was metal erosion in the diverter. The water at the venturi exit has a speed equal to or greater than 300 ft/sec (at 400 GPM and with a 3/4" venturi) and hits the diverter outlet holes with an angle equal to $45^{\circ}$. After a run, the diverter comes back very clean and well polished. So far there is no trace of erosion.

During this leg, no obvious significant difference was found between the old style vent sub and the new style or prototype one. Unlike the previous leg where the XCB recovery with the prototype vent sub was very good (nearly 100%), the XCB recovery was around 70% on this leg and did not improve with the new vent sub. To increase the XCB recovery, it is not enough to have a vent sub reducing the pressure at the top of the core. More work has to be done on the cutting shoe itself.

To prevent the vent sub plugging and to ease its cleaning, the diverter must be modified. The communication hole diameter between the ball area and the venturi, which is now equal to 3/16", must be increased. To prevent o-ring damage, the vent sub body and the diverter must be modified. More comparison tests between the old and the new vent sub must be done. The new vent sub, which is more expensive than the old one, has not yet proved to be much more effective.

### Cutting Shoe

The new cutting shoe design's main purpose is to increase the flow rate to the cutting shoe. A new bit with bit nozzles and a longer core guide were also designed for that purpose. Very often the cutting shoe comes back plugged and the Delrin bushing has been found to melt. We believe that these conditions are caused by not enough flow to the cutting shoe outlet holes.

A surface test of this new cutting shoe was done during the Marseille port call (see special report). This first sequence of tests was not detailed enough to fully understand the flow pattern in the XCB bit. More tests are necessary but already we can say that even with the new design, less flow than expected goes to the cutting shoe.

All in-hole tests were done with the old style XCB bit during leg 108. The new XCB bit is not compatible with the old style cutting shoe. As the core guide is longer in the new bit, the old cutting shoes are too short.

When the XCB is fully extended, the cutting shoe inlet holes are in front of the core guide, preventing any flow from going to the cutting shoe.

During the first sites, when most of the XCB coring was done during this leg, the formations were not very hard and usually very sticky. Very often the bit nozzles were plugged and all the flow had to go through the cutting shoe or through the annulus between the core guide and the cutting shoe. As a consequence, the cutting shoes were rarely plugged and at least one or two outlet holes were left open. The overheating of the bushing was never noticed.

The first test was done at Hole 657A in very sandy formations. Only some pieces of core were recovered in the core catcher (Table 7). The recovery from the previous core (657A-17) was not significant. The liner was found completely burst, indicating that the pipe had not been filled up before dropping the XCB.

When dismantling the cutting shoe after this test, two outlet holes were found plugged. On the isolation sleeve, the "aerocote" dark cover was eroded in front of the cutting shoe inlet holes. This was proof that a high flow rate flowed through the cutting shoe.

One explanation for the poor recovery was too many leaks at the core catchers or spacers junction. The water leaking through these junctions may have washed away the sandy formation.

The next test was done at Site 659A. The core catcher mounting had been modified by making the isolation sleeve longer, thus preventing too much water from leaking between the core catchers or spacers junctions. Once again the recovery was much smaller with the new cutting shoe (Table 7). The cored formations were a very sticky clay. The new cutting shoe was found completely plugged. But the added sleeve had slipped down, stopping the circulation to the cutting shoe. It was tied to the isolation sleeve by punched holes. It is not known when the sleeve slipped down but from the core aspect, it seems that only some core was recovered when no flow went to the cutting shoe.

At Holes 660A and 661A the cored formations were similar to the one cored at Hole 659A. After these two unsuccessful tests, no more tests were done until Hole 667A. The last test was done during Hole 667A in a rather hard formation. With parameters close to the ones used with the old cutting shoe, the recovery was much better with the new cutting shoe. The new cutting shoe was used with no extra sleeve, as on the original design.

Once again the cutting shoe was found completely plugged. Sediment was found up to the inlet holes. It seems that the formation came through the junctions between core catchers and spacers. It is impossible to know when the circulation was stopped to the cutting shoe outlet holes. If the plugging was progressive, we can think that nearly always some water was flowing through the spacers or core catchers junctions, lubricating the core.

The three new cutting shoe tests were not very successful. The main conclusion from these tests is that the flow rate to the cutting shoe must be adjusted as a function of the cored formation. With the flow restriction ring, such an adjustment can be achieved. But the leaks towards the core must be completely eliminated, except in some formations where lubricating the core can help.

After the necessary design modifications, the new cutting shoe must be tested at an onshore test facility and the results compared with the current cutting shoe. Such tests could be performed at the ODP test facility. A low pressure, high flow rate pump will be necessary.

## APPENDIX II. SUMMARY DIAGRAMS

Leg 108 had a duration of 58.0 days. The break-down of cruising, in-port and on-site time is shown in Figures 8 and 9 (also in Tables 1 and 2).

## TABLE AND FIGURE CAPTIONS

Table 1. Summary information of holes cored during Leg 108.

Table 2. Time and recovery summary.

Table 3. Summary of beacons used during Leg 108.

Table 4. Summary of drilling bits used during Leg 108.

Table 5. Extended core barrel (XCB) vent sub comparison at Holes 659A and 661A.

Table 6. XCB vent sub comparison at Hole 667A.

Table 7. XCB new cutting shoe test results.

Figure 1. Geographic location of Leg 108 sites.

Figure 2. Comparison of cored length vs. recovered length for each site.

Figure 3. Comparison of the APC performance at each site.

Figure 4. Diagram showing free-fall re-entry cone as viewed through television camera at Hole 658A.

Figure 5. Advanced pressure core barrel (APC) split liner rate *versus* site numbers.

Figure 6. APC liner performance on Leg 108.

Figure 7. XCB performance on Leg 108.

Figure 8. Summary diagram showing time usage during Leg 108.

Figure 9. Summary diagram showing Leg 108 time usage while on site.

## TABLE 1

### OCEAN DRILLING PROGRAM
### SITE SUMMARY
### LEG 108

| HOLE | LATITUDE | LONGITUDE | DEPTH METERS | NUMBER OF CORES | METERS CORED | METERS RECOVERED | PERCENT RECOVERED | METERS DRILLED | TOTAL PENET. | TIME ON HOLE | TIME ON SITE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 657A | 19 89N | 20 56.93W | 4231.6 | 19 | 178.2 | 126.9 | 71.1 | | 178.2 | 46.25 | |
| 657B | 19 89N | 20 56.93W | 4231.6 | 19 | 166.1 | 133.4 | 80.3 | | 166.1 | 39.00 | 85.25 |
| 658A | 20 44.95N | 18 34.85W | 2270.7 | 33 | 300.4 | 294.9 | 98.3 | | 300 | 73.25 | |
| 658B | 20 44.95N | 18 34.85W | 2274.7 | 18 | 163.8 | 176.1 | 100.7 | | 163.8 | 22.25 | |
| 658C | 20 44.95N | 18 34.85W | 2270.3 | 8 | 72.9 | 70.3 | 96.4 | | 72.9 | 13.50 | 109 |
| 659A | 18 04.63N | 21 01.57W | 3081.7 | 29 | 273.8 | 174.5 | 63.7 | | 273.8 | 43.50 | |
| 659B | 18 04.63N | 21 01.57W | 3083.9 | 22 | 202.1 | 163.9 | 81 | | 202.1 | 29.25 | |
| 659C | 18 04.63N | 21 01.57W | 3081 | 8 | 76.0 | 72.4 | 95.3 | 120 | 196 | 19.25 | 92.00 |
| 660A | 10 00.809N | 19 14.738W | 4342.8 | 19 | 164.9 | 163.9 | 99.3 | | 164.9 | 34.00 | |
| 660B | 10 00.809N | 19 14.738W | 4342.8 | 16 | 148.8 | 143.9 | 96.6 | | 143.8 | 25.75 | 59.75 |
| 661A | 9 26.810N | 19 23.166W | 4023.2 | 32 | 296.1 | 235.1 | 79.3 | | 296.1 | 71.75 | |
| 661B | 9 26.810N | 19 23.166W | 4023.2 | 9 | 81.7 | 81.4 | 99.6 | | 81.7 | 16.50 | 88.25 |
| 662A | 1 23.41S | 11 44.35W | 3824.3 | 22 | 200.0 | 204.1 | 102 | | 200 | 29.50 | |
| 662B | 1 23.41S | 11 44.35W | 3824.3 | 12 | 114.0 | 114.6 | 100.6 | 74 | 188.2 | 27.75 | 57.25 |
| 663A | 1 11.87S | 11 52.71W | 3708.1 | 16 | 147.2 | 119 | 80.8 | | 147.2 | 20.75 | |
| 663B | 1 11.87S | 11 52.71W | 3708 | 16 | 152.0 | 153.5 | 101 | | 152.0 | 20.00 | 40.75 |
| 664A | 0 06.44N | 23 13.65W | 3836 | 1 | 9.5 | 9.6 | 101.5 | | 9.5 | 8.00 | |
| 664B | 0 06.44N | 23 13.65W | 3816.8 | 26 | 247.0 | 244.9 | 99.1 | | 247.0 | 25.00 | |
| 664C | 0 06.44N | 23 13.65W | 3817.3 | 7 | 61.2 | 57.1* | 93.3 | | 61.2 | 7.50 | |
| 664D | 0 06.44N | 23 13.65W | 3812.2 | 32 | 296.8 | 302.8 | 102 | | 296.8 | 29.00 | 69.50 |
| 665A | 2 57.07N | 19 40.07W | 4750 | 11 | 97.9 | 99.9 | 102.1 | | 97.9 | 22.00 | |
| 665B | 2 57.07N | 19 40.07W | 4752 | 9 | 82.0 | 72.4 | 88.3 | | 82.0 | 46.50 | 68.50 |
| 666A | 3 29.84N | 20 10.03W | 4527.3 | 16 | 150.5 | 150.4 | 100 | | 150.5 | 37.50 | 37.50 |
| 667A | 4 34.15N | 21 54.68W | 3535.2 | 41 | 381.3 | 309.2 | 81 | | 381.3 | 93.00 | |
| 667B | 4 34.15N | 21 54.68W | 3535.2 | 15 | 139.1 | 128.5 | 92.4 | | 139.1 | 21.50 | 114.50 |
| 668A | 4 46.14N | 20 55.52W | 2700.5 | 1 | 8.8 | 8.8 | 100.0 | | 8.8 | 22.50 | |
| 668A | 4 46.14N | 20 55.52W | 2703.6 | 4 | 31.2 | 31.3 | 100.0 | | 31.3 | | |
| TOTALS | | | | 161 | 4243.7 | 3842.8 | 90.5 | 194 | 4437 | | 858 |

## TABLE 2

### OCEAN DRILLING PROGRAM
### TIME AND RECOVERY SUMMARY
### LEG 108

| | | |
|---|---|---|
| TOTAL DAYS (18 FEBRUARY 1986 - 17 APRIL 1986) | | 58 |
| TOTAL DAYS IN PORT | | 3.47 |
| TOTAL DAYS CRUISING INCLUDING SITE SURVEY | | 18.8 |
| TOTAL DAYS ON SITE | | 35.73 |
| TRIP TIME | 8.21 | |
| DRILLING TIME | 0.32 | |
| CORING TIME | 23.33 | |
| LOGGING TIME | 2.00 | |
| REPAIR TIME | 0.04 | |
| OTHER | 1.83 | |
| TOTAL DISTANCE TRAVELED INCLUDING SURVEY(n. mi) | | 5607 |
| AVERAGE SPEED (kt) | | 12.7 |
| NUMBER OF SITES | | 12 |
| NUMBER OF HOLES | | 27 |
| NUMBER OF CORES | | 461 |
| TOTAL METERS CORED | | 4242.7 |
| TOTAL METERS RECOVERED | | 3842.8 |
| PERCENT RECOVERED | | 90.5 |
| TOTAL METERS DRILLED | | 194 |
| TOTAL METERS OF PENETRATION | | 4437 |
| MAXIMUM PENETRATION (m) | | 381.0 |
| MINIMUM PENETRATION (m) | | 8.8 |
| MAXIMUM WATER DEPTH (m) | | 4750 |
| MINIMUM WATER DEPTH (m) | | 2270 |
| AVERAGE WATER DEPTH (m) | | 3734 |

## TABLE 3

### OCEAN DRILLING PROGRAM
### BEACON SUMMARY
### LEG 108

| SITE NO. | MAKE | FREQ. KHz | SERIAL NUMBER | SITE TIME HOURS | REMARKS |
|---|---|---|---|---|---|
| 657 | DATASONICS | 15.5 | 196 | 85.2 | Good, Dropped 2/27/86 |
| 658 | DATASONICS | 14.5 | 242 | 6.0 | Good, Dropped 3/4/86 |
| 658 | DATASONICS | 15.5 | 243 | 109.0 | Good, Dropped 3/4/86 |
| 659 | DATASONICS | 16.5 | 244 | 92.5 | Good, Dropped 3/9/86 |
| 660 | DATASONICS | 14.5 | 245 | 59.0 | Good, Dropped 3/15/86 |
| 661 | DATASONICS | 15.5 | 193 | 88.2 | Good, Dropped 3/17/86 |
| 662 | DATASONICS | 16.5 | 200 | 57.2 | Good, Dropped 3/24/86 |
| 663 | DATASONICS | 14.5 | 233 | 40.7 | Good, Dropped 3/26/86 |
| 664 | DATASONICS | 14.5 | 239 | 75.7 | Good, Dropped 3/30/86 |
| 665 | DATASONICS | 15.5 | 246 | 68.5 | Good, Dropped 4/3/86 |
| 666 | DATASONICS | 16.5 | 247 | 37.5 | Good, Dropped 4/6/86 |
| 667 | DATASONICS | 16.5 | 241 | 114.5 | Good, Dropped 4/8/86 |
| 668 | DATASONICS | 15.5 | 240 | 35.7 | Good, Dropped 4/13/86 |

## TABLE 4

### OCEAN DRILLING PROGRAM
### BIT SUMMARY
### LEG 108

| HOLE | MFG | SIZE | TYPE | SERIAL NUMBER | METERS CORED | METERS DRILLED | TOTAL PENET | CUMULATIVE METERS | HOURS THIS HOLE | TOTAL HOURS | CONDITION | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 657A | RBI | 11-7/16 | C4-RR | AS813 | 178.0 | | 178.0 | 294 | 3.50 | 26.0 | | 22-1/2 HRS ON LEG 107 |
| 657B | RBI | 11-7/16 | C4-RR | AS813 | 166.0 | | 166.0 | 960 | 2.25 | 28.5 | T1,B2 G | AS NEW |
| 658A | RBI | 11-7/16 | C4-RR | AS813 | 300.0 | | 300.0 | 1260 | 9.50 | 38 | | |
| 658B | RBI | 11-7/16 | C4-RR | AS813 | 163.8 | | 163.0 | 1423 | 2.00 | 40 | | |
| 658C | RBI | 11-7/16 | C4-RR | AS813 | 72.9 | | 72.9 | 1499 | 1.00 | 41 | T1,B2 G | |
| 659A | RBI | 11-7/16 | C4-RR | AS813 | 273.8 | | 273.9 | 1769+ | 4.75 | 45.5 | T1,B2 G | |
| 659B | RBI | 11-7/16 | C4-RR | AS813 | 202.1 | | | | 5.0 | 50.5 | | |
| 659C | RBI | 11-7/16 | C4-RR | AS813 | 76.0 | 120 | 202.0 | 1965+ | 3.00 | 53.5 | T1,B2 G | |
| 660A | RBI | 11-7/16 | C4-RR | AS813 | 164.9 | | 164.9 | 2130 | 1.75 | 55.25 | | |
| 660B | RBI | 11-7/16 | C4-RR | AS813 | 148.8 | | 148.8 | 2279+ | 1.00 | 56.25 | T1,B2 G | |
| 661A | RBI | 11-7/16 | C4-RR | AS813 | 296.1 | | 296.1 | 2570 | 9.50 | 67.75 | | |
| 661B | RBI | 11-7/16 | C4-RR | AS813 | 81.7 | | 81.7 | 2651.7 | 2.50 | 70.25 | | |
| 662A | RBI | 11-7/16 | C4-RR | AS813 | 200.0 | | 200 | 2851.7 | 1.0 | 71.25 | T2-B2 IG | |
| 662B | RBI | 11-7/16 | C4-RR | AS813 | 114.0 | 74 | 188 | 3039.7 | | 71.25 | | |
| 663A | RBI | 11-7/16 | C4-RR | AS813 | 147.2 | | 147.2 | 3186.9 | .75 | 71.75 | | |
| 663B | RBI | 11-7/16 | C4-RR | AS813 | 152.0 | | 152.0 | 3338.9 | .75 | 72.50 | | |
| 664A | RBI | 11-7/16 | C4-RR | AS813 | 9.5 | | 9.5 | 3348.4 | —— | 72.50 | | |
| 664B | RBI | 11-7/16 | C4-RR | AS813 | 247.0 | | 247.0 | 3595.4 | 1.25 | 73.75 | | |
| 664C | RBI | 11-7/16 | C4-RR | AS813 | 61.2 | | 61.2 | 3656.4 | —— | 73.75 | | |
| 664D | RBI | 11-7/16 | C4-RR | AS813 | 296.8 | | 296.8 | 3953.2 | 1.0 | 74.75 | | |
| 665A | RBI | 11-7/16 | C4-RR | AS813 | 97.9 | | 97.9 | 4051.1 | | 74.75 | | |
| 665B | RBI | 11-7/16 | C4-RR | AS813 | 82.0 | | 82.0 | 4133.1 | | 74.75 | | |
| 666 | RBI | 11-7/16 | C4-RR | AS813 | 150.5 | | 150.5 | 4283.6 | | 74.75 | | |
| 667A | RBI | 11-7/16 | C4-RR | AS813 | 381.3 | | 381.3 | 4664.9 | 7.5 | 82.25 | | |
| 667B | RBI | 11-7/16 | C4-RR | AS813 | 139.1 | | 139.1 | 4804.0 | | | | |
| 668A | RBI | 11-7/16 | C4-RR | AS813 | 8.8 | | 8.8 | 4812.8 | | 82.25 | | |
| 668B | RBI | 11-7/16 | C4-RR | AS813 | 31.2 | | 31.3 | 4844.0 | | 82.25 | T2-B2 IG | |

## TABLE 5

### LEG 108 HOLE 659 A

| CORE # | VENTSUB TYPE | PLUGGED | RECOVERY | SPM | REMARKS |
|---|---|---|---|---|---|
| 21 | NVS 3/4 | N | 4.5 | 45 | |
| 22 | PVS 3/4 | N | 6.7 | 50 | |
| 23 | NVS 3/4 | N | 8.4 | 50 | |
| 24 | PVS 3/4 | N | 2.7 | 50 | NEW CUTTING SHOE |
| 25 | NVS 3/4 | N | 7.8 | 50 | |
| 26 | PVS 3/4 | N | 0 | 50 | CORE CATCHER FAILURE |
| 27 | NVS 3/4 | N | 9.7 | 50 | |
| 28 | PVS 3/4 | N | 0.5 | 50 | |
| 29 | NVS 3/4 | N | 1.3 | 55 | |

### LEG 108 HOLE 661 A

| CORE # | VENT SUB TYPE | PLUGGED | RECOVERY | SPM | REMARKS |
|---|---|---|---|---|---|
| 16 | NVS 5/8 | ? | 9.7 | 40 | |
| 17 | NVS 3/4 | Y | 1.9 | 40 | |
| 18 | NVS 5/8 | Y | 3.0 | 43 | |
| 19 | NVS 3/4 | PARTLY | 9.5 | 43 | 4 METERS VOID |
| 20 | NVS 5/8 | Y | 9.7 | 44 | 2 METERS VOID |
| 21 | ? | ? | 3.5 | 60 | |
| 22 | ? | ? | 2.3 | 60 | |
| 23 | ? | ? | 5.6 | 70 | |
| 24 | OVS | N | 9.1 | 70 | |
| 25 | PVS 1 | N | 8.3 | 70 | |
| 26 | OVS | N | 8.5 | 70 | |
| 27 | NVS 3/4 | N | 3.1 | 70 | |
| 28 | OVS | N | 8.5 | 66 | |
| 29 | PVS 1 | N | 5.9 | 66 | |
| 30 | OVS | N | 3.2 | 66 | |
| 31 | NVS 3/4 | N | 5.7 | 65 | |
| 32 | OVS | N | 8.0 | 70 | |

NVS : NEW OR FINAL VENT SUB
PVS : PROTOTYPE VENT SUB
OVS : OLD OR CURRENT VENT SUB

5/8,3/4,1 ARE THE VENTURI DIAMETER (INCHES)

PUMP LINER SIZE 6 1/2 INCHES

## TABLE 6

### LEG 108 HOLE 667 A

| CORE # | VENTSUB | TYPE | PLUGGED | RECOVERY | SPM | REMARKS |
|---|---|---|---|---|---|---|
| 24 | PVS | 3/4 | N | 4.7 | 40 | |
| 25 | OVS | | N | 5.4 | 25 | |
| 26 | PVS | 3/4 | N | 4.7 | 30 | |
| 27 | OVS | | N | 6.0 | 32 | |
| 28 | PVS | 3/4 | N | 4.8 | 30 | |
| 29 | OVS | | N | 9.2 | 30 | |
| 30 | PVS | 3/4 | N | 8.0 | 30 | |
| 31 | OVS | | N | 5.4 | 32 | |
| 32 | PVS | 3/4 | N | 8.6 | 40 | |
| 33 | OVS | | N | 6.0 | 60 | |
| 34 | PVS | 3/4 | N | 6.9 | 55 | |
| 35 | OVS | | N | 6.0 | 55 | |
| 36 | PVS | 3/4 | N | 5.6 | 60 | |
| 37 | PVS | 3/4 | N | 7.9 | 52 | AFTER INTERRUPT. OF 24 H |
| 38 | OVS | | N | 6.7 | 55 | |
| 39 | PVS | 3/4 | N | 4.3 | 60 | |
| 40 | OVS | | N | 8.8 | 55 | NEW CUTTING SHOE TEST |
| 41 | PVS | 3/4 | N | 4.7 | 60 | |

## TABLE 7

### NEW CUTTING SHOE TEST

| SITE | CORE | RECOVERY | % | SPM | PRES | RPM | WOB | REMARK |
|---|---|---|---|---|---|---|---|---|
| 657A | 17X | 0.70 | 7.4 | 15 | 250 | 60 | 6 | BURST LINER |
| | 18X | 0.04 | 0.4 | 30 | 450 | 60 | 6 | NEW CUTTING SHOE TEST |
| | 19X | 4.1 | 43.2 | 15 | 250 | 60 | 6 | |
| 659A | 23X | 8.41 | 88.5 | 50 | 900 | 55 | 15 | |
| | 24X | 2.68 | 28.2 | 50 | 900 | 55 | 15 | NEW CUTTING SHOE TEST |
| | 25X | 7.35 | 77.4 | 45 | 800 | 55 | 15 | |
| 667A | 39X | 4.28 | 45.1 | 60 | 1100 | 65 | 10/15 | |
| | 40X | 8.83 | 92.9 | 55 | 950 | 65 | 12/15 | NEW CUTTING SHOE TEST |
| | 41X | 4.69 | 49.4 | 55 | 950 | 65 | 12/15 | |

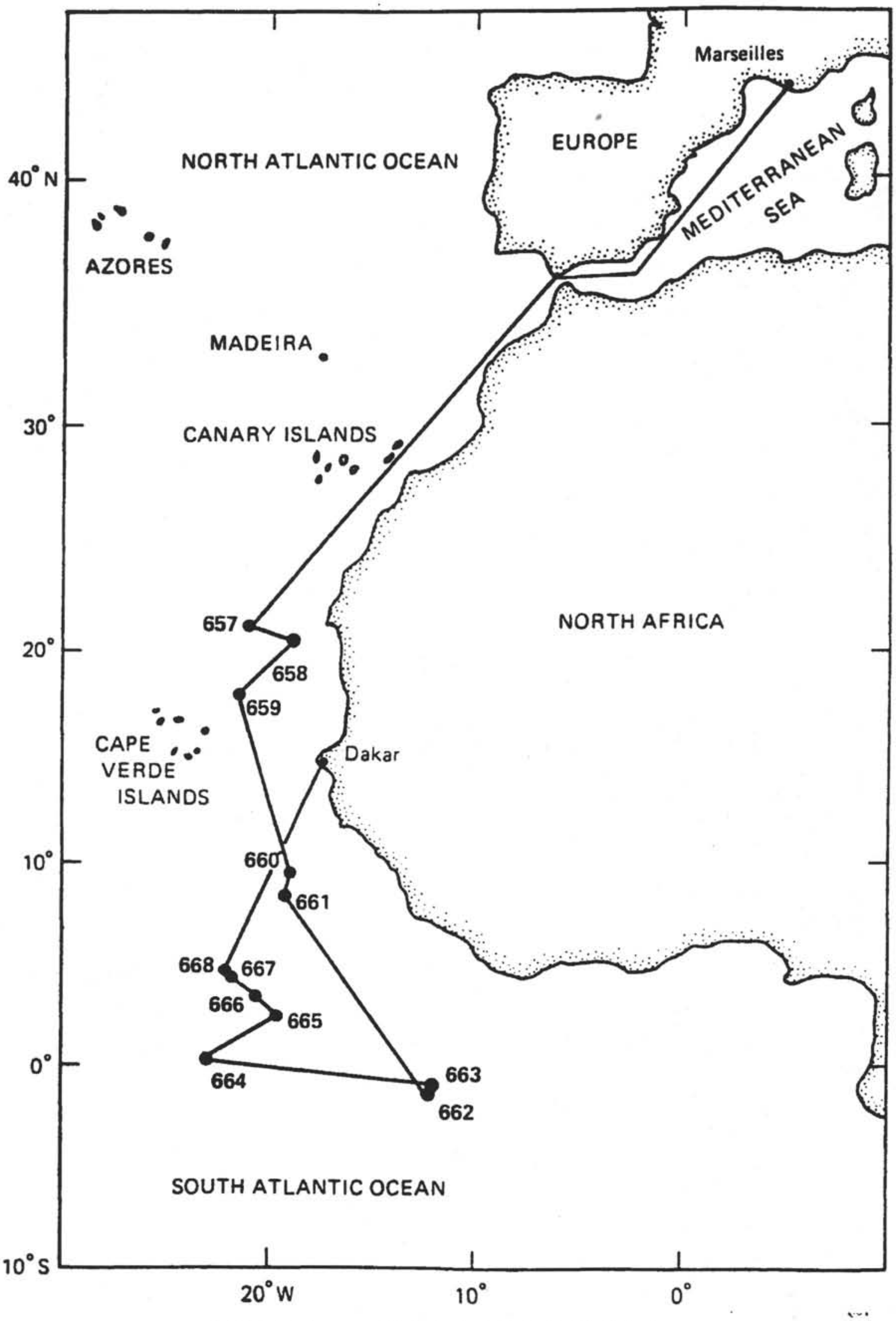
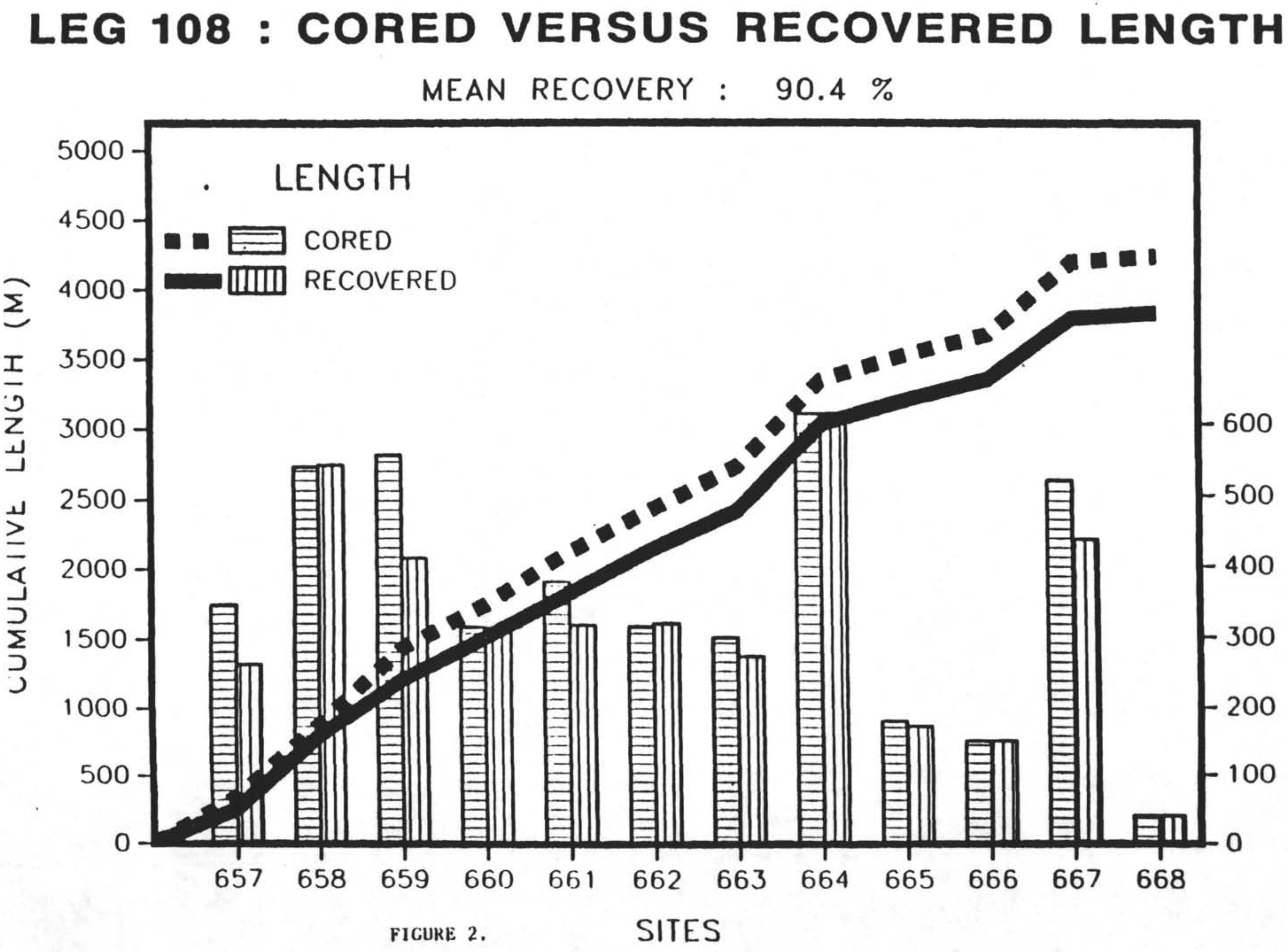


FIGURE 1 LEG 108 OPERATING AREA



LEG 108 : CORED VERSUS RECOVERED LENGTH

MEAN RECOVERY : 90.4 %

FIGURE 2.

# LEG 108 : APC PERFORMANCE

MEAN RECOVERY : 94.2 %

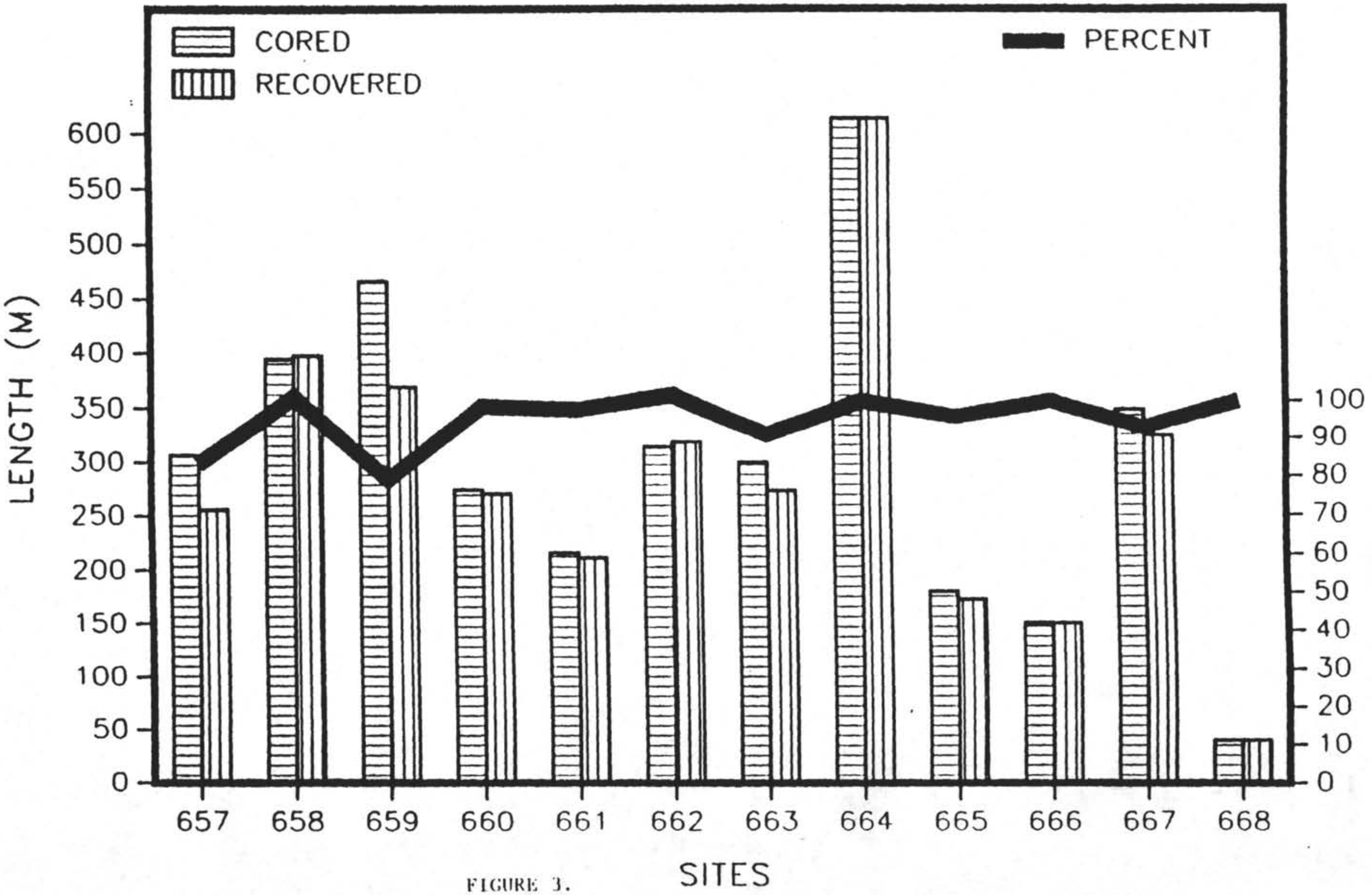
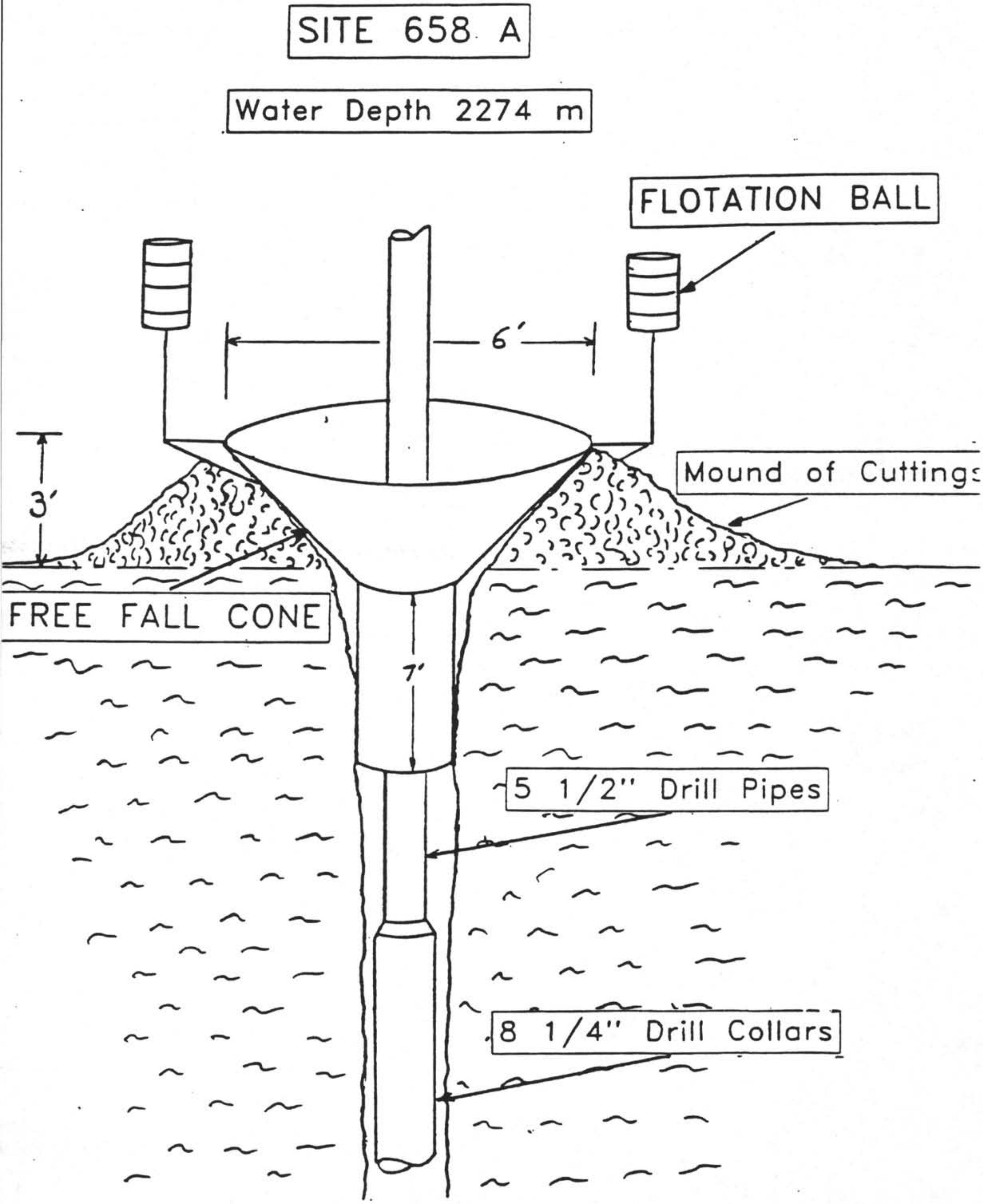
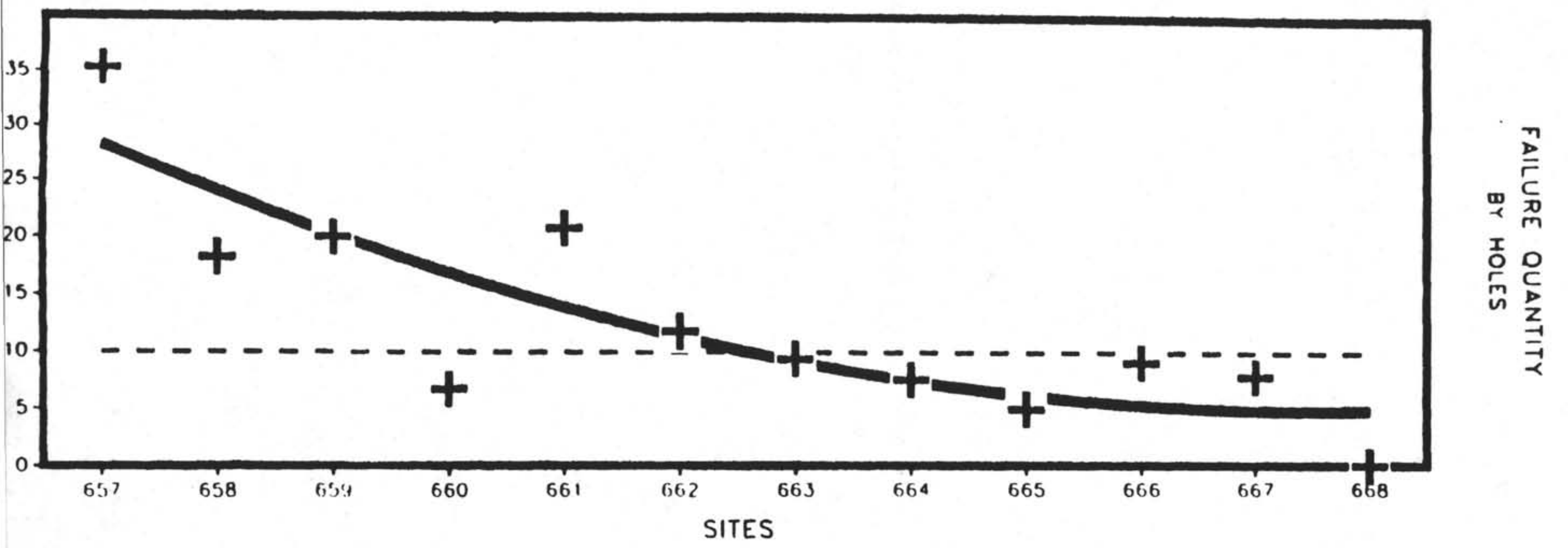


FIGURE 3.


SITE 658 A
Water Depth 2274 m
FLOTATION BALL
6′
3′
Mound of Cuttings
FREE FALL CONE
7′
5 1/2" Drill Pipes
8 1/4" Drill Collars

## LEG 108 : APC SPLIT LINERS



## LEG 108 : APC COLLAPSED LINERS

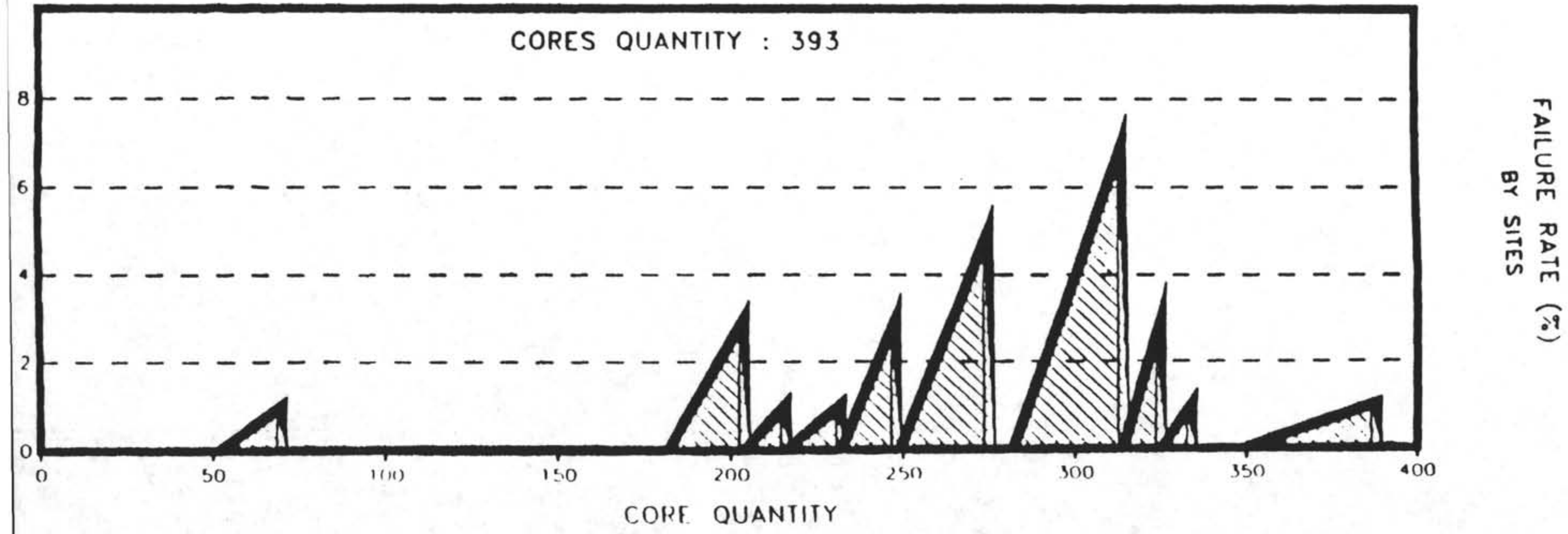


FIGURE 5.

# APC LINERS PERFORMANCE

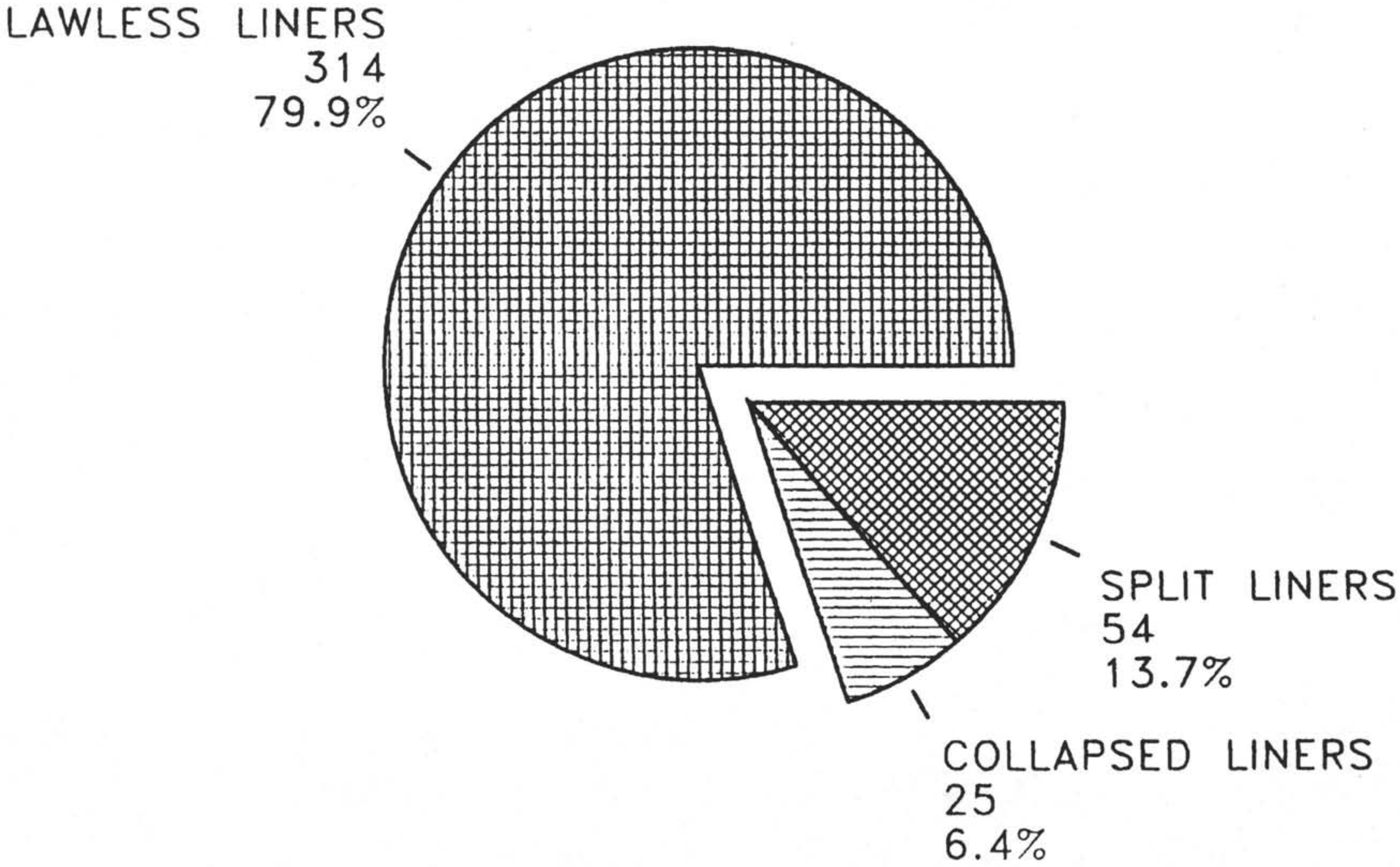


FIGURE 6.

# LEG 108 : XCB PERFORMANCE

MEAN RECOVERY : 69.7 %

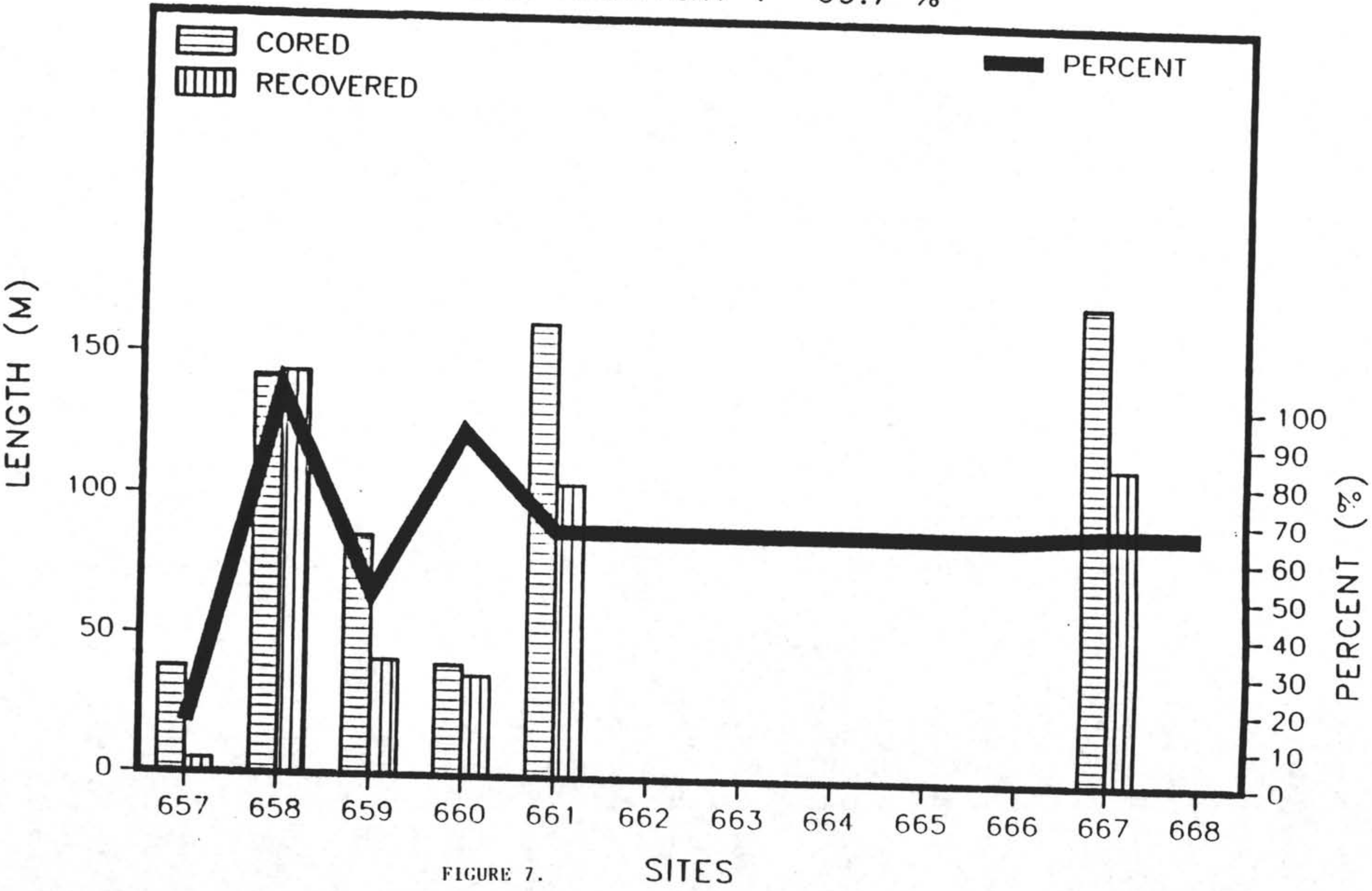


FIGURE 7.

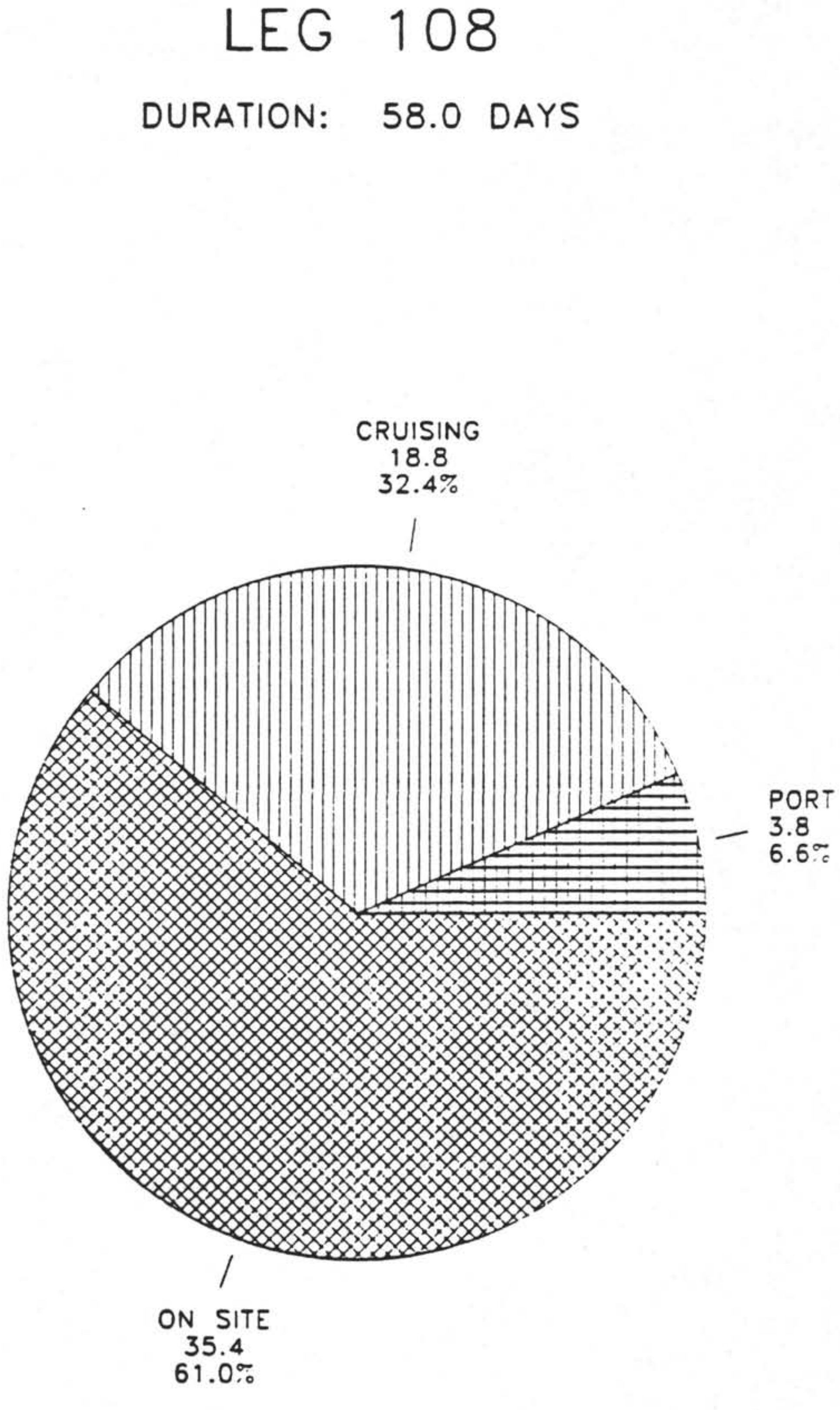

LEG 108
DURATION: 58.0 DAYS
CRUISING
18.8
32.4%
PORT
3.8
6.6%
ON SITE
35.4
61.0%

FIGURE 8.

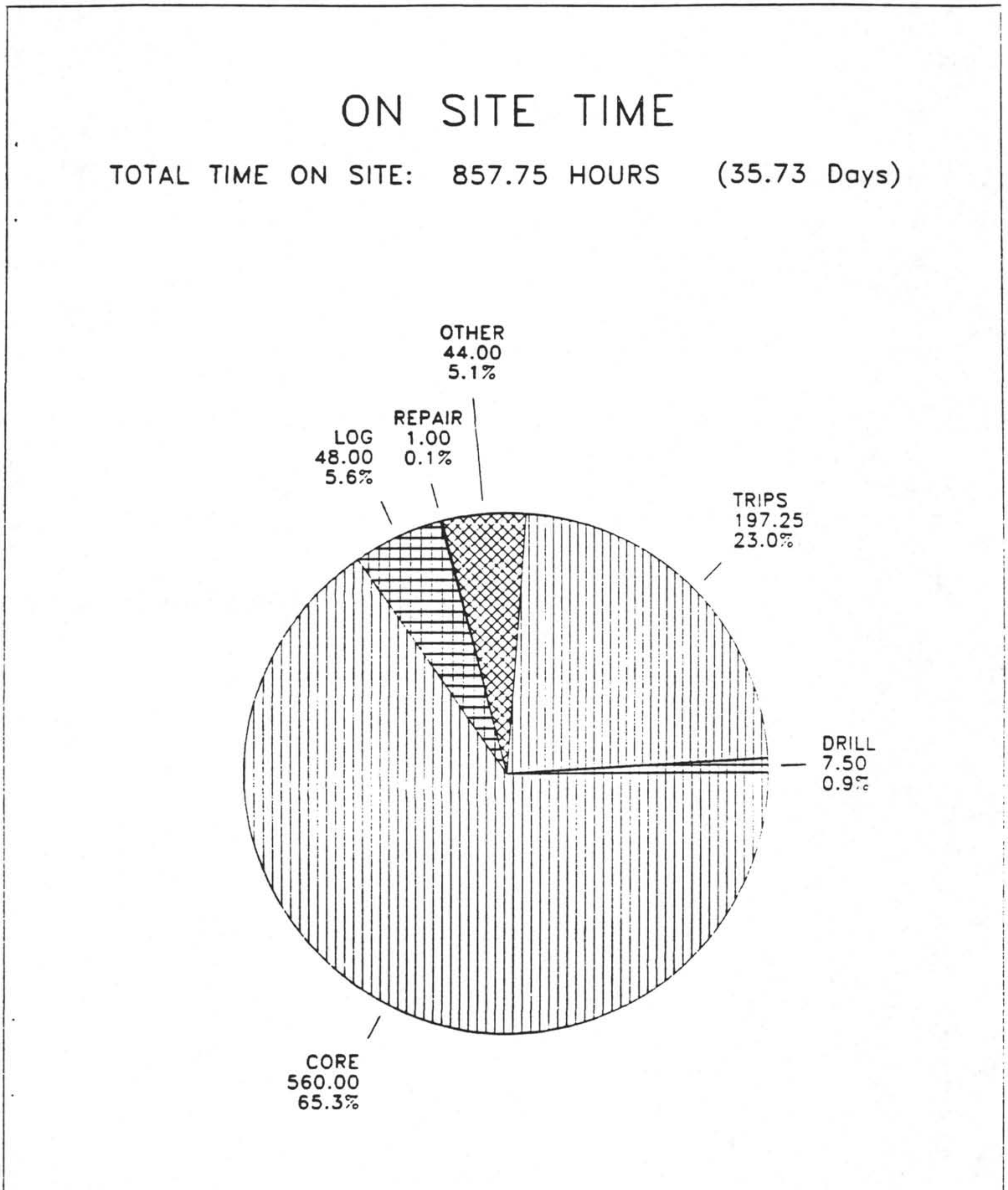

ON SITE TIME
TOTAL TIME ON SITE: 857.75 HOURS (35.73 Days)
OTHER
44.00
5.1%
REPAIR
1.00
0.1%
LOG
48.00
5.6%
TRIPS
197.25
23.0%
DRILL
7.50
0.9%
CORE
560.00
65.3%

Figure 9.

# TECHNICAL REPORT

**The ODP Technical and Logistics personnel aboard JOIDES Resolution for Leg 108 of the Ocean Drilling Program were:**

| | |
|---|---|
| **Laboratory Officer:** | **Burney Hamlin** |
| **Computer System Manager:** | **Daniel Bontempo** |
| **Curatorial Representative:** | **Chris Mato** |
| **Assistant Curatorial Representative:** | **Patsy Brown** |
| **Yeoperson:** | **Michiko Hitchcox** |
| Photographer: | Kevin DeMauret |
| Electronics Technician: | Daniel Larson |
| Electronics Technician: | Mike Reitmeyer |
| Chemistry Technician: | Matt Mefferd |
| Chemistry Technician: | Katie Sigler |
| Marine Technician: | Mark Dobday |
| Marine Technician: | Jenny Glasser |
| Marine Technician: | Peggy Myre |
| Marine Technician: | Joe Powers |
| Marine Technician: | Kevin Rogers |
| Marine Technician: | Christian Segade |
| Marine Technician: | Don Sims |
| **Marine Technician:** | **John Tauxe** |

## INTRODUCTION

<u>JOIDES Resolution</u> sailed from Marseille, France on February 21, 1986, to begin Leg 108 operations. During the 35.7 days of drilling, over 3800 meters of sediment was cored from 27 holes. More than 14,000 samples were taken to support the scientific objectives of the cruise. Despite the intense and prolonged effort needed to achieve these records, the technical personnel and equipment performed well throughout the cruise.

## PORTCALL

The four day portcall commenced in Marseille on the morning of February 18, 1986. Crossover proceeded on February 18 and 19, and included reviews of instrument performance and maintenance, and cross-training. A specialist from Woods Hole Oceanographic Institution trained physical properties technicians from both teams to use the new heat flow software.

Several pieces of lab equipment were serviced in port. The x-ray fluorescence unit was returned to good operating condition after an ARL representative swapped some connectors, changed a pulse height discriminator board, and installed an updated version of the software. With newly arrived spare parts, the chemistry technicians repaired the Rock-Eval pyrolysis unit. They also installed the Coulometrics Total Carbon Apparatus. The cryogenic magnetometer was topped off with liquid helium, and some changes in plumbing were made.

Oncoming freight arrived in a timely sequence, allowing efficient resupply of consumables. Over 400 boxes of D-tubes accounted for the bulk of the onloaded supplies. Technicians offloaded materials from Leg 107, including all cores, frozen samples, freight and operations equipment.

During the portcall, technical personnel assisted in public tours of the ship, and attended a reception hosted by the French agencies IFREMER and CNRS. The party was enjoyed by all, and gave the technicians an opportunity to meet several of the scientists who have participated in guiding and funding the Ocean Drilling Program.

The ship sailed on the evening of February 21, 1986. Ship clocks were changed to GMT and underway activities for Leg 108 began.

## LABORATORY OPERATIONS

### Underway Geophysics

For navigation, dependence on the GPS system was especially high, due to the infrequency of reliable fixes from transit satellites in equatorial regions. Navigation information was collected on magnetic tape from port, through all sites, and on the way to Dakar. In addition, continuous GPS/SAT hard copies were generated. Seismic gear, consisting of a pair of 80 cu in water guns, a single channel hydrophone array, and a magnetometer sensor, were deployed for the survey of all sites. Approximately 300 nm of seismic records were collected at survey speeds of 5-6 kt. The surveys made at 5.5 kt, generally of high quality, were the key to selecting drill sites throughout the cruise.

To facilitate comparisons with digital seismic data from other sources, some of the records were reprocessed at sea. The geophysics technician, busy processing core while on site, was able to do this only while under way. However, our dual Masscomp computers are not complete enough to record navigation header tapes on one unit while reprocessing data on the other. Additional hardware to complete the Masscomp system may be necessary, if reprocessing data is to be done at sea.

Tests with the magnetometer sensor indicated, as on previous cruises, that selection of the unit not adjacent to the hydrophone array produces the quietest records.

In the absence of a weather observer on Leg 108, expendable bathythermographs (XBTs) were made prior to departing each site.

## Physical Properties

A prototype P-wave logger (primary/compressional sound velocity device) was added to the instruments measuring whole core properties. The assembly was mounted just ahead of the source on the G.R.A.P.E. (Gamma Ray Attenuation and Porosity Evaluator). The P-wave logger allows continuous measurement of sound velocity through the sediment in the liner. Variations in core liner diameter were also measured and included in the velocity records. Data output was generated in the form of real time continuous x-y plots of the entire core. The data from Leg 108 will be processed in England, and returned to ODP.

The performance of the P-wave logger was exemplary. An agreement was made to purchase the complete P-wave logger package. The software and operating system utilized on the cruise was left on board for future cruises. This allows us to use the instrument while software and hardware that integrate the device into the shipboard computer system are developed. The equipment made available to us includes a BBC computer, a second processor, a Microvitec monitor, a dual disc drive, an EPSON plotter and printer, and a spare dual disc drive.

The P-wave logger proved fairly easy to operate, introducing little extra handling of the core. The instrument did require considerable bench space, however, to accommodate the 220-volt computer system, including monitor, peripherals and converters. Core processing was delayed for four hours while the cores approached temperature equilibrium; they were sprayed with water before being run through the P-wave logger.

This instrument will be used primarily on the uppermost hundred meters of APC holes, where core liners are full. The Hamilton frame will still be used for discrete samples, but may be improved by incorporating a refinement demonstrated in the P-wave logger circuitry. In the latter, arrival of a wave triggers the timing circuits at selected sine wave nulls rather than at a threshold level that intersects the amplitude-dependent sine slope. This different approach may improve the accuracy of discrete velocity measurements by 10 to 20 m/second depending on the cored material.

Physical properties scientists preferred the format of the P-wave logs, plotting continuously through entire core, over the G.R.A.P.E. outputs which cover only individual sections. With considerable editing of G.R.A.P.E. data a computer program was implemented for the latter, generating an x-y plot similar in scale and format to that of the P-wave logger. This satisfied the needs of the physical properties scientists who wished to correlate the two sources of data.

Exceptional data were also collected from the magnetic susceptibility meter. This three-meter long unit was set on the counter between the mini drill press and the parallel bladed sample saw, reducing workspace for the curatorial technician. The close sampling increment desired during Leg 108 required manual advance of samples through the coils, a very time consuming, monotonous task. Automation of data collection should be a priority if future legs require the same sample increment. The magnetic susceptibility meter, like the P-wave logger, was developed primarily for analysis of APC cores. Combination of both instruments into one tool is being considered.

Heat flow and thermal conductivity measurements were made at several sites during the cruise. The multishot tool was used for core orientation at the last few sites.

## Curatorial Lab

Both curatorial representatives were involved in sampling and sample tracking, as well as refining SAM, the sampling computer program. SAM, complete with label making capabilities, was installed in the Chemistry lab. In addition, the curatorial representatives wrote and enhanced programs for SAM editing, data processing, and report writing. This will enable future curatorial representatives to edit data entries and generate their own reports.

Coring a 'C' hole at two sites was intended to provide core material for special studies. Material recovered from Hole 658C was dedicated for organic geochemistry studies. Over 150 organic geochemistry samples (fifty centimeters each) were frozen on board, and will be shipped to Texas A&M University from Barbados. Hole 668C was planned for core geriatrics studies, supervised by Russ Merrill at ODP. A sampling program and pH meter were prepared for the project. Due to a medical evacuation, however, coring at Site 668 was abbreviated and the project was not started. It will be attempted on a future cruise.

## Chemistry Lab

Work in the Chemistry lab was dominated by carbonate analyses, with over 1100 samples analyzed for inorganic carbon concentration. The Coulometrics Carbonate Carbon Apparatus performed very well, despite the high volume of samples. Total carbon measurements were made primarily on the CHN elemental analyzer, with organic carbon values determined by difference. The newly installed Coulometrics Total Carbon Apparatus was also tested, yielding total carbon values in good agreement with results from the CHN. However, use of the Coulometrics apparatus for carbon measurements was limited by the single coulometer cell, which was usually being used for carbonate analysis. Heavier use of the Total Carbon Apparatus will require a second coulometer cell.

Over 500 samples were analyzed for organic maturity on the Rock-Eval pyrolysis unit. Natural gas was analyzed at one site where high levels of methane were encountered.

### XRF/D Lab

During the portcall in Marseille, a representative from ARL restored the detector signals. He re-configured the pulse height discriminator board, and swapped two goniometer cables. Finally, he loaded updated software. The XRF passed all check-out tests during the portcall, and remained in good working order throughout Leg 108. During the cruise, the major emphasis in the XRF lab was recalibration of the major element programs. Both standards and samples were analyzed with very good results.

The XRD equipment successfully analyzed over 650 samples with no significant problems.

### Thin Section Laboratory

A few thin sections were made during this leg, primarily for sediment geriatrics studies. The sections were made from billets from DSDP Legs 11 and 15. They will be examined for alteration, and compared with thin sections made previously from the same material.

### Computer System

The System manager finished the G.R.A.P.E. data plotting program, expanded parameters stripped from seismic tape, integrated magnetic susceptibility measurements into the shipboard database, refined the shipping program, and trained ODP personnel to make sample program modifications and corrections. He also improved routines for satellite data transmissions.

### Special Projects

After completing Hole 658B, the sub-sea camera was lowered to the bottom to observe the condition of the hole around the pipe and the character of the seafloor. This was in preparation for dropping a 6' diameter steel re-entry cone down the drill pipe and into the mound of sediment debris around the pipe. The cone was set and the pipe raised to clear the mud line while the ship was offset. The site was then re-occupied and the hole successfully re-entered. This test demonstrated the capability of re-entering a hole without setting a full size cone, a routine which may allow limited multi-bit holes in the future.

A side entry sub was utilized for the first time at Site 667. This sub allows the logging cable to exit the drill pipe under the drill floor. If a bridge in the hole is found and needs clearing, more pipe can be added at the drill floor, rather than pulling the logging tool. The sub worked but requires a few refinements.

An Alden Marinefax III was installed in the radio room, and used successfully throughout the cruise by the radio operator. The Alden satellite system was not used.

## IMPROVEMENTS

### Communications

Communications between ship and shore were improved with the limited use of BLAST (Block Asynchronous Transmission). This procedure permits rapid data transmission between linked computers, in this case via satellite. Messages composed on the word processors could readily be transferred to the VAX for periodic transmissions. This method of communication, less costly than TELEX, may be used more commonly as the details of message confirmation and distribution are worked out.

### Air Conditioning

A Carrier air cooler was installed in the X-ray laboratory, on the wall behind the XRF unit. This stabilized temperatures in the mid-seventies in the X-ray laboratory, but did not improve the conditions of the chemistry lab. In the latter, temperatures rose into the eighties.

The air conditioning system in the underway geophysics laboratory was also improved after a duct was extended from the warehouse into the lab, terminating in a central ceiling diffuser.

### Personnel

Morale remained high during the cruise, with good cooperation between the technical, scientific and drilling crews. The highlight of Leg 108 was the equator crossing, celebrated with a traditional ceremony. Eighty-five low-life pollywogs were metamorphosed into esteemed Shellbacks before King Neptune's court. A barbecue on the bridge deck followed the ceremonies.

### Safety

Routine fire and boat drills were conducted as usual during Leg 108. The Marine Emergency Technician Squad (the METS) assisted in simulated fire drills, participating in SEDCO hose teams and other firefighting tasks.