OCEAN DRILLING PROGRAM

LEG 150 PRELIMINARY REPORT

NEW JERSEY CONTINENTAL SLOPE AND RISE

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ABSTRACT

After a 10-year hiatus, Ocean Drilling Program Leg 150 (May 28-July 24, 1993) returned to offshore New Jersey to evaluate the effects of global sea-level change on clastic sediments of a passive continental margin. Initial efforts by Legs 93 and 95 of the Deep Sea Drilling Project (DSDP) together with studies by oil companies paved the way for a focused sea-level study on the New Jersey margin by Leg 150 and related drilling. We used industry seismic and well data to plan a multichannel seismic (MCS) survey in 1990 that ties continental shelf sections into the continental slope. By drilling at four holes tied to our MCS grid, we dated numerous sequence boundaries traced from the continental shelf. Leg 150 drilled a transect of four sites on the slope in water depths of 444 m, 811 m, 913 m, and 1123 m (Sites 903, 902, 906, and 904, respectively; Figs. 1 and 2). Site 905 was located on the continental rise in 2698 m water depth. Recovery was excellent (88%) with a total of 4034.5 m of sediments brought on board.

INTRODUCTION

The primary goal of Leg 150 was to date major Oligocene to Holocene unconformities on the New Jersey margin and to evaluate their correlation with glacio-eustatic age estimates obtained from the $\delta^{18}O$ record. Secondary goals were to determine ages of major Eocene "Doubthouse" unconformities and to evaluate the relative importance of along-slope vs. downslope sediment-transport processes and evaluate their links to eustatic variations.

SITE 902

Site 902 (proposed site MAT10) is in ~811 m of water on the upper continental slope off the shore of New Jersey. It is located on CDP 1532 of Ew9009 Line 1027 (Figs. 1, 2, and 3), 2 km north of, and slightly upslope from, the COST (Continental Offshore Stratigraphic Test) B-3 well. The primary objective was to core and log a post-lower Eocene section containing seismic reflections that can be traced to sequence boundaries beneath the adjacent continental shelf. Shipboard paleontologic and paleomagnetic analyses provide preliminary ages for many of these surfaces; physical, chemical and sedimentologic descriptions, along with downhole log measurements, characterize the sedimentologic facies. In combination with results from Sites 903 (proposed site MAT11) and 904 (proposed MAT12A), these data provide a detailed study of the effect of glacio-eustatic change on the stratigraphic record of siliciclastic passive margins.

Hole 902A began on June 11 after a seismic tie-in and a detailed bathymetric survey were completed. Continuous APC coring with 101.4% recovery to 31 mbsf sampled Holocene green muds and middle to upper Pleistocene gray sandy, silty clay. Operations were terminated when a core barrel became stuck at the bit face and could not be retrieved. Hole 902B was offset 20 m west and APC operations resumed. Irregular seafloor topography led to miscalculation of true water depth, and the first core failed to recover the mud line. Hole 902C was spudded without further offset, the mud line was recovered, and APC coring continued to refusal at 130 m with 104.5% recovery. These cores recovered a thin cover of Holocene green muds overlying thick middle to upper Pleistocene gassy, gray sandy, silty clays that include several thin slumps. Shipboard correlations of the GRAPE and biostratigraphic data indicate that this unit was nearly complete from within glacial Stage 5 to Stage 13, with a probable hiatus within stage 10. Three seismic reflections apparently correlate with Pleistocene transitions from interglacial to glacial stages; slumps, reflections, and the inferred stage 10 paraconformity correlate with glacio-eustatic lowerings. Upper Miocene sediments were recovered at the base of the hole (123-130 mbsf). Hole 902D was offset another 20 m to the west and began with APC coring to 145 mbsf and 99.1% recovery. XCB coring began at that depth and continued with high recovery (90.0%) to a total depth of 736 mbsf. The hole was logged with separate runs of the sonic induction, litho-porosity, and Formation Microscanner tools. The site was plugged and abandoned on 18 June.

Six lithostratigraphic units are recognized at Site 902 (Fig. 4). They are numbered so that designations for correlating units correspond among the four Leg 150 slope sites (Sites 902-904 and Site 906). The most complete lithostratigraphic section was recovered at Site 903. Unit II is missing at Site 902. Units I and III through V are primarily siliciclastic upper Pleistocene to upper Oligocene sediments, consisting of clays and silts with sporadic interbeds of fine- to medium-sized quartz and glauconitic sands. Fragments of woody material are common in the Miocene section. These units indicate high terrigenous input. In contrast, Unit VII is a biogenic carbonate interval without significant terrigenous influence. Preliminary seismic correlations indicate that the boundaries between these subunits correspond to reflections, and that several other reflections match glauconitic sand layers within various subunits. The units include:

Unit I (0-124 mbsf), Holocene to uppermost Pleistocene (Stage 13 and younger) gray sandy silty clays with several thin slump units at Hole 902C.

Unit III (124-153 msbf), poorly fossiliferous upper Miocene gray silty clays with scattered layers of glauconite sands.

Unit IV (153-404 mbsf), upper and middle Miocene homogeneous gray silty clay and clayey silt with occasional siderite nodules/bands and abundant plant and wood fragments. Pyrite is present in disseminated and nodular form. Calcareous fossils are generally absent, and diatoms and dinoflagellates provide stratigraphic control.

Unit V (404-595 mbsf), middle middle to lower Miocene gray glauconitic silty clays and clayey silts, clayey siltstone and sandy silts with glauconitic sand beds.

Unit VI (595-682 mbsf), lower lower Miocene to upper Oligocene silty claystones and silty clays distinguished by their brownish color, greater induration than is found in overlying units, and common nannofossils and diatoms.

Unit VII (682-736 mbsf), upper Eocene siliceous nannofossil clayey chalks containing foraminifers. The striking lithologic contact between this and the overlying unit corresponds to an unconformity between the uppermost lower Oligocene and the upper Eocene. This boundary marks a significant change in depositional regime from pelagic, carbonate-dominated deposition during the Eocene to predominantly terrigenous deposition in the early Oligocene.

Bulk density varies cyclically downhole, and values determined with GRAPE are used for Pleistocene correlations to the SPECMAP time scale; they also show significant variations in the Miocene section. Magnetic susceptibility peaks are also associated with GRAPE maxima in the Pleistocene section. Water content and porosity vary inversely with bulk density, but closely mirror trends in bulk density. This relationship suggests that most variations in bulk density are the result of variations in porosity. Physical properties units and subunits defined on the basis of index properties are identified on the thermal conductivity profile. The Adara temperature shoe was deployed at Site 902, and 18 sub-bottom temperature equilibration data sets were collected for a pilot study of possible temperature signatures left by bottom water temperature changes in the past. Analysis is in progress.

Calcareous microfossils are abundant to common in the Pleistocene and lower Miocene to Eocene sediments, and in these intervals they provide good biostratigraphic resolution. In contrast, calcareous microfossils are generally absent from the upper and middle Miocene silty clays; diatoms and dinoflagellates provide stratigraphic control for these sections. Dinoflagellates provide the only zonal control in cores barren of calcareous microfossils and nonsignificant diatom assemblages. Rich benthic foraminiferal assemblages indicate transport of material from the shelf during the Pleistocene, with little in situ fauna found; they also indicate a shallowing from late Eocene (middle bathyal; 600 to 1000 m) to early Miocene (upper bathyal; 200 to 600 m).

Chloride ions and salinity increase with depth at Site 902, and this trend is associated with a sharp drop in pH to a minimum value of 6.5 at 609 mbsf. These slightly acidic pH values are associated with rare occurrences and ghosts of calcareous microfossils. The return to higher pH at 640 mbsf corresponds to an increase in calcareous fossils. A similar increase in salinity was observed at nearby DSDP Site 612, indicating that the migration or diffusion of a salt brine came from greater depths.

High concentrations of methane (up to 64%) were detected in headspace samples from Site 902; heavier volatile hydrocarbons (C2-C5) are present in trace levels. However, elevated C1/C2 ratios and correspondingly high interstitial water alkalinity values (30 mM) indicate that the gas was biogenically generated. Rapid sedimentation rates caused by mass flows and slumping off the continental shelf plus an abundant supply of terrestrially derived organic matter have produced total organic carbon (TOC) values which range between 0.3% and 3.9%. Low carbonate contents (<0.8%) between 150 and 550 mbsf are associated with scarce calcareous microfossils; low pH values in this interval indicate that carbonate has been dissolved during diagenesis.

Determining magnetic stratigraphy at Site 902 is hampered by weak intensities of magnetization, downhole changes in the stability of magnetization under AF demagnetization, and suspected diagenetic changes in the magnetic mineralogy of the sediments. Remanent magnetization from the upper part of Holes 902C and 902D indicate a thick Brunhes polarity interval; dominantly reversed polarity magnetizations between 130 mbsf and 400 mbsf may represent a discontinuous record of the upper middle to upper Miocene. Polarity reversals in the lower middle Miocene to Eocene section suggest that further study will yield correlations to the time scale.

After the first logging run was stopped by a narrow hole (bridge) at 216 meters below sea floor (mbsf), the Side-Entry Sub (SES) was used to log to nearly total depth in Hole 902D. Three additional logging runs were completed: sonic induction from 30 m above sea floor (through the pipe) to 676 mbsf, litho-porosity from 508 to 710 mbsf, and Formation Microscanner (FMS) from 502 to 689 mbsf. Despite the incomplete coverage, these logging data provide valuable correlations between the borehole and the seismic profiles that pass through this site. Four log units are recognized:

Unit 1 (66-465 mbsf). This unit begins at the bottom of the drill pipe with relatively high and variable resistivity values (generally above 1.0 ohm meters) and low velocities (1620 m/sec). Values of both measurements decrease with depth to 300 mbsf where velocities increase rapidly and remain roughly 1700 m/sec to the bottom of the unit. The base of this unit is marked by a bridge.

Unit 2 (465-604 mbsf). Resistivity values decrease with depth from 0.6 to 0.45 ohm meters with several thin intervals with higher values. Natural gamma ray values are higher than in the overlying unit. Sonic velocities increase steadily to about 1733 m/sec and correspond with other log peaks in this unit.

Unit 3 (604-681 mbsf). Changes in density and velocity characterize this unit. Densities are higher and more variable than they are in Unit 2, while velocities are highly variable and in the range of 1940 to 2900 m/sec.

Unit 4 (681-689 mbsf). This unit corresponds to the siliceous nannofossil clayey chalks of Lithologic Unit VI and was logged only with the gamma ray tool and FMS.

The principal result from Site 902 is that sequence boundaries traced from beneath the shelf to the slope can be recognized as stratal surfaces and dated at Site 902 (Table 1, Figs. 3 and 4). Numerous (~17) potential sequence boundaries are observed within the Ew9009 MCS grid on the shelf. Some of these were originally defined by Greenlee and Moore (1988) and refined by Greenlee et al. (1992) based on studies of a grid of seismic data acquired by Exxon Production Research. Others have been added based on an ongoing study of data collected by Lamont-Doherty Earth Observatory (Mountain, Miller and Christie-Blick, in prep.). To avoid the possibility of having to re-assign correlations between these two parallel and evolving data sets, we adopt a strictly local set of reflector names tied to the Leg 150 cores (Table 1). For example, we correlate reflector m6 with the surface separating the lower lower Miocene from the uppermost Oligocene (hiatus ~23-26 Ma) and with the pink-3 sequence boundary on the shelf (Table 1, Figs. 3 and 4). Similarly, reflector m5 separates the lower and middle Miocene (~16 Ma) and is the same surface as the shelf sequence boundary Green of Greenlee et al. (1992). Other reflectors observed on Line Ew1027 (Fig. 3) and their ages (Table 1) include: p1, stage 6/7 transition; p2, stage 7/8 transition; p3, stage 11/10 boundary; p4, an unconformity between the middle Pleistocene and upper Miocene; m0.5, intra-upper Miocene; m0.7, within lower upper Miocene; m1 (= Tuscan of Greenlee et al., 1992), near the middle/upper Miocene boundary; m2 (= Yellow-2 of Greenlee et al., 1992), within the middle middle Miocene; m3 (= Blue of Greenlee et al., 1992), within middle middle Miocene; m4 (= Pink-2 of Greenlee et al., 1992), in the lower middle Miocene; m5 (= Green of Greenlee et al., 1992), near the lower middle Miocene boundary; m5.2, lower Miocene; m5.4, lower Miocene; m6, an unconformity separating upper Oligocene from lower Miocene strata; and o1, an unconformity separating uppermost Eocene from upper lower Oligocene strata.

SITE 903

Site 903 (proposed Site MAT11) was drilled in ~445 m of water on the upper continental slope of offshore New Jersey, 4.4 km (2.4 nmi) upslope of Site 902 (Figs. 1, 2, and 5). Site 903 is the shallowest of four sites on a slope transect (Sites 902-904, 906) designed to sample post-lower Eocene sequence boundaries traced on Ew9009 Line 1005 from the adjacent continental shelf (Fig. 5). Data from these sites will be used to evaluate the effect of glacio-eustatic change on the stratigraphic record of siliciclastic passive margins.

Site 903 was selected at CDP 9140 on Ew9009 Line 1005 (Fig. 5). While Site 902 provides the thickest upper middle Miocene section, Site 903 provides the best opportunity to sample lower middle Miocene strata and, along with Site 904, should provide good representation of the lower Miocene in this region. Continuous APC coring with 97% recovery to 169.5 mbsf sampled Holocene green muds and middle Pleistocene gray sandy, silty clay at Hole 903A. We switched to XCB and continuously cored with high recovery (89%) to a total depth of 702.8 mbsf. Excellent logs were obtained with the seismic stratigraphic (74-604 mbsf) and litho-porosity (0-492 mbsf) tools (Fig. 6A). Hole 903B was APC cored with 97% recovery to 154 mbsf. Hole 903C obtained spot cores from 506-535 mbsf and 587-612 mbsf, recovering intervals lost at Hole 903A. Continuous coring began at 698 mbsf and continued to the total depth of 1149.7 mbsf with 60% recovery (Fig. 6B). Logs were obtained using the seismic stratigraphic tool (975-823 mbsf) and Quad Combo (868-475 mbsf); hole conditions were not good because of bridges and washouts. Hole 903D was drilled and spot cored between 774.9 and 1037.0 mbsf to get cores from sections with poor recovery at Hole 903C when limited operation time remained after Site 906 was completed.

Six lithostratigraphic units are recognized at Site 903 that can be correlated with similar units at Site 902 (Fig. 8), with the exception of Unit II, which is absent from the latter. At both sites, the upper five units are siliciclastic and the lowermost unit is carbonate:

Unit I (0-273.9 mbsf), middle to upper Pleistocene silty clay with fine sand layers containing a thick succession of slumps and debris flows below 221.5 mbsf.

Unit II (273.9-358.9 mbsf), lower to middle Pleistocene nannofossil silty clay and coarse sand. Subunit IIA (273-307.5 mbsf), has a coarse sandy mass flow layer at the base. Subunit IIB (307.5-358.9 mbsf), has a coarse pebbly sand layer with abundant glauconite at the base.

Unit III (358.9-522.9 mbsf), upper and middle Miocene alternations of silty clays and glauconitic sands, distinguished from the unit above by abundant glauconite.

Unit IV (522.9-733.1 mbsf), middle Miocene diatomaceous silty clay to clayey silts with generally lower abundance of glauconite than above. Subunit IVA (522.9-624.6 mbsf) and Subunit IVB (624.6-733.1 mbsf) are defined by basal slump, debris flow and glauconitic sand layers.

Unit V (733.1-974.4 mbsf), lower to middle Miocene glauconitic, diatomaceous, organic-rich silty claystone distinguished from above by higher organic content.

Unit VI (974.4-1064.1 mbsf), lowermost Miocene to upper Oligocene silty claystone, distinguished by minor glauconite, common nannofossils, and rare diatoms.

Unit VII (1064.1-1149.7 mbsf), upper Eocene clayey nannofossil chalk.

Six physical properties units are recognized at Site 903 based on correlative trends in wet bulk density and thermal conductivity. Significant bulk density shifts are associated with the top of each interval and correlate very well to the predicted depths of reflectors p6 (indigo), m0.5 (Red), m1 (Tuscan), m2 (Yellow-2), m3 (Blue), m4 (Pink-2), and o1 (green-2). Intervals are subdivided by pronounced and repetitive cycles of increasing or decreasing average bulk density, which probably represent variations in primary depositional fabric. Additional physical properties measured at Site 903 include sub-bottom temperatures at Site 903A with the Adara coring shoe and natural gamma-ray emissions in whole sections with the newly installed detector on the MST. A preliminary review indicates that both devices obtained useful data; further processing is planned.

Integration of magnetic susceptibility, density, and biostratigraphic data provides a remarkably good time scale for the Pleistocene section. Preliminary correlations indicate an apparently continuous section from oxygen isotope stage 5.5 through stage 15.1 (~120-574 ka). Calcareous microfossils occur at irregular intervals in the Pliocene to upper middle Miocene, where biostratigraphic subdivision relies primarily on dinoflagellates and diatoms. Uppermost Pliocene strata appear at 358.9 mbsf (Zone NN15), whereas the first evidence for Miocene strata appears at 363 mbsf. The placement of the upper/middle Miocene strata is uncertain; foraminiferal evidence indicates that it is as high as 510 mbsf and dinoflagellates as low as 625 mbsf. Nannofossils, diatoms, and dinoflagellates provide excellent control for the lower middle and lower Miocene section. Nannofossils and planktonic foraminifers provide good control on upper Oligocene and upper Eocene strata. Transported benthic foraminifers from the shelf are ubiquitous in the Pleistocene and common in the Miocene, while evidence for transport is minimal in Oligocene and Eocene benthic foraminiferal assemblages. Eocene to lowermost Oligocene assemblages indicate that the paleodepth was >600 m, shallowing to 200-600 m by the Miocene. Overall shallowing and increased downslope transport accompanied the progradation of clinoforms from a location 90 km landward of Site 903 in the early Miocene to less than 20 km landward in the Pleistocene.

The pore water profiles of Site 903 are similar to those from Site 902. A steep chloride (salinity) gradient occurs across the unconformity between the lower to middle Pleistocene and Miocene strata at Site 903. The increase in salinity is associated with a drop in pH to slightly acidic values (6.6). Several alkalinity and ammonium maxima are associated with organic-rich sediment intervals. The Ca and Mg profiles suggest that diagenetic carbonate minerals are precipitating at the alkalinity maximum.

Methane values are high in the uppermost 150 m at Site 903, but no C2 or C3 were detected. Three separate subsurface hydrocarbon gas maxima were observed. This gas is considered to be primarily biogenic because the elevated concentrations correspond with zones that are relatively enriched in organic carbon and that have generally high C1/C2 ratios. However, the possibility of some migrated, thermogenically generated gas contribution to the deepest gassy zone (693-1149.7 mbsf) cannot be ruled out. Minor amounts (127 ppm ethane, 52 ppm propane) of thermogenically produced gas are suspected to be associated with the high salinity interstitial water and subsurface increases in sulfate, which indicate migration of fluids, possibly from local salt diapirs at depth. Organic carbon content averages 0.5% in the Pleistocene sediments. This value is considerably lower than comparable sediments at Site 902 and is probably caused by high sedimentation rates having a dilution effect. In the Miocene, organic carbon values climb to 3.5%, and sulfur is in high concentrations (up to 3±0.33%). These characteristics are considered to be caused by high primary productivity that induced suboxia/anoxia in the water column and sediments.

Determining magnetic stratigraphy at Site 903 is hampered by weak intensities of magnetization. We constructed a provisional magnetostratigraphic framework for the uppermost middle Miocene to Pleistocene at Hole 903A. Much of the Miocene and older sections are below the detection limit of 1 mA/M for shipboard analyses of 6 cm^3 discrete samples, but above the limit of 0.1 mA/M for larger volume discrete samples to be analyzed onshore. Therefore, we are optimistic that this section will provide a magnetostratigraphic framework with shore-based studies.

Excellent logs were obtained from Hole 903A, and preliminary synthetic seismograms constructed from log data are encouraging. Log quality was much lower at Hole 903C due to deteriorating hole conditions; however, logs obtained across the major lower and middle Miocene sequences should provide sufficient log signatures to allow recognition of major sequence boundaries.

The principal result from Site 903 is that sequence boundaries traced from beneath the shelf to the slope can be recognized and dated. Precise correlations for some sequence boundaries will require additional shore-based studies, especially to obtain a magnetochronology for weakly magnetized lower upper Miocene and older sediments. Nevertheless, shipboard studies provide excellent correlations for several boundaries:

1. Reflector m2 (Yellow-2) is associated with a reversed magnetozone tentatively correlated to Chron C5Ar and has an age estimate of approximately 12.4 Ma;
2. We precisely dated the reflector m5 (Green) sequence boundary for the first time. This reflector correlates with an interval spanning the boundaries between the middle/lower Miocene, Zones NN4 and NN5. It has an estimated age of 16.2 Ma;

3. At both Sites 902 and 903, the reflector m6 (pink-3) sequence boundary separates the lower lower Miocene from the uppermost Oligocene;

4. At both Sites 902 and 903, the o1 (green-2) sequence boundary separates uppermost lower Oligocene from uppermost Eocene strata.

SITE 904

Site 904 (proposed site MAT12-A) was drilled in 1123 m of water on the upper continental slope, offshore New Jersey, 7.5 km south and slightly downslope from Site 902 (Figs. 1, 2, and 7). This is the deepest of four sites (Sites 902-904 and Site 906) on a slope transect designed to sample post-lower Eocene sequence boundaries traced from the adjacent continental shelf. Information from these sites will be used to evaluate the effect of glacio-eustatic change on the stratigraphic record of siliciclastic passive margins.

Although Sites 902 and 903 met their objectives, they sampled intervals of poorly fossiliferous Miocene strata. Slightly acidic pore waters are thought to have caused dissolution of the calcareous microfossils, while laminae and concretions associated with alkali maxima were the locus of reprecipitated carbonate. The primary objective of Site 904 was to sample a Miocene succession where its downdip location relative to the other Leg 150 sites suggests that it is more fossiliferous due to less destructive pore water dissolution. An additional objective was to drill through and sample a relatively thick upper and middle Eocene section, and continue down across a diagenetic boundary near the middle/lower Eocene boundary.

Site 904 was spudded on July 1, and APC coring proceeded with 99.8% recovery to 222 m below seafloor (mbsf). Excessive overpull dictated refusal at this depth. Coring resumed with the XCB, and we had complete recovery until we encountered a formation change from silty clay and mudstone to chalk with porcellanite at 340 mbsf (Fig. 8). Rate of penetration slowed considerably, and recovery fell off with increasing depth into this lithologic unit. Scientific objectives had been met, and with a total of 94.7% recovery for the entire hole, coring ended at 576.7 mbsf on July 2. Three logging runs comprising the seismic stratigraphy, lithoporosity, and FMS tools were completed with the Side-Entry Sub from TD to 96 mbsf. The hole was plugged and abandoned on July 4.

Sites 902-904 and Site 906 comprise a transect of post-lower Eocene section of continental slope sediment. The lithologies at these sites are very similar, and we maintained the same lithologic unit designations among them. Those at Site 904 are the same as at 902 and 903 except that erosion between the upper Miocene and middle Pleistocene removed lithologic Units II and III (Fig. 8). As at the other sites, the deepest unit is carbonate; the overlying units are all siliciclastic.

Unit I (0-106.2 mbsf), Holocene to middle Pleistocene silty clay; very uniform and fine-grained in the upper 64 m; laminae and beds of graded fine sand are common from 64 to 92 mbsf; slump deposits of poorly sorted sand and lithic clasts make up the base of this unit, ending with a sharp contact.

Unit IV (106.2-223.9 mbsf), upper to middle Miocene diatomaceous silty clay to clayey silts with carbonate and pyrite nodules and a 4 m interval of poorly sorted medium to very coarse sand near the middle of the unit; 5 m of sorted fine sand makes up a slump at the base of the unit.

Unit V (223.9-296.5 mbsf), lower to middle Miocene glauconitic, diatomaceous silty clay with abundant diatoms.

Unit VI (296.5-341.2 mbsf), lower Miocene to upper Oligocene silty clay with minor glauconite, common nannofossils, and rare diatoms; the basal 4 m of this unit contains abundant sand- and silt-sized glauconite, ending in a sharp, burrowed contact.

Unit VII (341.2-576.7 mbsf), upper to middle Eocene clayey nannofossil chalk with diatoms, radiolarians, and foraminifers. A microtektite layer occurs 8 m above the upper/middle Eocene boundary, as determined by nannofossils; this layer is part of a 15 cm laminated interval containing well sorted silt- to sand-sized particles. Intervals of opal-CT are common below 525 m.

Five physical properties units are recognized at Site 904 based on trends in wet bulk density. Values generally increase steadily and rapidly in the Pleistocene sediments of physical properties Unit I, reaching the highest values of the site (2.19 g/cm^3) at 106 mbsf. Except for locally high densities in sand-prone intervals (several of which correspond to seismic reflectors), density values remain below 1.7 g/cm^3 down to Unit V, which corresponds to the siliceous-cemented chalk at the base of lithologic Unit VII. Compressional wave velocities increase from 1517 m/sec at the top of the section to 1700 m/sec at the base of physical property unit IV; velocities increase abruptly to as high as 2000 m/sec and more in the siliceous-cemented chalks of unit VII. Downhole shifts in porosity, thermal conductivity and penetrometer values generally follow changes in wet bulk density. Natural gamma ray emissions were measured routinely on the Multi-Sensor Track and show close parallels to values measured in the downhole log.

Density, magnetic susceptibility, and biostratigraphic data provide good correlations of the Pleistocene section to the SPECMAP time scale; this site contains a record of part of the middle Pleistocene back to stage 12. The middle Pleistocene is underlain by lower upper Miocene strata. Considerable uncertainties surround placement of the upper/middle Miocene boundary, with planktonic foraminifers and nannofossils indicating a disconformable contact over 20 m below that indicated by diatoms and dinocysts (Fig. 8). The upper middle Miocene section contains a spotty record of calcareous plankton, and shipboard biostratigraphy of this section is uncertain (Fig. 8). The lower middle Miocene to upper Oligocene section has reasonable calcareous biostratigraphic control, and at least two possible hiatuses were detected (NN5/NN7 and NN2-3/NN4) (Fig. 8). As at Sites 902 and 903, most or all of the early Oligocene is not represented, with possible hiatuses near the Oligocene/Miocene boundary and in the late Oligocene. Eocene biostratigraphic control is good. Preliminary biostratigraphic studies of a microtektite layer show that it is lower upper Eocene.

Pore water study reveals patterns similar to both Sites 902 and 903. Salinity increases abruptly at the unconformity between Pleistocene and Miocene strata and continues to increase with depth, suggesting evaporite deposits at depth. There is a corresponding downward decrease in pH to slightly acidic values that explain the disappearance of calcareous microfossils. Local ammonium maxima associated with organic-rich intervals are sites of reprecipitated carbonate minerals.

Methane at Site 904 reaches a maximum of 4% (39,787 ppm) at 446 mbsf as measured in headspace gas. Ethane was the only other hydrocarbon gas detected. Its profile mimics methane and reaches a maximum of 14 ppm at 559 mbsf, and it is thought to be biogenically derived. As at Site 903, the values of organic carbon are below 0.5% in Pleistocene sediment and in the Eocene chalk; values in Miocene sediment, by contrast, are as high as 2.1%, and sulfur concentrations reach nearly 3%. This pattern is probably caused by high primary productivity that induced suboxia/anoxia in the water column and sediments. Low C/N ratios (<10) suggest that the organic matter preserved in these sediments is primarily marine.

As at Sites 902 and 903, magnetization intensities in sediments at Site 904 are generally below the detection limit of 1 mA/M for shipboard analyses. Values are strongest in the Pleistocene section above 106 mbsf, and pass-through measurements of both split cores and discrete samples indicate a normal, presumably Brunhes, polarity. Intensities remain measurable through a reversed interval from here to 133 mbsf that may correlate to Chron C4Ar. Intensities are sufficient in five additional intervals between 200 and 400 mbsf to enable tentative assignments to 1 reversed and 4 normally polarized magnetochrons. These samples will be re-examined in more detailed shore-based study.

An excellent suite of logs was obtained under good borehole conditions (Fig. 10), particularly below 230 m. These logs will provide a means of evaluating correlations of seismic reflections to Site 902, including computing impedance contrasts and synthetic seismograms.

The principal result from Site 904 is that we recovered a lower Miocene section with calcareous microfossils. There is great potential for improved integration among biostratigraphic, Sr-isotopic, and magnetostratigraphic chronologies crucial to the objectives of Leg 150. In addition, Site 902 recovered the thickest upper Eocene section yet found in this region. Definitive age estimates of seismic reflectors require further study; the interpretations completed thus far are consistent with the ages of reflectors traced from the continental shelf and dated at Sites 902 and 903 (Fig. 8). For example, 1) reflector m1 (Tuscan) appears to correlate to a possible disconformity spanning the middle/upper Miocene boundary; 2) reflector m2 (Yellow-2) correlates with a reversed magnetozone that may be Chron C5Ar (~12.5 Ma) as it does at Site 903; 3) reflector m5 (Green) is associated with the middle/lower Miocene boundary; 4) reflector o1 (Green-2) correlates with an unconformity separating upper Oligocene siliciclastic from upper Eocene carbonate sediment; and 5) reflector e2 (= A^c) correlates to the top of porcellanitic chalk whose age is approximately the same as at nearby Site 612 (middle-lower part of Zone NP15).

SITE 905

Site 905 (proposed Site MAT-14) was drilled at latitude 38° 36.828' N and longitude 72° 17.024' W in 2698 m of water on the upper continental rise of offshore New Jersey, 33 km (17.8 nmi) from the foot of the continental slope (Fig. 1). This is the deepest water depth of the five sites drilled during Leg 150, and constitutes the most seaward member of the New Jersey Sea Level Transect. This is part of an ongoing effort to integrate drilling results from the coastal plain to the rise, and to sample the spectrum of geologic effects of glacio-eustatic change along siliciclastic margins. The immediate goal at Site 905 was to determine the deep-sea expression of Oligocene to Holocene eustatic changes resolved in the other Leg 150 sites drilled on the New Jersey slope. This sea-level history is to be compared with any evidence we may find of deep-water circulation at Site 905 in order to establish temporal relationships between downslope and along-slope sediment transport processes.

Site 905 was selected at the intersection of two multichannel profiles collected during reconnaissance surveying of the U.S. margin. This location is at shotpoint 4008 on USGS Line 25, and at shotpoint 10880 of BGR Line 201 (Fig. 1). Drilling at this position provides the opportunity to sample three major reflecting surfaces that have been traced across the continental rise. Each reflector has been shown elsewhere to correlate to an erosional hiatus formed during intensification of a southwest-flowing precursor to the modern Western Boundary Undercurrent. Reflector A^u was formed near the Eocene/Oligocene boundary, Reflector Merlin during the late middle Miocene, and Reflector Blue during the late Pliocene. A puzzling seismic character of discontinuous, hummocky reflectors beneath Merlin has been interpreted to be the result of either submarine fan processes or those of sediment drifts. Determining which of these conflicting interpretations is more applicable to Site 905 is crucial to the goal of evaluating downslope vs. along-slope sediment transport processes and their linkages to global sea-level change.

Operations at Site 905 began on the morning of July 4 with an underwater video survey of the seabed at the proposed drill site. This was necessary because we were operating within 10 km of sites used to dispose of explosives and chemical wastes during the last several decades. No man-made objects were observed during an extensive search, though we did locate a partially buried, indurated boulder several meters across. We suspect this is composed of Eocene chalk that was calved and transported from the slope during a Pleistocene mass transport event of impressive proportions.

We spudded Hole 905A that evening and encountered Pleistocene clay conglomerates beneath 20 meters below seafloor (mbsf) (Fig. 9). This lithology was stiff and frequently prevented full stroke with the APC. We switched to XCB at 134 mbsf, but achieved only 30% recovery in sediments that became softer and/or sandier with depth. We reverted to APC and continued with improved recovery down to 219 mbsf, where once again XCB was brought on line and continued with nearly 100% recovery to 655 mbsf. This hole was then logged with the induction-sonic and lithoporosity tools using the Side-Entry Sub. Despite variable hole conditions, logs were of good quality. XCB operations resumed in the same hole on July 10 with the plan of continuing until

XCB refusal. A second hole was then to be washed to similar depth, cored with RCB to the proposed TD of 1300 mbsf, and then logged up to the bottom of the first logging run. XCB coring went smoothly with extraordinarily high recovery. Gas volume (predominantly methane) was variable throughout this section. Methane/ethane ratios declined with depth below 820 mbsf. Traces of liquid hydrocarbons were detected by fluorescence in the solvent cut at 886 mbsf. Under advisement by Science Operations at TAMU we advanced one core at a time measuring gas chromatography and solvent fluorescence. We met XCB refusal abruptly at 888 mbsf on July 12, and to minimize time at a site that might have to be abandoned for safety reasons, we modified our plans and dropped a free-fall funnel, recovered the XCB bit, reentered Hole 905A, and resumed coring with RCB. This was completed without incident, and we resumed in the "core one and measure it" mode. After several cores with little recovery at a TD of 910.6 mbsf, the hole was cemented and abandoned under direction by ODP (consultation with PPSP). Though indications of liquid hydrocarbons and hexane had diminished, methane/ethane ratios had continued to decline.

Four lithostratigraphic units are recognized at Site 905:

Unit I (20-215 mbsf), lower Pleistocene conglomeratic clay; all but parts of 2 cores are mass transport deposits containing clasts of clay, silt and sand-sized sediment, pebbles and shell fragments; terrigenous components dominate. The uppermost 20 m were not cored because of safety concerns.

Unit II (215-537 mbsf), lower Pleistocene to upper Miocene homogeneous silty clay with uniformly low terrigenous composition; diatom abundances increase downward.

Unit III (537-680 mbsf), at least five upper to middle Miocene units of conglomeratic clay; polycyclic mass transport units indicated by clasts within clasts, by clasts composed of two or more sediment types in sharp contact, and by clasts composed of indurated sandy matrix with flow structures and folds.

Unit IV (680-911 mbsf), upper middle Miocene homogeneous silty clay, and like Unit II with uniformly low terrigenous composition and abundant diatoms.

Eight physical properties units are recognized at Site 905 based on correlative trends in wet bulk density and natural gamma ray (NGR) counts. Significant shifts in these properties are associated with the four seismic reflectors that were penetrated (Fig. 9). These are: 1) the base of the Pleistocene mass flow unit and an abrupt drop in density of 0.4 g/cm^3 (Reflector Brown); 2) a more gradual increase of 0.3 g/cm^3 and increase in gamma ray count (Reflector Blue); 3) another 0.3 g/cm^3 increase at the top of the first Miocene mass flow unit (Reflector Merlin); and 4) another 0.3 g/cm^3 increase at the base of this same unit (Reflector Yellow). The NGR counts show a uniform character to lithologic Units II and IV, but suggest higher clay content in the latter. Compressional wave velocities were difficult to measure in the mass flow units; excellent porosity and grain density profiles were measured.

Biostratigraphic studies show that the 910.6 m of lower Pleistocene to lower middle Miocene section may be subdivided into four main units bracketed by unconformities. The upper unit, 218.7 m thick, is lower Pleistocene nannofossil Zone NN19 (1.37-1.45 Ma). This unit overlies a thin (~55 m) interval of upper Pliocene hemipelagic silty clays (224-279 mbsf); a late Pliocene-early Pleistocene hiatus separating these units encompasses about 0.6 m.y. (nannofossil Zones NN19 to the upper part of Zone NN17 are not represented). A ~278 m thick, apparently continuous lower Pliocene to upper Miocene section constitutes a third unit extending from 290.4 to 568.3 mbsf; an intra-Pliocene hiatus encompasses about 1 m.y. (nannofossil Zones NN14 and NN13 are not represented). The lowest unit, (576.49 to 909.66 mbsf) is poorly understood at this time. Dinocyst and diatom stratigraphies indicate that this is an essentially continuous middle Miocene section. Alternatively, there are suggestions from calcareous nannofossil stratigraphy that abnormal stratigraphic successions occur. The hiatus associated with the boundary between the upper and middle Miocene is at least ~2 m.y. (calcareous nannofossil Zones NN10 and NN9 and possibly NN8 are absent).

The interstitial water trends of Site 905 differ significantly from those observed on the slope sites drilled previously on Leg 150. The high salinity and chloride values observed at the slope sites below the top of the Miocene are absent at Site 905. Chloride decreases with depth in a manner consistent with the presence of gas hydrates. The pH decrease is also less at Site 905 and results in much better preservation of calcareous fossils. The profiles related to organic matter degradation at Site 905 (sulfate, phosphate, alkalinity and ammonium) are similar to those observed on the slope.

Shipboard organic geochemical studies included hydrocarbon and non-hydrocarbon gas analysis, Rock-Eval pyrolysis, and elemental analysis. After a near-surface maximum, methane concentration remains steady at about 11% down to 592 mbsf. At this level it is accompanied by trace amounts of ethane, which gradually increases with depth. Both gases increase from 600 to 765 mbsf (reaching maxima of 19% and 2% respectively), and propane is detected in trace amounts within this zone as well. All three increase gradually from 842 mbsf to TD. Hydrocarbons up to C5 are detected in headspace gases and up to C6 in vacutainer samples in the last 35 m above TD. Thermally maturated hydrocarbons migrated from a deeper source are indicated by common C2-C6 hydrocarbons and by methane/ethane ratios <50. High gas pressures in sporadic intervals beginning at 304 mbsf were apparent as liners were removed from the core barrel. Pore water chlorinity concentration relative to seawater drops in a stepwise pattern downhole, reaching 7% dilution at 910 mbsf (TD). The high gas pressures, gas composition, and this chlorinity evidence raise the possibility that gas hydrates are stable at the TD reached at Site 905.

Organic carbon content is low (<0.5%) in the lower Pleistocene mass flow sediments. By contrast, values are uniformly higher, reaching 3.7 wt. %, in the underlying Pliocene and Miocene sediments. This latter fact suggests high surface productivity and intervals of organic-rich terrestrial matter that were brought to the site during Miocene mass transport events. All of the samples measured from Hole 905A have pyrolysis signatures of immature organic matter of a mixed terrestrial and marine origin. C/N ratios indicate a more marine nature.

Determining magnetic stratigraphy at Site 905 was hampered by weak intensities of magnetization and mass flow deposition. Future shore-based studies are needed to establish whether a primary signal may be present in the weakly magnetized, homogeneous silty clays at this site.

Good quality logs were obtained despite marginal hole stability in the upper two-thirds of Hole 905A. The induction-sonic tool was run with the aid of the SES between 105 and 647 mbsf. The litho-porosity tool was run from 81 to 581 mbsf. The caliper showed that most of the hole was 12-15 inches in diameter, and that part shallower than 165 mbsf was washed out to greater than 16 inches; these few intervals will be difficult to interpret.

The principal result from Site 905 is that mass wasting has on occasion been a volumetrically important depositional agent on the upper continental rise. The lower Pleistocene mass flow unit, roughly 200 m thick, can be traced in profiles for tens of kilometers along the rise parallel to the margin, as well as an equal distance seaward from Site 905. Furthermore, middle Miocene mass transport deposits comprise many tens of meters in the middle of the interval recovered at Site 905. Remarkably uniform, homogeneous hemipelagic sedimentation prevailed for most of the time since the middle Miocene, punctuated by bottom current erosion at roughly 9.5 Ma and 4 Ma. Evidence is not found to support a submarine fan origin for the hummocky seismic facies beneath Reflector Merlin. However, an origin related to current-controlled bedforms is not apparent either, and additional shore-based sedimentologic and log analyses are planned.

SITE 906

Site 906 was drilled in 923 m of water on the middle continental slope of offshore New Jersey, 0.6 km (1.1 nmi) north of Site 902 (Figs. 1, 2, and 3). This site was selected after drilling at Site 905 was terminated due to safety concerns. We located Site 906 in the thalweg of modern Berkeley Canyon in order to minimize upper Neogene sediments and to penetrate a buried Miocene canyon (Fig. 3). This buried canyon structure is strikingly revealed on an oblique crossing by Ew9009 Line 1027 (Fig. 3). We conducted a detailed seismic survey of the buried canyon structure on approach in order to map its geometry. Scientific objectives at Site 906 were:

1. To compare the depositional history of a site on an interfluve of an extinct middle Miocene canyon (Site 902) with that of a site in the thalweg of the buried canyon (Site 904);
2. To evaluate the timing and mechanism of sediment deposition in both environments; and
3. To determine the timing of canyon cutting and sedimentation changes with respect to global sea-level change.

Site 906 was spudded on July 14, and APC coring proceeded with 107% recovery to 62.5 m below seafloor (mbsf). Difficulties in drilling the shoulder indicated refusal at this depth. Coring resumed with the XCB to a total depth of 602 mbsf with 83% recovery. A chalk unit was penetrated at 552 mbsf; the rate of penetration slowed considerably and recovery fell off with increasing depth into this lithologic unit. Scientific objectives had been met, and coring was terminated in the upper Eocene on July 16. Four logging runs, comprising the seismic stratigraphy (84-590 mbsf), litho-porosity (103-583 mbsf), FMS (119-577 mbsf) , and geochemical (146-569 mbsf) tools, were completed with the Side-Entry Sub. The hole was plugged and abandoned on July 17.

Several of the lithologic units penetrated at slope Sites 902-904 are represented at Site 906, and we maintained the same lithologic unit designations among the slope sites (Fig. 10). Units II and III are not represented at Site 906. However, the canyon fill penetrated at Site 906 between 361.8 mbsf and 478.2 mbsf contains lithologies that are very different from the coeval Unit V at Sites

902-904, and we designated three subunits of Unit V for these canyon fill deposits at Site 906. As at the other sites, the deepest unit is carbonate; the overlying units are all siliciclastic.

Unit I (0-55.4 mbsf), Holocene to upper Miocene silty clay with mudclasts. It was divided into subunits IA, a silty clay with abundant mud clasts and rare quartz sand, and subunit IB, a glauconitic sandy clay with possible mud clasts.

Unit IV (55.4-279.2 mbsf), upper and middle Miocene diatomaceous silty clay to clayey silts with siderite and pyrite nodules. Gravity flow deposits occur in the middle and base of the unit. At Site 904, this unit was subdivided into subunit IVA, a silty clay with nodules and glauconitic sandy interbeds, and subunit IVB, a uniform slightly glauconitic silty clay.

Unit V (279.2-478.2 mbsf), middle Miocene canyon fill divided into three subunits. Subunit VA consists of a predominantly laminated silty clay. Subunit VB is a thinly bedded fine quartz sand. Subunit VC comprises mainly silty clay interspersed with mud-clast conglomerates.

Unit VI (478.2-563.8 mbsf), upper Oligocene silty claystone and clayey siltstone with abundant glauconite, common nannofossils, clastic sills, and microfaults.

Unit VII (563.8-602.4 mbsf), upper to middle Eocene clayey nannofossil chalk.

Eight physical properties units are recognized at Site 906 based on trends in GRAPE bulk density and index properties. Many of these boundaries coincide with lithostratigraphic unit boundaries. Good velocity measurements were obtained, and post-cruise studies will generate synthetic seismograms from the borehole velocities and densities. Velocities increase gently to 1800 m/s at 380 mbsf, attain a general maximum of 2000 m/s at 500 mbsf, and decrease to ~1565 m/s below this. Downhole shifts in porosity, thermal conductivity and penetrometer values generally follow changes in wet bulk density. Natural gamma ray emissions were measured routinely on the Multi-Sensor Track and show close parallels to values measured in the downhole log.

The Pleistocene section at Site 906 is thin (43 m) and younger than the *Pseudoemiliania lacunosa* LAD (<474 ka). The upper Miocene section at Site 906 contains Zones NN9-10 and N16-17, and is thus lower upper Miocene (8.2-10.4 Ma). The boundary between the upper and middle Miocene is not recognizable using biostratigraphic criteria.

Stratigraphic interpretation of the middle Miocene section recovered at Hole 906A is the least constrained of any of the slope sites because of a thick interval (~90-420 mbsf) barren of calcareous fossils and an interval of wide ranging zonations in the mass flow deposits below this interval. The only stratigraphic control currently available for the interval between 90 and 420 mbsf is provided by diatoms, which indicate assignment to the middle Miocene *R. barboi* Zone.

All of the canyon fill at Site 906A is assigned to the *R. barboi* Zone (older than about 11±0.5 Ma). High sedimentation rates for this section (minimum rate of 14 cm/k.y.) may be indicated by integration of diatom and magnetostratigraphic data. The mud clast conglomerate found at the base of the canyon fill (421.1-478.2 mbsf) contains both lower Miocene (Zone N6) and middle Miocene fossils (*R. barboi* Zone). We assume that the older ages are due to reworking of older clasts, and that the canyon fill is middle middle Miocene and younger (< about 15 Ma).

The Oligocene section is assigned to Zones NP25 and P22 (upper part) and undifferentiated Zones NP24/25 (lower part). Calcareous plankton indicate that a ~66 m section of upper Oligocene glauconitic silty clay (Zones NP24-NP25 and P22) overlies an upper Eocene nannofossil clayey chalk (Zones NP19/20 and P15-17).

Pore water study reveals patterns similar to Sites 902-904, although the interstitial water profiles differ above the upper Miocene due to the thin Pleistocene section. As at the other sites, bacterial degradation of organic matter reduces sulfate concentrations to 0 by ~30 mbsf; below this degradation proceeds via methanogenesis. Salinity increases abruptly at the top of the Miocene section and continues to increase with depth, suggesting evaporite deposits at depth. There is a corresponding downward decrease in pH to 6.7 at 135 mbsf with values as low as 6.4 at 539 mbsf; these low pH values explain the disappearance of calcareous microfossils. Local ammonium maxima associated with organic-rich intervals are sites of reprecipitated carbonate minerals.

Headspace gas at Hole 906A consisted of predominantly methane with minor amounts of ethane and traces of propane. The gases are of biogenic, rather than thermogenic, origin. Headspace methane concentrations ranged between 586 and 83,019 ppm in two maxima. An upper maximum occurs between 32.5 mbsf and 317.0 mbsf below the zone of sulfate reduction; C1/C2 ratios in excess of 1000 indicate biogenic origin. A gas-lean interval occurs between 328.3 and 433.3 mbsf associated with lower TOC contents. A deeper gas-enriched sediment zone lies between 443.1 and 663.8 mbsf. Within this interval, ethane generally increases with depth from 1 ppm at 420.8 mbsf up to a maximum of 432 ppm at 555.1 mbsf; propane appears occasionally up to concentrations of 5 ppm. C1/C2 values drop dramatically across the Miocene/Oligocene unconformity (472.0 mbsf) and remain below 500 down to 539.3 mbsf. However, TOC values are high in this section; C1/C2 values rise in the Eocene. The irregularity of the C1/C2 ratio with depth and high organic carbon content suggest that bacterial degradation of organic material is the source of the gas in the Oligocene sediments of this site.

TOC values at Hole 906A ranged from 0.29% in Pleistocene sediments and up to 3.27% in Oligocene sediments. Middle Miocene laminated lithologic Subunit VA exhibits slightly lower than average values (1.4%), and it is surprising to see lower TOC contents in the presence of such thinly bedded, burrow-free silty clays.

As at Sites 902-904, magnetization intensities in sediments at Site 906 are generally below the detection limit of 1 mA/M for shipboard analyses. Values are strongest in the section above 107 mbsf including a representation of the Brunhes polarity Chron, but diminish downhole. A zone of very strong magnetization between about 282 and 465 mbsf contains a thick reversed magnetozone (282 and 393 mbsf). This may reflect secondary magnetization due to diagenesis. However, it is also possible to correlate this long magnetozone with Chron C5Ar. Shorebased studies will re-examined the in more detailed shorebased study, including evaluating the effects of diagenesis on the rock magnetic record.

An excellent suite of logs was obtained under good borehole conditions. These logs will provide a means of evaluating correlations of seismic reflections to Site 906 and generating synthetic seismograms.

The principal result from Site 906 is that we recovered a remarkable history of a middle Miocene canyon. The canyon was cut between about 12.5 and 15 Ma. We previously traced reflector m3 (= shelf Reflector Blue of Greenlee et al., 1992) as the base of the canyon. This reflector dates to about 13.5 Ma, consistent with its being the surface of canyon incision. This event may correlate with an inferred glacio-eustatic lowering that is part of the middle Miocene $\delta^{18}O$ increase, although additional chronostratigraphic studies are needed to document this. Subsequent to the cutting of this canyon, it rapidly filled first with debris from the canyon walls, then with turbiditic sands as it served as a conduit for sands carried downslope. The demise of the canyon was marked as it rapidly filled with 100 m of laminated mud in less than about 1 m.y.; this period of lamination marked an unusual interval of low oxygen noted not only at Site 906, but also at other slope sites. The entire birth and demise of the canyon took less than about 2 m.y.

OVERALL RESULTS

Leg 150 was successful in attaining its primary scientific goal: sequence boundaries traced from beneath the shelf to the slope were recognized as stratal surfaces and dated at slope Sites 902-904 and 906. We traced seismic reflectors from the continental shelf to the slope using the Ew9009 MCS seismic grid, including the following Oligocene-Miocene reflectors of Greenlee et al. (1992): Red, Tuscan, Yellow-2, Pink-2, and Green. In addition, we traced the informal ochre, sand, true blue, pink-3, and green-2 reflectors of Christie-Blick, Mountain and Miller (unpublished), and several reflectors identified on Leg 150. However, there are uncertainties in some correlations of the shelf reflections due to problems with downlapping, erosion, and masking of reflectors. Therefore, we established a local alphanumeric scheme (Table 1) that is tentatively correlated with the shelf reflections. For example, we correlate reflector o1 with a sequence boundary separating uppermost lower Oligocene from uppermost Eocene strata at all four slope sites; this boundary also represents a major change in depositional regime from Eocene chalks to Oligocene and younger siliciclastic sediments that was firmly dated for the first time by Leg 150. Reflector m6 is correlated with a surface separating the lower Miocene from the uppermost Oligocene (hiatus ~23-26 Ma) at all four slope sites and with the pink-3 sequence boundary on the shelf. Other reflectors and their tentative ages are supplied in Table 1.

Shipboard age estimates of the sequence boundaries on Leg 150 compare favorably with other proxies for sea-level change. For example, reflector m3 can be traced to the continental shelf, where it is recognized as the distinct Green sequence boundary on the basis of onlap, downlap, and erosional truncation. At Site 903, we correlated reflector m3 with the Zone NN4/NN5 boundary, with an age of about 16.2 Ma. This apparently correlates with an oxygen isotope increase that is inferred to be a glacio-eustatic lowering (i.e., the Mi2 $\delta^{18}O$ increase that began ~17 Ma and culminated at 16.1 Ma; Miller et al., 1991).

At Site 906, we recovered a middle Miocene submarine valley fill. The valley, which may represent a slope canyon, formed and was infilled between about 15 and 12.5 Ma. This event may correlate with an inferred glacio-eustatic lowering that is part of the middle Miocene $\delta^{18}O$ increase. The demise of the canyon was marked by rapid infilling with 100 m of laminated mud, representing an interval of low bottom-water oxygen noted not only at Site 906, but also at other slope sites.

Physical properties data (GRAPE density, index properties, magnetic susceptibility) allowed good correlations to the Pleistocene SPECMAP time scale (Imbrie et al., 1984). The strata recovered at the four slope sites apparently represent a complete record of stages 12 to 5.2 (474-122 ka). Pleistocene mass wasting events tended to correlate with transitions from interglacials to glacials, i.e., during glacio-eustatic lowerings.

High surface water productivity in the early to middle Miocene is indicated by diatom blooms, supply of abundant organic matter, and locally reducing conditions. Terrigenous supply greatly increased in the late middle to late Miocene, resulting in increased terrestrial organic carbon, generation of biogenic methane, reduction of pore water pH, formation of pyrite, and dissolution of calcareous microfossils. Salinity increases abruptly at the top of the Miocene at all slope sites and continues to increase with depth, suggesting evaporite deposits at depth. A microtektite layer in the upper Eocene at Sites 903 and 904 correlates with a similar layer at Site 612 and records an impact of the extraterrestrial body.

The principal result from rise drilling is that mass wasting has intermittently been a volumetrically important depositional agent on the upper continental rise, although deep-sea currents were important also, as evidenced by bottom current erosion at roughly 9.5 Ma and 4 Ma.

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Table 1. Tentative correlation of seismic reflectors, New Jersey continental slope, ODP Leg 150.

Reflector	Color	Correlation	
p1	yellow	oxygen isotope stage 7/6 transition***	middle Pleistocene
p2	blue	oxygen isotope stage 9/8 transition***	middle Pleistocene
p3	green	oxygen isotope stage 10 hiatus; stage 11/10 transition***	middle Pleistocene
p4	purple	oxygen isotope stage 12.4/12.3 transition***	middle Pleistocene
p5	orange	oxygen isotope stage 13/12 transition***	middle Pleistocene
p6	indigo	disconformity separating stage 15*** & upper Pliocene	middle Pleist./upper Plio.
m0.3	yellow	near base of C4n	middle upper Miocene
m0.5*	Red	C4Ar?	middle upper Miocene
m0.7	blue	below is C4Ar?	lower upper Miocene
m1*	Tuscan	C5r?	upper middle Miocene
m1.5**	orange	C5r?	upper middle Miocene
m2*	Yellow-2	C5Ar?	upper middle Miocene
m3*	Blue	older than C5Ar, NN7, & FO *G. fohsi fohsi*	middle middle Miocene
m4*	Pink-2	?near NN5/NN6 boundary	middle middle Miocene
m5*	Green	near Zone NN4/NN5 boundary; possibly upper NN4	near lower/middle Miocene boundary
m5.2**	ochre	?unconformity NN2/NN4?	lower Miocene
m5.4**	sand	within Zone NN2	lower Miocene
m5.6**	true blue	within Zone NN2	lower Miocene
m6**	pink-3	unconformity NN2/NP25	near Oligocene/Miocene boundary
o1**	green-2	unconformity NP23/NP19-20	middle Oligocene/upper Eocene
e1	yellow	unconformity NP16/NP19-20	middle/upper Eocene boundary
e2**	red-3	middle part of Zone NP15	top lower middle Eocene porcellanites

* Possibly equivalent to the shelf reflectors of this color (Greenlee et al., 1992).

**Possibly equivalent to the shelf reflectors of this color (Mountain et al., unpublished).

***Based on GRAPE and magnetic susceptibility correlations to SPECMAP oxygen isotope time scale.

FIGURE CAPTIONS

Figure 1. Generalized bathymetric location map of the Mid-Atlantic margin showing *Maurice Ewing* 9009 MCS seismic grid (solid lines), other MCS profiles (dashed lines), proposed shelf drill sites (stippled circles), onshore drill sites (open circles), and Sites 902-906 (large closed circles) drilled by ODP Leg 150.

Figure 2. Detailed bathymetric location map of the continental slope between Carteret and Berkeley Canyons, DSDP Site 612, COST B-3 well (Scholle, 1980), outcrop sampled with the DSV *Alvin* in 1989 (Miller, unpublished), AMCOR 6021 borehole (Hathaway et al., 1976), and ODP Leg 150 Sites 902-904 and 906. Contour interval 100 m. SeaBeam bathymetric data provided by W.B.F. Ryan and D. Twitchell. MCS Profiles 1027 (thick line; Figs. 3, 7) and 1005 (thin line; Fig. 5) are indicated.

Figure 3. MCS profile EW9009 1027 crossing Sites 902 and 906. Top panel is processed data; bottom panel is line-drawing interpretation. Vertical scale is two-way traveltime (s). Reflector terminology and ages are given in Table 1. Note that Site 906 was drilled in a buried canyon cut at reflector m3 time.

Figure 4. Preliminary correlation of core and downhole log data with seismic reflectors, Site 902.

Figure 5. MCS profile EW9009 1005 crossing Site 903. Intersection with profile 1027 (Figs. 3, 7) is shown. Top panel is processed data; bottom panel is line-drawing interpretation. Vertical scale is two-way traveltime (s). Reflector terminology and ages are given in Table 1.

Figures 6A and 6B. Preliminary correlation of core and downhole log data with seismic reflectors, Site 903.

Figure 7. MCS profile EW9009 1027 crossing Sites 904 and 612 (Poag, Watts, et al., 1987). Profile is a continuation of Figure 3. Top panel is processed data; bottom panel is line-drawing interpretation. Vertical scale is two-way traveltime (s). Reflector terminology and ages are given in Table 1.

Figure 8. Preliminary correlation of core and downhole log data with seismic reflectors, Site 904.

Figure 9. Preliminary correlation of core and downhole log data with seismic reflectors, Site 905.

Figure 10. Preliminary correlation of core and downhole log data with seismic reflectors, Site 906.

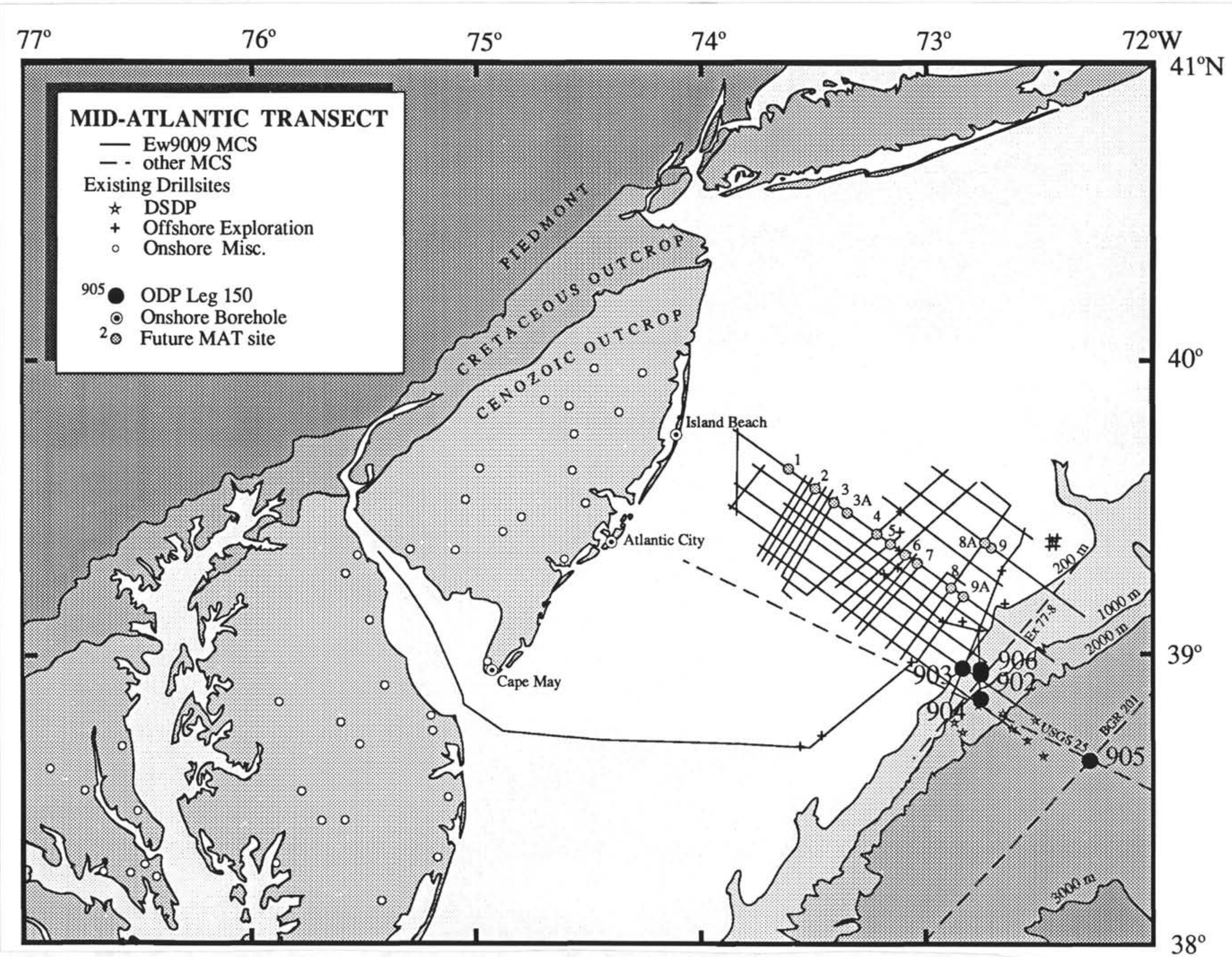

77°
76°
75°
74°
73°
72°W
41°N
40°
39°
38°
MID-ATLANTIC TRANSECT
Ew9009 MCS
other MCS
Existing Drillsites
DSDP
Offshore Exploration
Onshore Misc.
905 ODP Leg 150
Onshore Borehole
2 Future MAT site
PIEDMONT
CRETACEOUS OUTCROP
CENOZOIC OUTCROP
Island Beach
Atlantic City
Cape May
1
2
3
3A
4
5
6
7
8
8A
9
9A
903
906
902
904
905
200 m
1000 m
2000 m
3000 m
EX 77-8
USGS 25
BGR 201

Figure 1

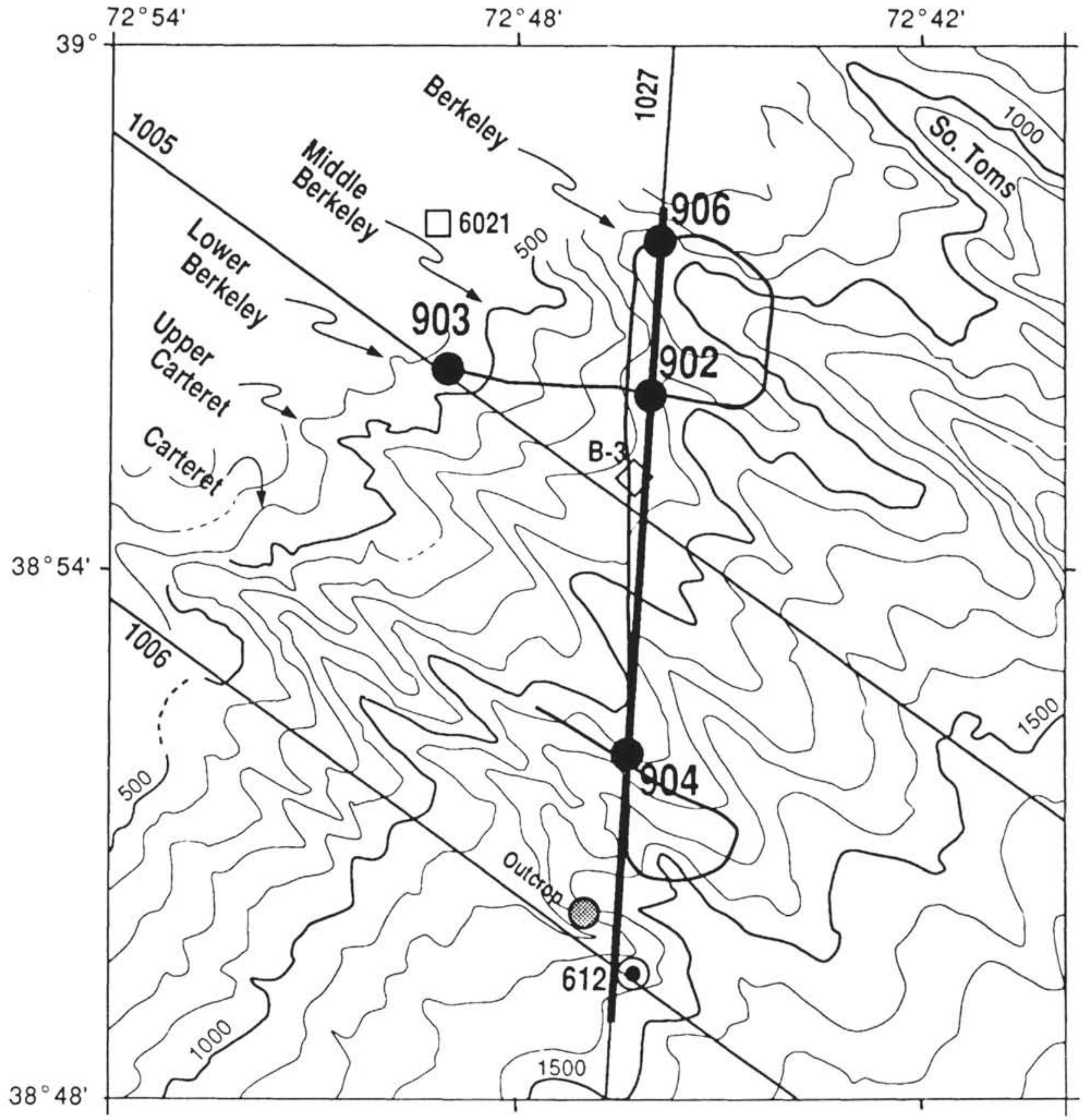

72°54'
72°48'
72°42'
39°
38°54'
38°48'
1005
1006
1027
Berkeley
Middle Berkeley
Lower Berkeley
Upper Carteret
Carteret
6021
906
903
902
B-3
904
Outcrop
612
So. Toms
1000
500
1500

Figure 2

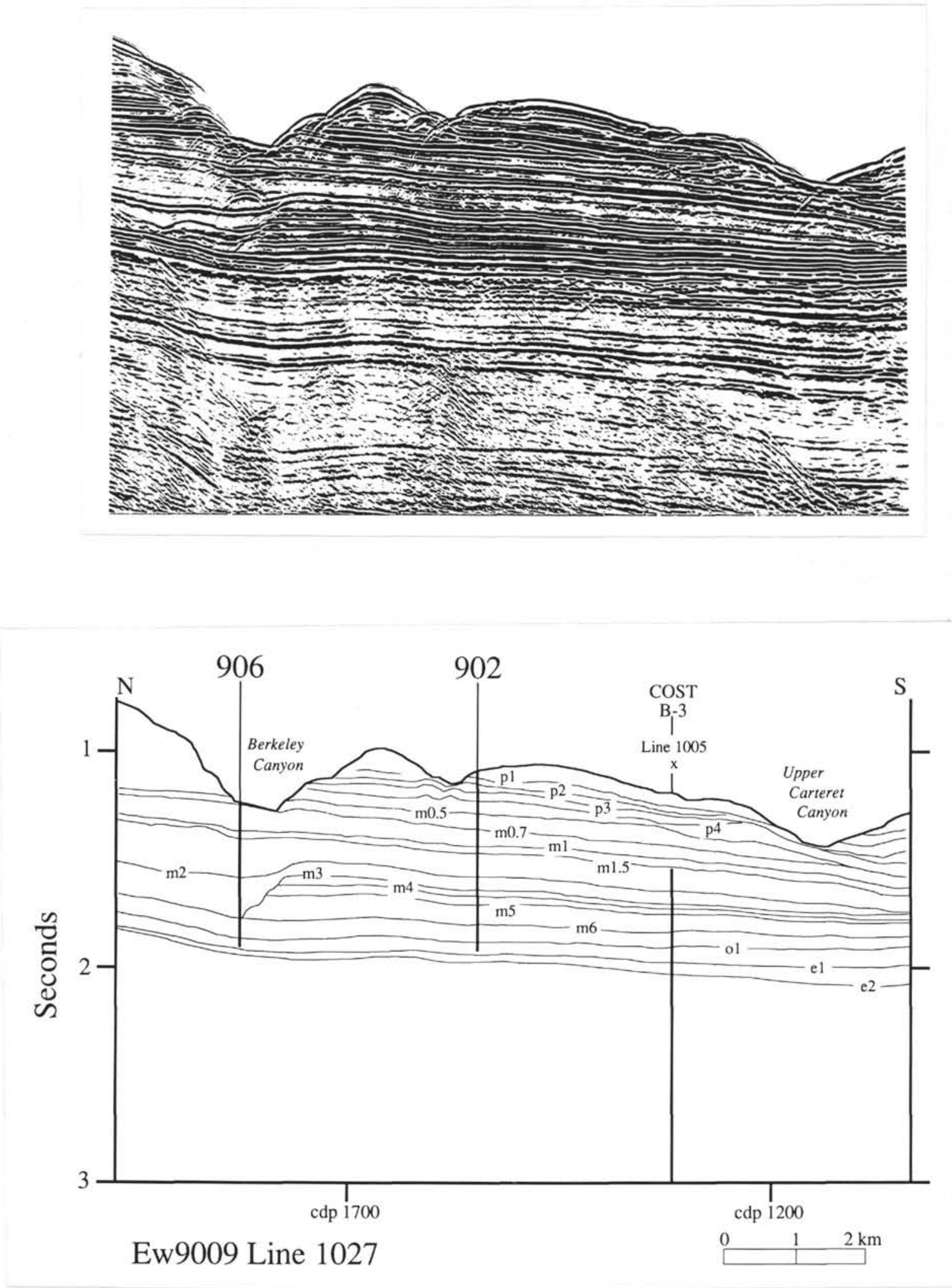

N
906
902
COST
B-3
Line 1005
x
S
Berkeley
Canyon
Upper
Carteret
Canyon
p1
p2
p3
p4
m0.5
m0.7
m1
m1.5
m2
m3
m4
m5
m6
o1
e1
e2
1
2
3
Seconds
cdp 1700
cdp 1200
0
1
2 km
Ew9009 Line 1027

Figure 3

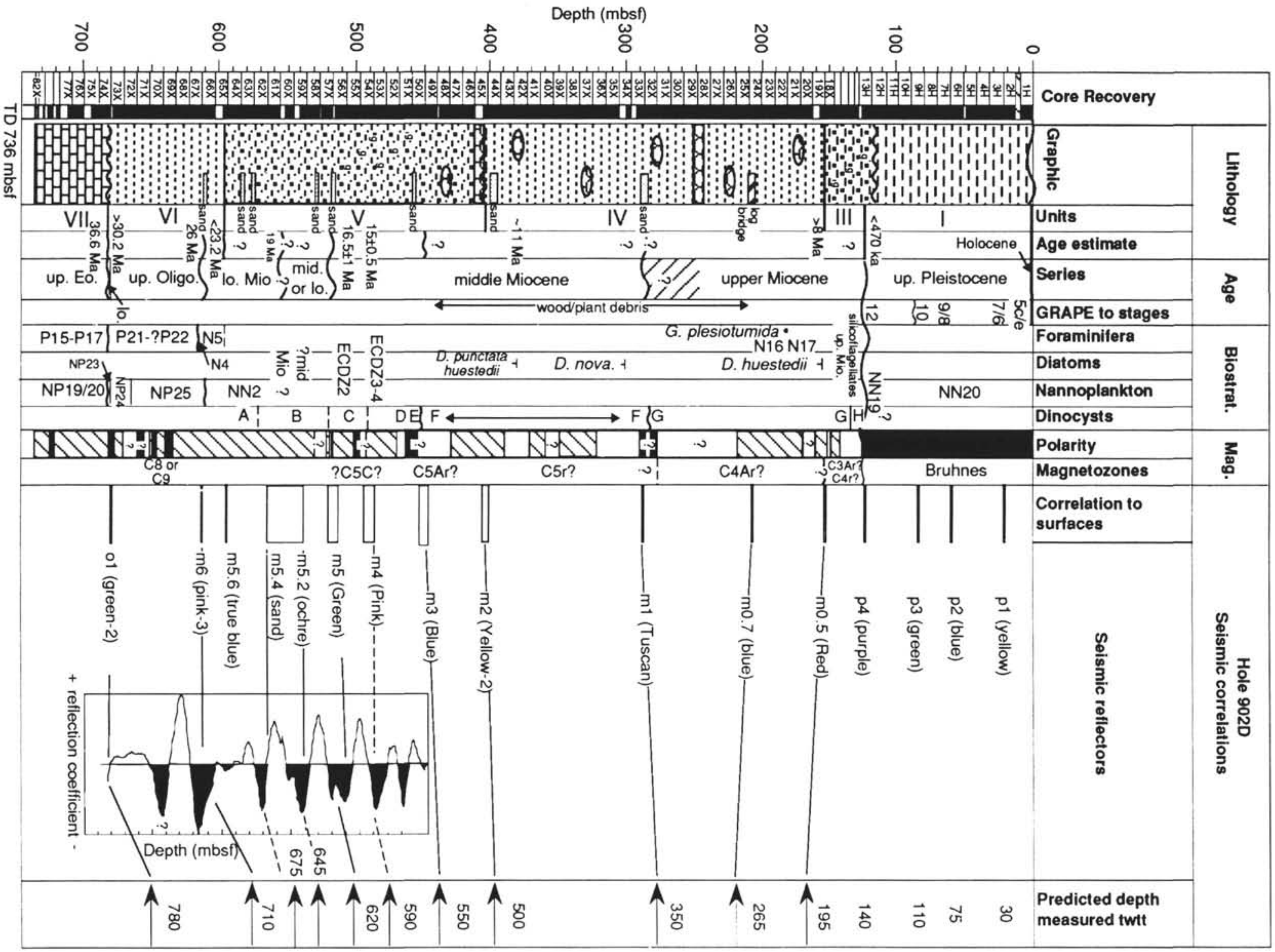

Depth (mbsf)
Core Recovery
Lithology
Graphic
Units
Age
Age estimate
Series
GRAPE to stages
Biostrat.
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Mag.
Polarity
Magnetozones
Correlation to surfaces
Hole 902D
Seismic correlations
Seismic reflectors
Predicted depth measured twtt
TD 736 mbsf
up. Eo.
up. Oligo.
lo. Mio
mid. or lo.
middle Miocene
upper Miocene
up. Pleistocene
Holocene
wood/plant debris
G. plesiotumida
D. punctata huestedii
D. nova.
D. huestedii
NP19/20
NP25
NN2
NN20
Bruhnes
C4Ar?
C5r?
C5Ar?
?C5C?
p1 (yellow)
p2 (blue)
p3 (green)
p4 (purple)
m0.5 (Red)
m0.7 (blue)
m1 (Tuscan)
m2 (Yellow-2)
m3 (Blue)
m4 (Pink)
m5 (Green)
m5.2 (ochre)
m5.4 (sand)
m5.6 (true blue)
m6 (pink-3)
o1 (green-2)
+ reflection coefficient -

Figure 4

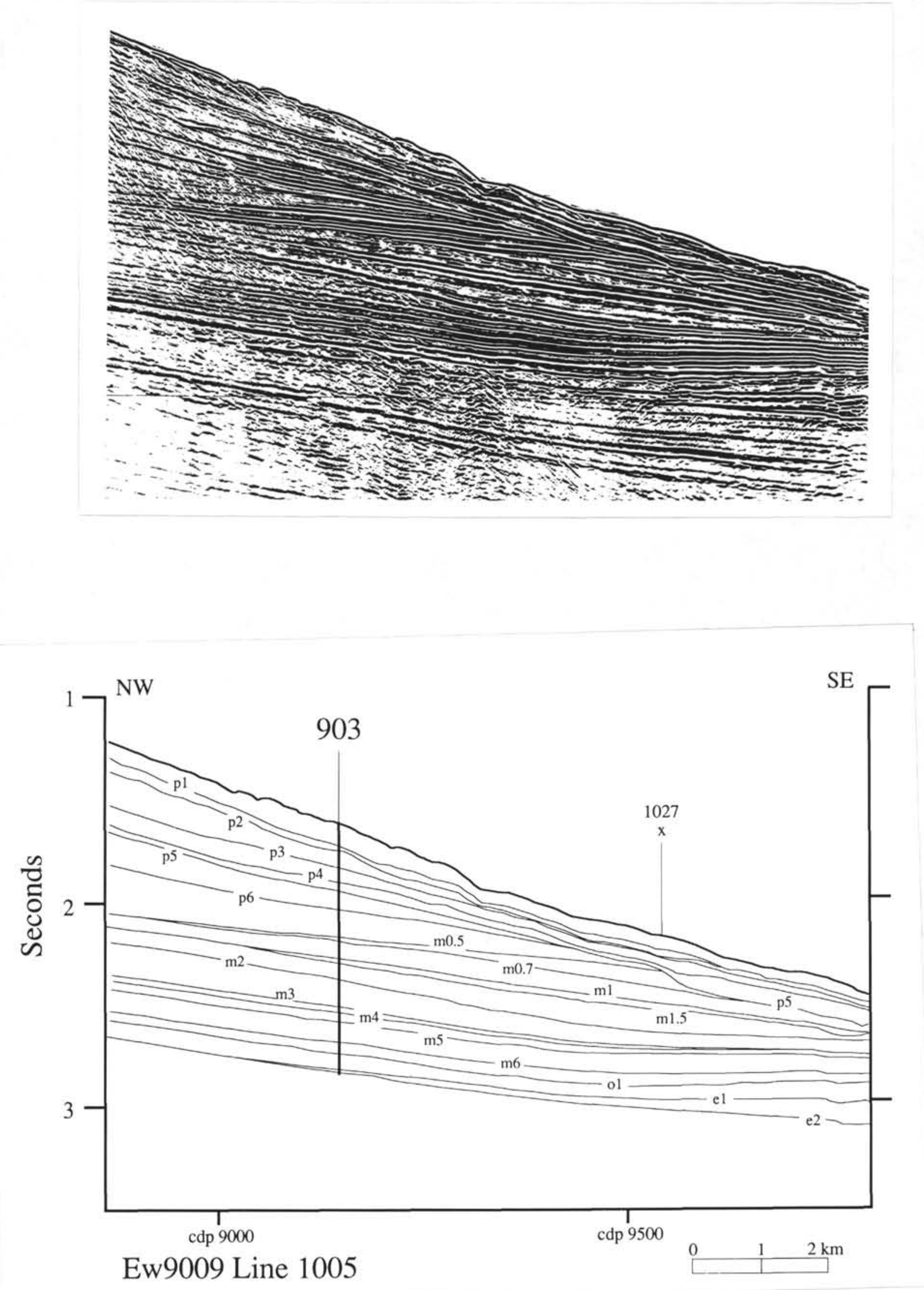

NW
SE
1
2
3
Seconds
903
1027
x
p1
p2
p3
p4
p5
p6
m0.5
m0.7
m1
m1.5
m2
m3
m4
m5
m6
o1
e1
e2
cdp 9000
cdp 9500
0
1
2 km
Ew9009 Line 1005

Figure 5

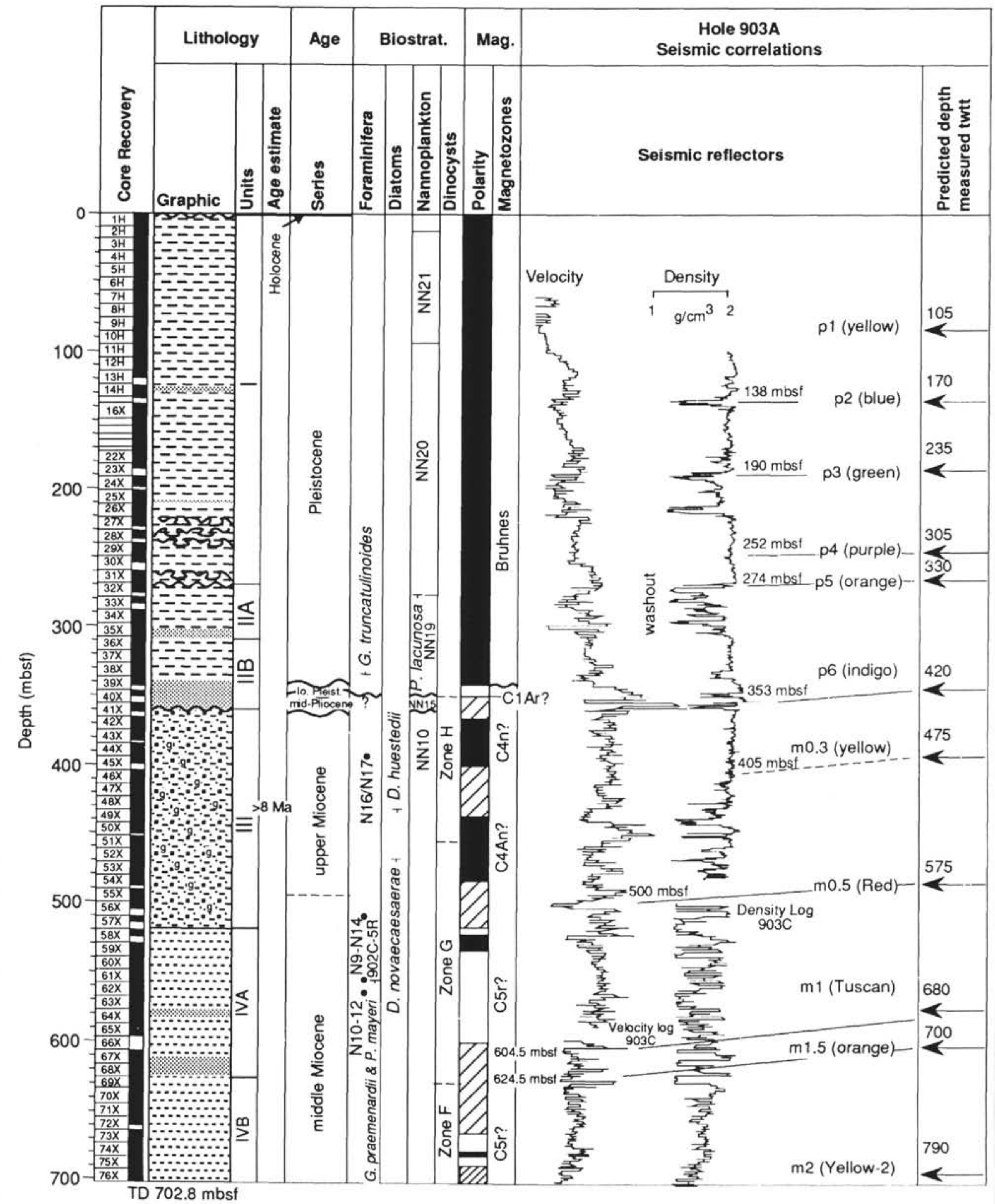

Hole 903A
Seismic correlations
Core Recovery
Lithology
Graphic
Units
Age estimate
Age
Series
Biostrat.
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Mag.
Polarity
Magnetozones
Seismic reflectors
Predicted depth
measured twtt
Depth (mbsf)
TD 702.8 mbsf
Holocene
Pleistocene
upper Miocene
middle Miocene
lo. Pleist.
mid-Pliocene
>8 Ma
I
IIA
IIB
III
IVA
IVB
G. truncatulinoides
N16/N17
N10-12
N9-N14
902C-5R
G. praemenardii & P. mayeri
D. huestedii
D. novaecaesaerae
NN21
NN20
P. lacunosa
NN19
NN15
NN10
Zone H
Zone G
Zone F
Bruhnes
C1Ar?
C4n?
C4An?
C5r?
Velocity
Density
1 g/cm3 2
washout
138 mbsf
190 mbsf
252 mbsf
274 mbsf
353 mbsf
405 mbsf
500 mbsf
Density Log 903C
Velocity log 903C
604.5 mbsf
624.5 mbsf
p1 (yellow)
p2 (blue)
p3 (green)
p4 (purple)
p5 (orange)
p6 (indigo)
m0.3 (yellow)
m0.5 (Red)
m1 (Tuscan)
m1.5 (orange)
m2 (Yellow-2)
105
170
235
305
330
420
475
575
680
700
790

Figure 6A

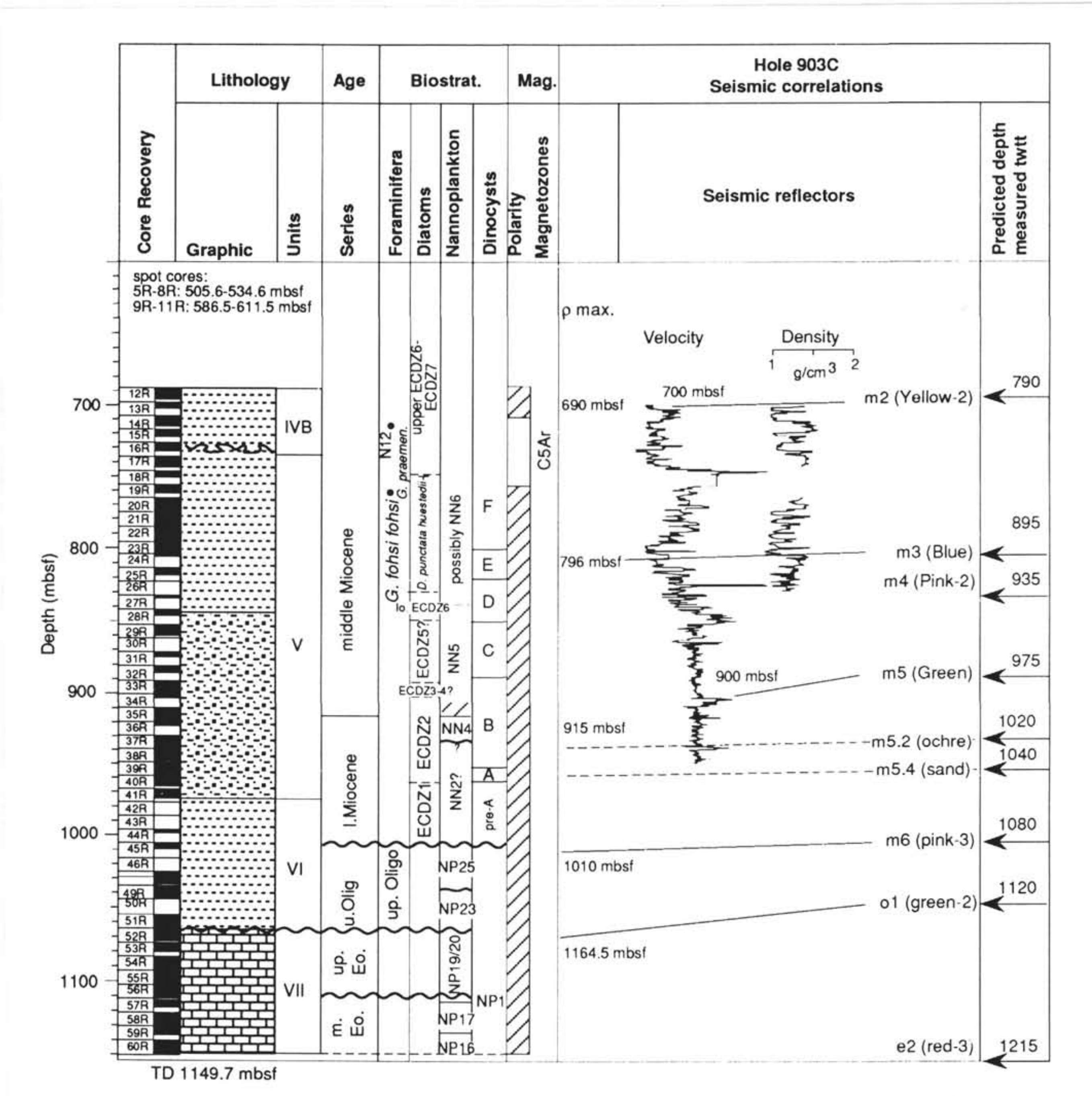

Core Recovery
Lithology
Graphic
Units
Age
Series
Biostrat.
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Mag.
Polarity
Magnetozones
Hole 903C
Seismic correlations
Seismic reflectors
Predicted depth
measured twtt
Depth (mbsf)
spot cores:
5R-8R: 505.6-534.6 mbsf
9R-11R: 586.5-611.5 mbsf
700
800
900
1000
1100
IVB
V
VI
VII
middle Miocene
l.Miocene
u.Olig
up. Eo.
m. Eo.
up. Oligo
N12
G. fohsi fohsi
G. praemen.
upper ECDZ6-ECDZ7
D. punctata huestedii
ECDZ6
ECDZ5?
ECDZ3-4?
ECDZ2
ECDZ1
possibly NN6
NN5
NN4
NN2?
NP25
NP23
NP19/20
NP17
NP16
NP1
F
E
D
C
B
A
pre-A
C5Ar
ρ max.
Velocity
Density
g/cm3
690 mbsf
700 mbsf
796 mbsf
900 mbsf
915 mbsf
1010 mbsf
1164.5 mbsf
m2 (Yellow-2)
m3 (Blue)
m4 (Pink-2)
m5 (Green)
m5.2 (ochre)
m5.4 (sand)
m6 (pink-3)
o1 (green-2)
e2 (red-3)
790
895
935
975
1020
1040
1080
1120
1215
TD 1149.7 mbsf

Figure 6B

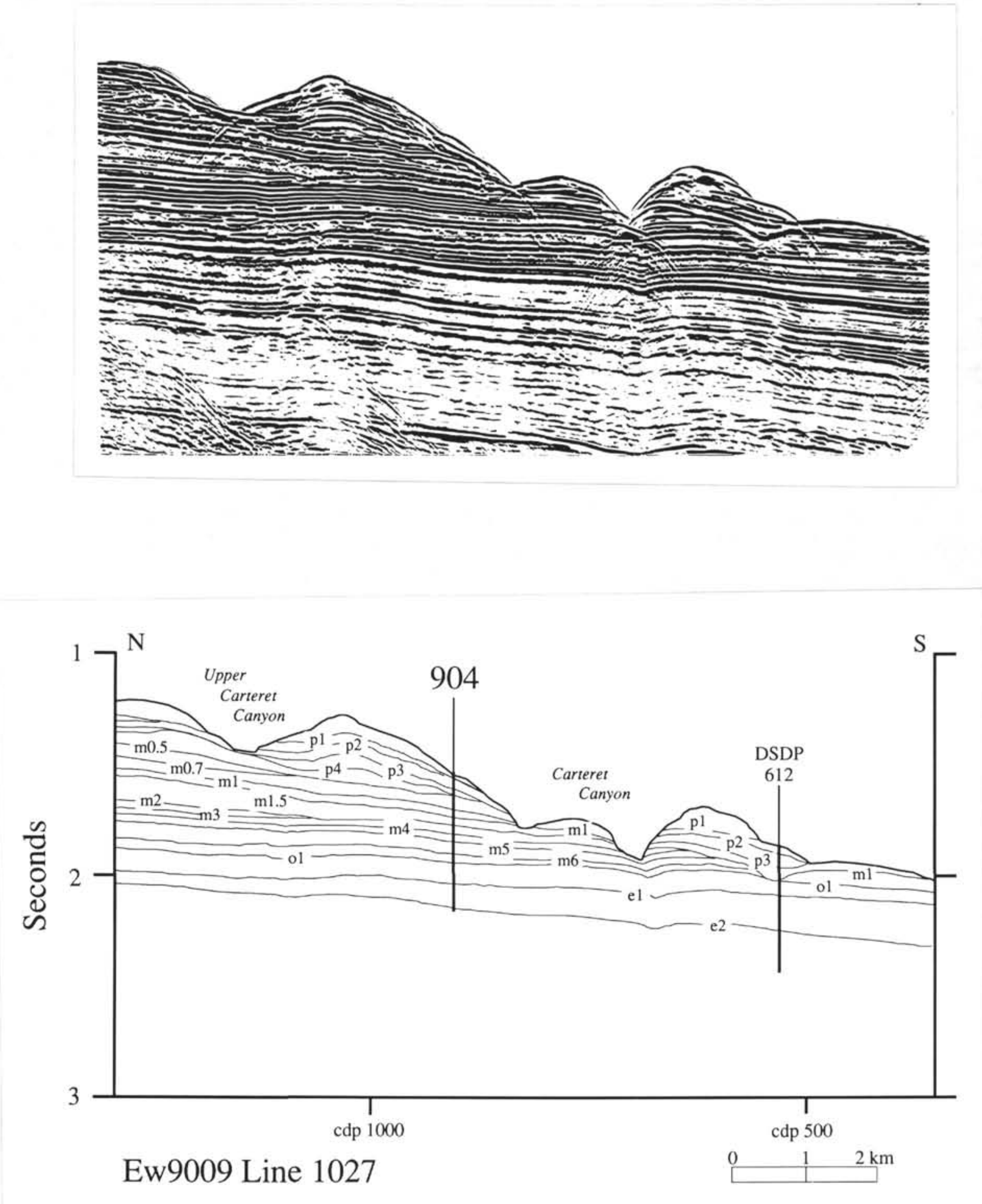

N
S
1
2
3
Seconds
Upper
Carteret
Canyon
904
p1
p2
m0.5
m0.7
p4
p3
m1
m2
m3
m1.5
m4
o1
Carteret
Canyon
DSDP
612
m1
m5
m6
p1
p2
p3
m1
o1
e1
e2
cdp 1000
cdp 500
0
1
2 km
Ew9009 Line 1027

Figure 7

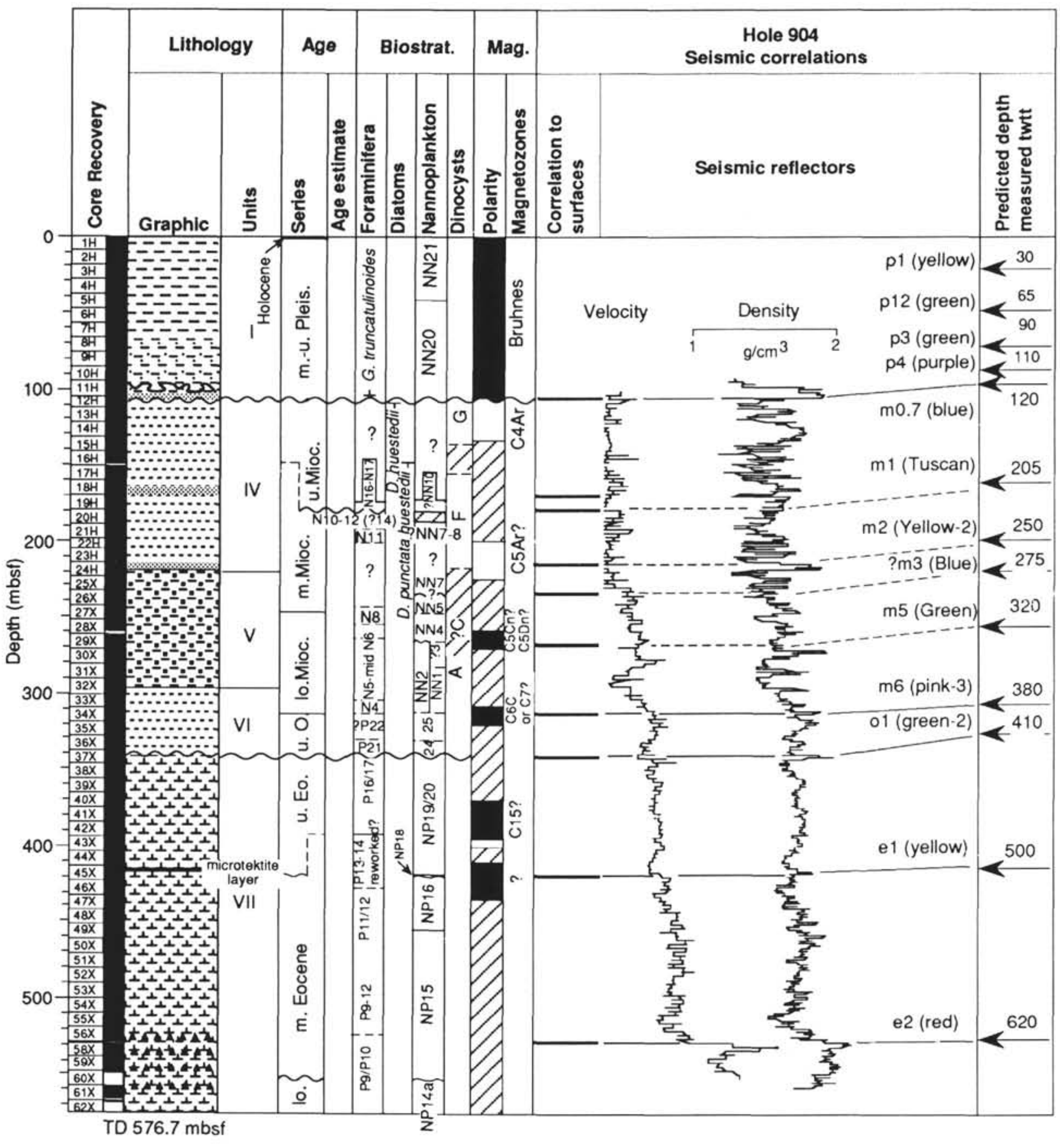

Core Recovery
Lithology
Graphic
Units
Age
Series
Age estimate
Biostrat.
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Mag.
Polarity
Magnetozones
Hole 904
Seismic correlations
Correlation to surfaces
Seismic reflectors
Predicted depth measured twtt
Depth (mbsf)
Velocity
Density
g/cm3
p1 (yellow)
p12 (green)
p3 (green)
p4 (purple)
m0.7 (blue)
m1 (Tuscan)
m2 (Yellow-2)
?m3 (Blue)
m5 (Green)
m6 (pink-3)
o1 (green-2)
e1 (yellow)
e2 (red)
microtektite layer
TD 576.7 mbsf

Figure 8

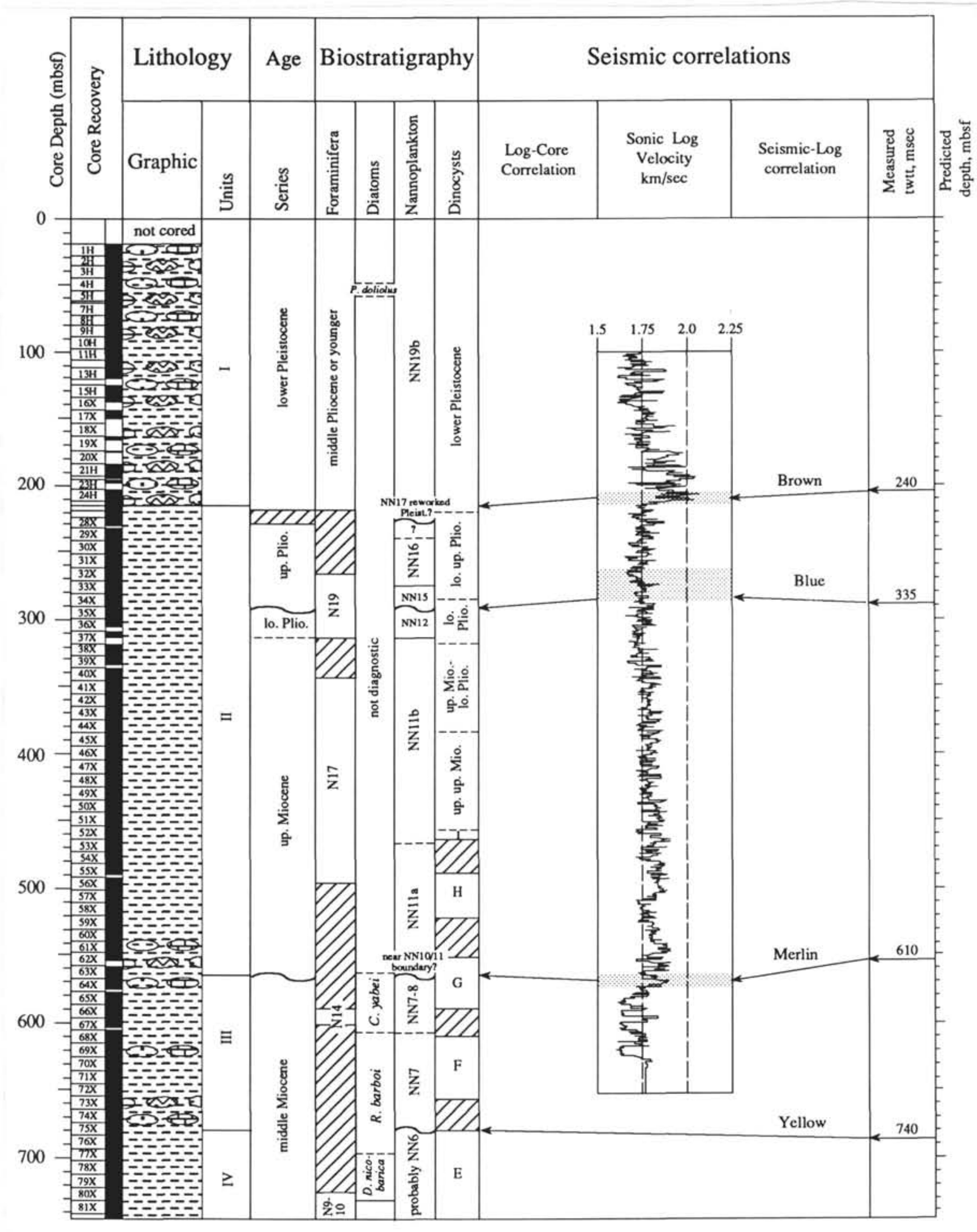
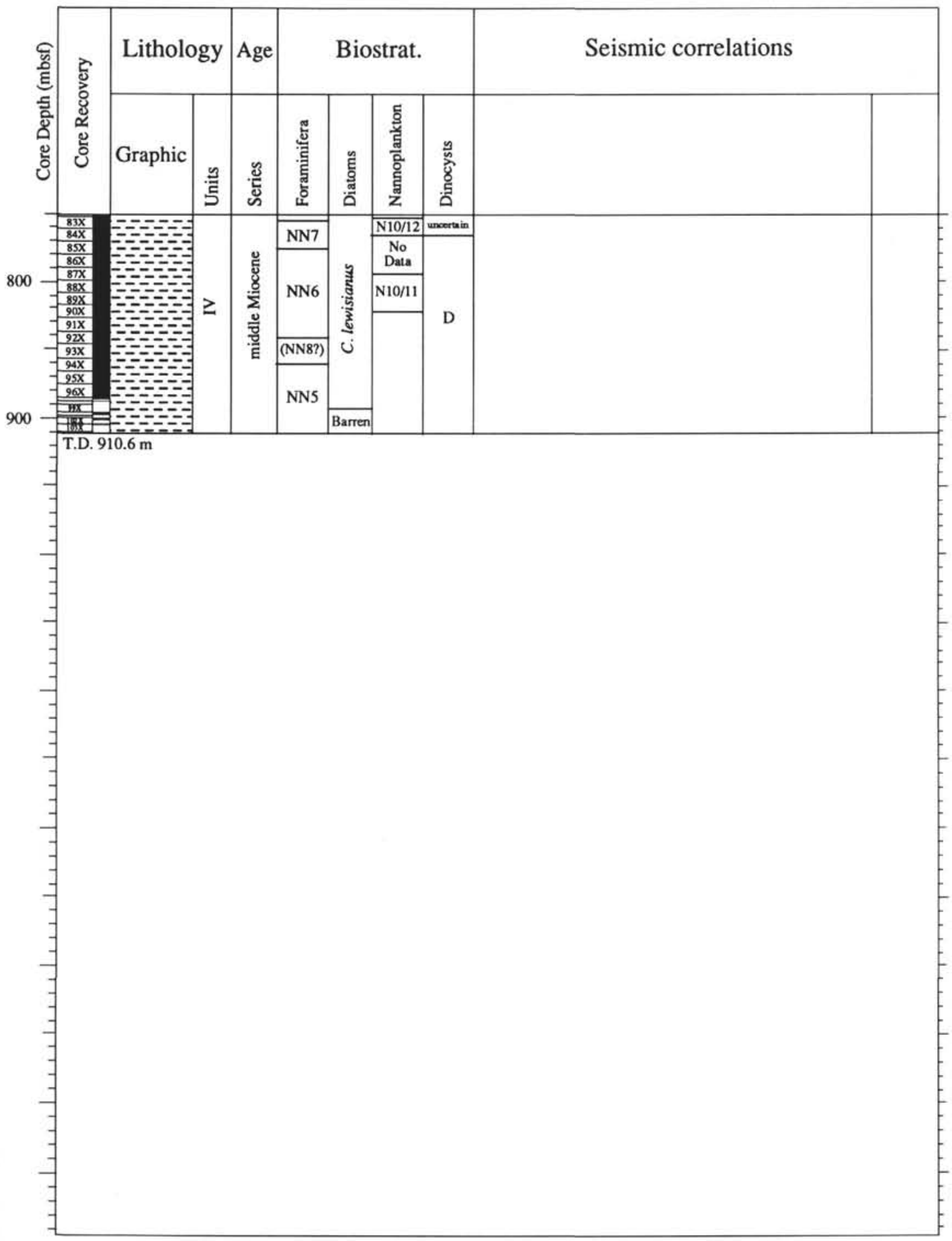

Core Depth (mbsf)
Core Recovery
Lithology
Graphic
Units
Age
Series
Biostratigraphy
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Seismic correlations
Log-Core Correlation
Sonic Log Velocity km/sec
Seismic-Log correlation
Measured twtt, msec
Predicted depth, mbsf
not cored
lower Pleistocene
middle Pliocene or younger
P. doliolus
NN19b
NN17 reworked Pleist.?
up. Plio.
lo. Plio.
up. Miocene
middle Miocene
NN16
NN15
NN12
NN11b
NN11a
near NN10/11 boundary?
NN7-8
NN7
probably NN6
N19
N17
N14
N9-10
not diagnostic
C. yabei
R. barboi
D. nicobarica
lo. up. Plio.
lo. Plio.
up. Mio.- lo. Plio.
up. up. Mio.
H
G
F
E
I
II
III
IV
1.5
1.75
2.0
2.25
Brown
Blue
Merlin
Yellow
240
335
610
740
0
100
200
300
400
500
600
700

Figure 9


Core Depth (mbsf)
Core Recovery
Lithology
Graphic
Units
Age
Series
Biostrat.
Foraminifera
Diatoms
Nannoplankton
Dinocysts
Seismic correlations
800
900
IV
middle Miocene
NN7
NN6
(NN8?)
NN5
C. lewisianus
Barren
N10/12
No Data
N10/11
uncertain
D
T.D. 910.6 m

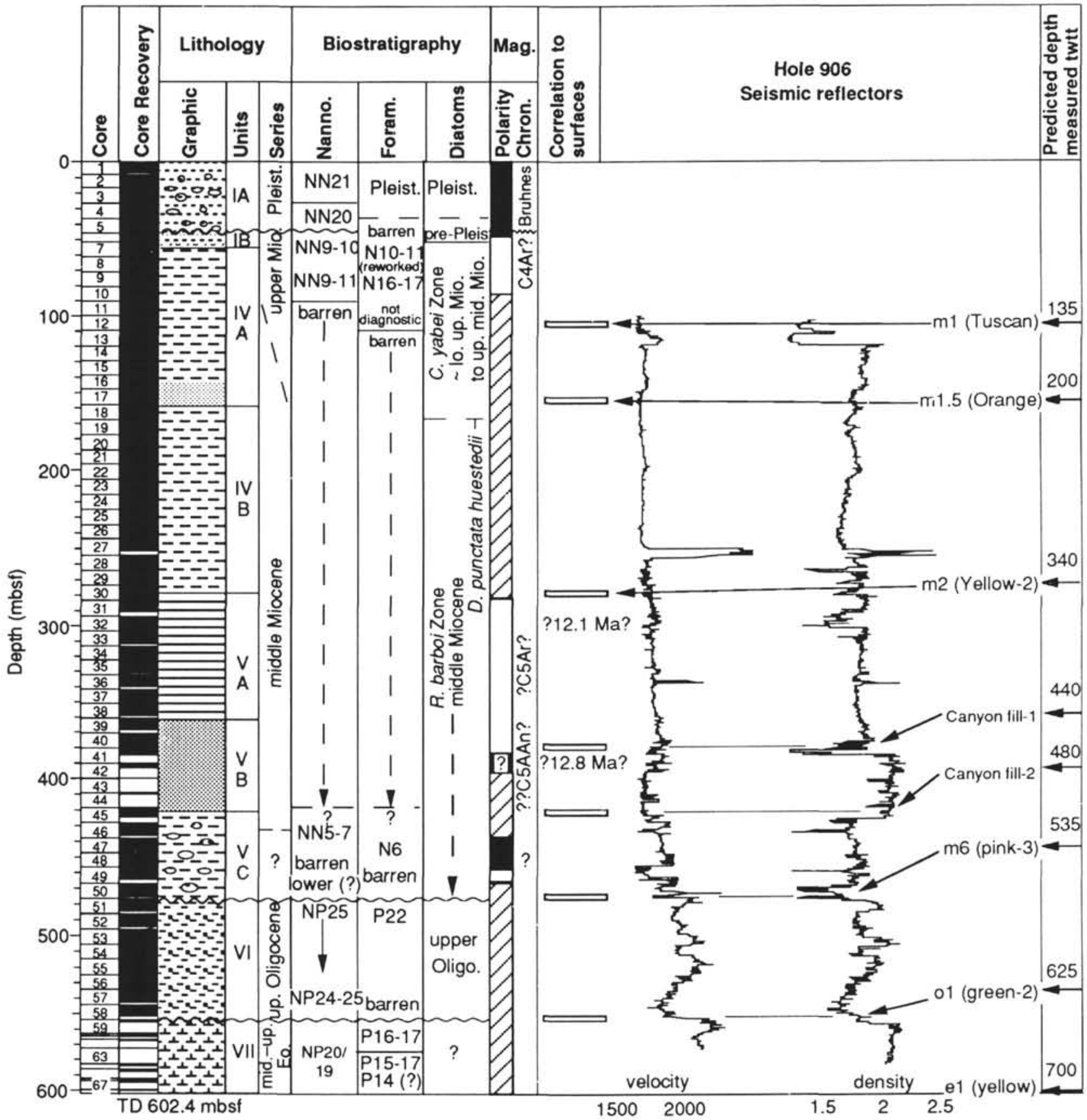

Core
Core Recovery
Lithology
Graphic
Units
Series
Biostratigraphy
Nanno.
Foram.
Diatoms
Mag.
Polarity
Chron.
Correlation to surfaces
Hole 906
Seismic reflectors
Predicted depth measured twtt
Depth (mbsf)
IA
IB
IV A
IV B
V A
V B
V C
VI
VII
Pleist.
upper Mio.
middle Miocene
up. Oligocene
mid.–up. Eo.
NN21
NN20
NN9-10
NN9-11
barren
NN5-7
barren
lower (?)
NP25
NP24-25
NP20/19
Pleist.
barren
N10-11
(reworked)
N16-17
not diagnostic
barren
N6
barren
P22
barren
P16-17
P15-17
P14 (?)
Pleist.
pre-Pleis
C. yabei Zone
~ lo. up. Mio. to up. mid. Mio.
R. barboi Zone
middle Miocene
D. punctata huestedii
upper Oligo.
Bruhnes
C4Ar?
?C5Ar?
??C5AAn?
?12.1 Ma?
?12.8 Ma?
m1 (Tuscan)
m1.5 (Orange)
m2 (Yellow-2)
Canyon fill-1
Canyon fill-2
m6 (pink-3)
o1 (green-2)
e1 (yellow)
135
200
340
440
480
535
625
700
velocity
density
1500
2000
1.5
2
2.5
TD 602.4 mbsf

Figure 10

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 150 were:

Operations Superintendent:	Glen Foss
Staff Superintendent:	Pat Thompson
Schlumberger Engineer:	Pablo Saldungaray

INTRODUCTION

During Leg 150, four drill sites on the continental slope and one on the continental rise were investigated. Eleven holes were drilled, and over four kilometers of core were recovered. All sites were logged. The primary depth objectives were reached at all the continental slope sites, but the site on the continental rise (Site 905) had to be terminated short of its goal because of a hydrocarbon hazard. Investigators stated that over 90% of the scientific objectives of the leg were met.

The above accomplishments were achieved in just 38.4 days of site occupancy. The voyage also encompassed over 4300 nautical miles of steaming.

Operational highlights and notable achievements of the leg included:

- A total cored interval of 4602 m with an overall core recovery rate of 87.6%
- Setting the longest drill-in casing string to date (11-3/4" casing to 149 mbsf)
- Using unscheduled reentries to sustain interrupted operations in two holes
- Evaluation of the anti-whirl PDC core bit as an effective tool for coring siliciclastic sediments

LISBON PORT CALL AND TRANSIT TO FIRST SITE

ODP Leg 150 began with arrival at Santa Apolonia Dock, Lisbon Harbor, at 0830 25 May 1993. The port call was relatively light in terms of logistical and repair activity. The major and pacing work item of the port call was the installation of a new satellite communication system by ODP. Other important jobs were the installation of the "LAWS" weather satellite receiving system, extensive maintenance and repairs to the drill-string motion compensator, and semi-annual maintenance and inspection of the rig's hoisting equipment. The latter two jobs were begun in port and completed during the transit to the first drill site. The required in-port work was completed during the night of 27-28 May, and the vessel departed at 0745 28 May.

When *JOIDES Resolution* had cleared Lisbon Harbor and the Tagus estuary, a rhumb-line course was set nearly due west for the operating area. The great-circle route was not taken because of the possibility of encountering icebergs and because it would have been directly into the main flow of the Gulf Stream current.

Almost from the beginning, rough-weather conditions prevailed, with 25-35 knot winds from the southwesterly quadrant the rule. Each day seemed to bring a new weather front. On 4 June, the remnants of the first numbered tropical depression of the year produced wind gusts to 48 knots. The following day, a developing storm struck from the northwest with gusts to 66 knots and forced the ship onto a southwesterly course for three hours to minimize the effects and duration of the storm. Weather conditions improved for the final three days of the transit, but opposing Gulf Stream currents limited speed over ground.

The two days gained by the brief port call were lost on the Atlantic crossing. Average transit speed for the 2952 nautical miles (nmi) from Lisbon to the survey way point was only 9.2 knots. At 1115 10 June, speed was reduced, and the seismic profiling gear was deployed.

An extensive preliminary survey was conducted to tie in the navigation of previous surveys used for reference in locating the drill sites. A dip line was run from about six nmi seaward of proposed site MAT-14 across the continental rise, up the continental slope, and across site MAT-12. Double crossings of slope sites MAT-15, 16, 10, and 11 were made before steaming northeastward about four nmi to record cross lines over site MAT-13. The seismic gear then was recovered, and the ship returned to the area of MAT-10, where a 2-1/4 hour precision depth recorder (PDR) survey was made to fix the final drilling location. At 0830 11 June, a positioning beacon was launched to begin site operations for the leg.

SITE 902

Hole 902A

The initial drill site of Leg 150 is located on the continental slope, about 79 miles off Barnegat Inlet, New Jersey, in approximately 800 m of water. The irregular bathymetry of the continental slope resulted in a discrepancy of 24 m between the corrected PDR depth reading and the actual seafloor depth below the vessel. That, in turn, caused a loss of about an hour in "feeling for bottom" and a premature spud attempt that recovered only water.

At 1545 hr, Hole 902A was spudded with an APC core "shot" from 819.5 m below driller's datum, the dual elevator stool (DES), to 829 m. Just under three meters of core were recovered, so water depth was set at 826 m. Continuous APC coring then began in clay that became quite stiff within one meter of the seafloor. Temperature measurements with the "Adara" shoe and magnetic core orientation were begun with Core 150-902A-3H.

The APC was being lowered for Core 150-902A-4H while the hole was being reamed to the depth of the top of the core interval when the coring assembly inadvertently was landed at the outer core barrel (OCB). The impact of landing caused the APC shearpins to fail and the corer to extend outside the bit. Attempts to recover the APC were unsuccessful, and a round trip of the drill string was necessary to recover the APC assembly.

Hole 902B

Hole 902B was spudded at 0130 hr, 12 June, with 20 m west offset relative to Hole 902A. The bit was positioned at 823 m for the "mud line" core to maximize core length while still recovering the seafloor interface. A full core barrel was recovered, indicating that the bit had been positioned below the seafloor for the shot. It was decided to start a new hole and try to recover the mud line.

Hole 902C

At Hole 902C, the corer was actuated from 818 m and found the seafloor at 822 m below DES (811 m below sea level) to begin continuous coring. Orientation and Adara temperature-shoe measurements again began with Core 150-902C-3H. Full stroke could be achieved through only the upper 43 meters in the exceptionally stiff silty clay. Orientation and temperature work were suspended after short cores and plastic liner failures on Cores 150-902C-6H and -7H to protect the instrumentation from impact damage. Though full-stroke indication was not regained, a lithology change to siltier material produced better coring conditions on the ensuing cores. Coring continued on an advance-by-recovery basis, but the majority of the liners were full. Cores were quite gassy below the heavy clay, and much of the "recovery" was due to numerous gas separations and "puffing" of the core. One additional temperature measurement was attempted on Core 150-902C-10H at 78 mbsf and was successful.

An isolated occurrence of relatively heavy gases of suspected thermogenic origin was noted in association with thin sand beds around 90 mbsf. Geochemical studies later indicated a biogenic origin. The total gas concentration already was decreasing at that depth, however, and gas quantity fell off sharply below about 120 mbsf.

At 130 mbsf, liner failures and decreasing penetration indicated that the effective penetration refusal point was near. Coring was terminated to begin the scheduled deeper APC/XCB hole, and the bit was pulled above the seafloor.

Hole 902D

After an additional positioning offset of 20 m west, a seafloor APC core fixed water depth at 819 m below driller's datum (808 m below sea level). To provide stratigraphic overlap, a 3.5 m interval was drilled from 9.0 to 12.5 mbsf. This later proved unnecessary because topography apparently offset the stratigraphic sections sufficiently relative to the seafloor. Continuous coring commenced with Core 150-902D-2H and proceeded to penetration refusal at 145 mbsf (Core150-902D-17H). Incomplete stroke began with Core 150-902D-5H, and all subsequent APC cores were on an advance-by-recovery basis. The temperature shoe was deployed on Cores 150-902D-6H to -16H with good success despite the repeated high impacts.

Coring continued with the XCB system. The fifth XCB barrel to be dropped came to an abrupt halt due to a damaged joint of pipe. Coring resumed after one hour's delay. A high rate of penetration (ROP) and good core recovery continued until coring was halted at 507 mbsf for the first logging stage. The hole was flushed with drilling mud, and a "wiper" trip was started at 0715 hr, 14 June, to condition the hole. No significant overpull was felt as the bit was raised to 75 mbsf and started back down the hole, but a solid obstruction was encountered at 291 mbsf on the down-trip. It yielded to circulation and rotation after the top drive was reinstalled. The top drive was then left in the string, and the hole was clean back to total depth with no further impediment. After an additional mud flush, the bit was pulled to logging depth at 82 mbsf.

The logging sheaves were rigged, and a sonic-induction-gamma-ray tool string was run for the first logging attempt. The tool descended freely until it met an obstacle at 215 mbsf. Efforts to work the tool past the bridge or ledge were unsuccessful, so logs were recorded over the available open-hole interval. To maximize the log interval, the blocks were raised until the bit was only 53 mbsf. Further logging attempts were deferred until the hole reached total depth.

As the performance of the XCB system had been exemplary beyond 500 mbsf, the decision was to continue deepening Hole 902D. When the logging sheaves had been rigged down, the drill string was run back to total depth. No sign of the obstacle at 215 mbsf was noted on the rig's weight indicator, but the bit again was stopped at 288 mbsf. Several minutes were required to open the hole using circulation only. Use of the top drive was avoided deliberately for the down-trip to determine if the side-entry sub (SES) could be used to place the logging tools below the obstructions. Two other minor bridges were cleared at 424 and 462 mbsf by means of the circulating head. Five meters of fill or tight hole were found at total depth.

XCB coring resumed at midnight 14/15 June. Excellent core recovery and ROP continued to 681 mbsf, where the lithology changed to chalk. One of the main bit's polycrystalline diamond compacts was recovered intact in the top of Core 150-902D-66X from 603 mbsf. Both recovery and ROP fell off rapidly in the chalk and became worse as induration increased with depth. Sufficient water could not be delivered to the XCB cutting shoe to "lubricate" it because small passages in the shoe became plugged. Consequently the cores became jammed off in the shoes. BHA weight was supported by the jammed-off core and was not applied to the cutting structure of either the bit or the cutting shoe. Coring was discontinued 70 m short of the ultimate target when Cores 150-902D-81X and -82X produced only about 30 cm of core each, and four hours of rotating time were required to advance 6.7 m.

Preparations for logging included a wiper trip, circulating bridges or ledges out at 292 and 448 mbsf, flushing ten meters of accumulated fill from the hole, and making up the SES into the string. The first logging tool (induction-sonic-gamma ray) was started down the pipe at 0230 hr, 17 June. An attempt was made to run the logging tool down into open hole after three stands of pipe had been run, but the tool came to rest on an obstruction only 55 m below the bit. After the tool was pulled back inside the drill string, the string was lowered until fill was tagged 10 m short of total depth. A successful log then was recorded from 677 to 103 mbsf as the tool followed the drill string back up the hole.

The same (SES) technique was used to obtain a log from 710-121 mbsf with the litho-porosity combination tool string. After a false start due to failure of the formation microscanner (FMS) tool, the backup tool was deployed for a successful log from 698-506 mbsf in a deteriorating hole. Caliper log records showed the hole to be in poor condition above about 500 mbsf, with numerous washouts and irregularities. Two or three restrictions in the hole almost certainly would have precluded logging without the use of the SES.

While the logging tools were being rigged down, the "Adara" temperature recorder was deployed on the coring line for a check on the seafloor baseline temperature. Downhole measurements were completed at 0730 hr, 18 June.

The bit was returned to a solid obstruction at 677 mbsf, from which the hole was displaced with 10 lb/gal mud. After the mud had been emplaced, the string was pulled to 141, mbsf and cement slurry was spotted from about 141-120 mbsf before the bit was pulled from the hole. When the residual cement slurry had been flushed from the drill string, the recallable positioning beacons were recovered. The drill string then was tripped for a bit change, and the DP move to Site 903 began. Site 902 was abandoned officially at 1430 hr, 18 June.

SITE 903

Hole 903A

A beacon was launched at 1530, 18 June. Because water depth was only about 540 m, low-power acoustic beacons were used. An additional 2-1/4 hours were spent in refining the position of the drill site by offsetting on the reference beacon to the proper water depth with the core bit a few meters above the seafloor. The soft sediment produced no clear indication of bit contact with the seafloor. An APC core "shot" with the bit positioned at 455.5 m from driller's datum recovered over 9.3 m of core, and seafloor depth was established at 455.5 m.

Continuous APC cores were taken to 169.5 mbsf. Temperature-shoe measurements were taken on Cores 150-903A-3H through -16H. Indication of incomplete stroke began with Core 16H at about 145 mbsf, and coring continued through Core 150-903A-20H by the advance-by-recovery technique. Following the switch to extended core barrel (XCB) coring, generally high core recovery was achieved to 703 mbsf (Table 1). Hole conditions were still excellent when coring was stopped for logging. The decision to terminate the hole at that depth in favor of the deeper RCB penetration was predicated partly on the desire to log before time and increased circulation could degrade the condition of the hole.

The initial logging attempt, without the side-entry sub (SES), was with the induction-sonic-gamma ray tool string. Though the logging tool had to be "worked" past several impediments, it eventually reached a depth of 604 mbsf. A good log was recorded from that depth up to the bit at 74 mbsf. On the second log run, the lithoporosity combination string would not pass a bridge/ledge at 492 mbsf. Again, good results were obtained over the upper hole interval, which the caliper log showed to be in much better condition than the equivalent depth interval in Hole 902D. Logging operations were terminated, the hole plugged, and the bit pulled clear at 1700, 21 June.

Hole 903B

While the vessel was being offset 15 m to the northeast, the drill string was flushed of cement, and the top drive was deployed. At 1900, the APC was actuated to spud Hole 903B from 450 m. Two meters of sediment were recovered to fix seafloor depth at 457.5 m. Coring operations consisted of a series of 17 consecutive APC cores offset 5.5 m vertically from the coring intervals of Hole 903A. Cores 150-903B-9H, -16H, and -17H gave incomplete-stroke indication, but the 9.5 m-advance coring mode was used to preserve stratigraphic overlap. After the flurry of 17 cores in six hours, the drill string was recovered and Hole 903B terminated.

Hole 903C

RCB bottom hole assembly (BHA) and a drill-in casing (DIC) string were installed. The casing-running operation began at 0315, 22 June. By 1415, eleven joints of 11-3/4" casing had been assembled into a 149 m DIC string, attached to the BHA, and fitted with a reentry funnel. When the assembly had been run to the seafloor, the top drive was deployed, and Hole 903C was spudded at 1530, 22 June. After release of the casing, 9-7/8" hole was drilled ahead to 485 mbsf, where "spot" cores were taken over an interval that was incompletely recovered in Hole 903A.

No core was recovered in two coring attempts, and the drill string was tripped to find and remedy the problem. The bit core guide was found to be jammed tightly by a carbonate/sand concretion with clay and silt packed around it. The bit was removed and, while the obstruction was being cleared, radial cracks were noted around the spearpoint inserts of the bit cones. A new bit and mechanical bit release (MBR) were installed, the OCB spacing was checked, and the bit was run back to reentry depth. About one hour was required to position the bit over the funnel. Part of that time was spent with the bit stuck in the mud upslope of the funnel and preventing the BHA from moving over the hole. Visibility was too poor to discern the problem. A successful reentry was made at 2100, 23 June, and the VIT was recovered before the trip resumed.

A bridge or ledge was encountered at 452 mbsf, so the top drive was deployed to clean the hole to total depth. Coring operations then resumed with two short cores which again had no recovery. Circulating pressure and markings on the deplugger put in place all indicated normal seating. Four additional cores (150-903C-5R to -8R) were taken to 535 mbsf with about 40% recovery in sandy sediment. Drilling continued to 689 mbsf with spot cores across the interval from 587 to 612 mbsf. Continuous coring resumed at that depth and proceeded with variable core recovery. Poorest recovery seemed to be in sand beds near intervals of presumed sequence boundary reflectors. Other factors in occasional substandard recovery were mechanical problems with the core barrels and the unavoidable lag in adjusting coring parameters to changing lithologies. Overall, RCB recovery for the 60 cores attempted to total depth (including the ill-fated spot cores) was 60%. Coring conditions in the chalk (from 1064 mbsf) provided excellent core quality and recovery. Scientific objectives were declared fulfilled, and coring was terminated at 1149.7 mbsf (Table 1).

While the hole was conditioned for logging, tight hole intervals were noted at 1084 and 340 mbsf. A single bridge or ledge was encountered at 823 mbsf, but the drill string passed it without circulation or rotation. Nine meters of fill were cleaned from the bottom of the hole with the top drive in the string. A second mud sweep was circulated before the bit was released for logging.

Logging operations began with the sonic-induction-gamma ray tool string. Because logging with the SES would have been limited to an open-hole interval approximately equal to water depth, the

SES was not deployed. The first lowering was interrupted by a mass of clay about 160 m above the end of the pipe, and the tool had to be recovered. After the sediment was circulated from the pipe and a slug of heavy mud introduced to prevent backflow, the tool was lowered again. A solid obstruction was met at the end of the drill string. Indications were that the inner sleeve of the mechanical bit release (MBR) had not been successfully down-shifted earlier and that the lowermost bore of the MBR top connector had become plugged with clay. Circulation was through the side "windows" of the top connector. It was necessary to punch the plug out mechanically with a core breaker on an inner barrel run on the coring line and then to run the RST again to shift the sleeve into place. On the third run, the logging tool string reached open hole, but stopped again on a bridge about five meters below the pipe.

Because over 16 hours had elapsed since circulation of the hole, another wiper trip was made to total depth, and the hole again was swept with mud. The drill string was pulled back only to 633 mbsf to isolate the bridge that had stopped the logging tool earlier.

The logging tools were stopped by obstructions a few meters below the pipe on the ensuing run and again with pipe at 765 mbsf. Finally, after the pipe had been lowered to 851 mbsf, the tool traversed enough open hole to record a sonic-induction-gamma ray log from 975 to 823 mbsf (with the pipe raised to the limit).

As the SES was the only hope of obtaining logs over a significant section of the hole, the end of the pipe was pulled to 447 mbsf, and the SES was installed. With the "quad combo" tool string inside the pipe, drill-string weight and circulation were used to place the tools at 868 mbsf. Tight hole forced the drill string to a halt about 40 m short of the depth limit imposed by the SES. Even with the aid of the SES, the logging operation was difficult. The logging tool became stuck at one point, and maximum allowable pull was required to free it. Sediment packed into the top connector and on the tool apparently prevented its reentry into the pipe, and 1-1/2 hours were required to pull it inside with the help of pump circulation. The caliper log showed the hole to be in deteriorated condition, with numerous washouts and some restrictions well below bit size. All logging equipment was rigged down, the hole plugged, the drill string recovered, the beacon recalled and retrieved, and the *JOIDES Resolution* departed Site 903 at 1700, 30 June.

RETURN TO SITE 903

After Site 906 was completed, insufficient operating time remained to start and complete a new site. The shipboard scientific party decided to use the limited time to drill an additional hole at Site 903 (proposed site MAT-11) and to recore the inadequately recovered intervals of Hole 903C. Despite complications from shifting currents, the DP move of about 3 nmi was completed during the round trip of the drill string. A beacon had been left in operation at Site 903, but its signal was too weak to use for position referencing upon the vessel's return. GPS and PDR navigation were used to position over the site, and a new beacon was launched at 1245 on 18 July.

Because the intervals to be cored were below XCB refusal depth at the other sites, and because PDC bits had been highly successful in XCB coring, an RCB BHA was made up with an experimental anti-whirl PDC core bit.

Hole 903D

The PDR depth was 2-3 m shallower than that of Hole 903A; the depth for Hole 903D was 453 m below driller's datum. Hole 903D was spudded with circulation and rotation. Drilling proceeded more rapidly with the PDC bit than it had in Hole 903C with the roller-cone C-3 bit. Drilling to 775 mbsf consumed only 15-1/2 hours, including the recovery of "wash" core barrels from 477 and 775 mbsf.

Core recovery was low on the first two cores of continuous RCB coring, though the quality of the core recovered was excellent. The third core was recovered full to the top, but with about 2.5 m missing from the bottom. It became apparent that the long, continuous core sections were too smooth and sometimes were not being engaged by the dog-type core catchers. The contrast of RCB cores taken with the PDC bit to those of Hole 903C cut by the roller-cone bit was dramatic. Cores from the same section in Hole 903C were poorly recovered, broken, and "biscuited," whereas the 903D cores were smooth cylinders several meters in length and often broken only during the process of removal from the core barrel. Full (99%) recovery was achieved over the next six cores in an interval that was recovered at a 35% rate in Hole 903C. Over the next seven cores, in an interval of extra-soft mud, however, the comparison was 53% in Hole 903D vs. 51% in Hole 903C.

Two full-recovery cores then were taken before a 29 m interval was drilled to reach the next inadequately recovered portion of the Hole 903C section. Cores 19R-21R recovered 92% before an empty barrel was retrieved for Core 22R. It was noted that the inner-barrel latch spring (which keeps the latch engaged under the downhole latch sleeve) was missing--apparently having broken and fallen out of its position. The lack of core recovery suggested that the inner barrel had been pushed up into the BHA by incoming core and that pieces of core probably were in the bit cavity below the float valve. A bit deplugger then was made up to an inner barrel and pumped to the bit to punch out any core fragments before the next core attempt. Core 23R was attempted next, but the ROP was low, and only 14 cm of core pieces were recovered. The entrance to the core catcher sub was blocked by a horizontally jammed chunk of hard core. A flat surface on the bottom side of the core fragment indicated that it had spun on the bottom of the hole and prevented new core from forming. A second run then was made to clear core from the bit--this time with a chisel-shaped core breaker. ROP remained low as a 3.7 m trial core (24R) was cut, but 3.4 m of core were recovered. Operating time ran out as Core 25R was being cut to 1037 mbsf at the rate of ten minutes per meter. The drastically lower ROP indicated a downhole problem. Full recovery length was achieved for the core, but core diameter was severely reduced over much of the length.

Because of the downhole mechanical problems and low ROP, coring had to be terminated 22 m short of the planned total depth as operating time ran out. The hole was plugged, the bit was pulled, and the positioning beacon was recalled. The vessel drifted while the drill string was recovered. At 1800 on 20 July, *JOIDES Resolution* departed for port at St. John's, Newfoundland.

SITE 904

The seismic gear was streamed as soon as the ship was under way from Site 902. A track was run connecting Sites 902, 903 and the COST B-3 well with the new Site 904. Speed was reduced as the MAT-12A GPS coordinates were approached and a positioning beacon was dropped on the first crossing.

Hole 904A

As the vessel returned to the beacon position and hydrophones and thrusters were lowered, the beacon was behaving strangely. The signal was received intermittently and appeared to be changing location, and shortly thereafter was floating on the surface. Though the beacon was grappled and recovered easily over the side of the ship, it was necessary to relocate the original drop position by maneuvering in dynamic positioning (DP) mode. A second positioning beacon was launched at 0045 on July 1, and the pipe trip began at 0130, three hours after the original beacon launch.

Because of sloping bathymetry, the water depth was poorly determined by the precision depth recorder (PDR). Four "water cores" were attempted for an additional two-hour delay before the APC found the seafloor at 1134 m below driller's datum --34 m deeper than the PDR reading.

Despite the slow start, coring proceeded rapidly in silty clays. Incomplete advanced piston corer (APC) stroke was the rule below about 80 mbsf, but coring advanced by recovery to 222 mbsf, where overpull refusal was reached. When the core barrel from Core 150-904A-24H could not be withdrawn with 120,000 lb overpull, it was necessary to "drill over" the barrel for five meters before the suction was broken. The recent APC modifications functioned properly to prevent over-torquing of the rods, but both sections of the core barrel were gouged severely by the PDC core bit.

Extended core barrel (XCB) coring proceeded with excellent recovery and rate of penetration (ROP) through more silty clay and mudstones to chalk at 340 mbsf. The benign conditions persisted until porcellanitic chalk was encountered at about 524 mbsf. Lower ROP and some core jamming prevailed below that depth, but scientific objectives were declared fulfilled at 576.7 mbsf, and coring operations were discontinued.

In contrast to the previous hole, logging operations went quite smoothly. The standard wiper trip was made, with no resistance encountered in the hole, and a mud sweep was circulated. With the pipe at 96 mbsf, the SES was rigged, and logging began. Successful induction-sonic-gamma ray, litho-porosity, and FMS logs were recorded from within about 30 m of total depth over the accessible open-hole interval. Though fill at the bottom of the hole increased by several meters after each run, the hole was found to be in excellent condition for logging below about 235 mbsf and fair to good above that. Favorable conditions were attributed to a "young" hole produced by rapid penetration and low circulation rates.

Upon completion of logging operations and rig-down of the SES and logging equipment, the drill string was run back into the hole for plugging. Tight hole or fill was encountered at 541 mbsf, so the bit was raised a few meters, and 150 bbl of 10 lb/gal mud were displaced into the hole. Plugging was completed by spotting a 15 bbl batch of 15 lb/gal cement slurry at 216 mbsf.

Site 904 was abandoned at 0830 July 4 when the core bit arrived on deck and the vessel departed for Site 905.

SITE 905

Site 905 (proposed site MAT-14) is located on the continental rise seaward of the main operating area. The scientific objectives included investigation of the nature of the continental rise sediments, their provenance, and their mechanism(s) of deposition. Site 905 is located 27 nmi southeast of Site 904, and the transit was made in 2-1/2 hours. At 1115 on 4 July, a positioning beacon was launched to begin site occupancy.

Hole 905A

Because the drill site was located near a charted explosives dump site, it was necessary to conduct a seafloor survey prior to spudding to ascertain that the immediate site area was free of man-made objects. Water clarity was good on the gently sloping seafloor at 2700 m water depth.

The search was initiated by tagging the seafloor with the bit at the initial offsets 50 m south of the beacon and recording the drill pipe depth at the DES. After the bit had been raised clear of the seafloor, an expanding-square search pattern was executed. Two targets were approached and videotaped 60 m west-northwest of the beacon. Both appeared to be large semi-rounded boulders. Altogether, eight hours were consumed by the survey.

An additional precaution against hazardous material on the seafloor was the requirement to drill 20 m before coring commenced. Progress was slow in surprisingly firm sediment, and over an hour was required to wash ahead to core point. The first APC core then was "shot" from 2729 m below driller's datum at 0115 on 5 July. Standpipe pressure indicated that complete APC stroke had not been achieved.

Coring conditions proved difficult in the upper sedimentary unit, a slump deposit. Incomplete stroke and variable recovery were the rule in muds, clays, and sands having diverse properties. After disappointing results below 100 mbsf, the APC was abandoned in favor of the XCB. Cores 150-905A-16X through -20X from 134.5 to 183 mbsf achieved only 30% recovery in sediments that became softer and/or sandier with depth. The coring mode was switched back to APC, and better apparent core recovery resulted, though much of it proved to be flow-in material when the cores were opened later.

During retrieval of Core 150-905A-23H, the coring line parted about 1600 m above the sinker bars. Fortunately the lower end of the break frayed and unlaid sufficiently to become caught in the restriction of the oilsaver atop the swivel. The wire and APC were suspended inside the pipe. Instead of an in-pipe fishing job, it was necessary only to clamp off the broken wire, rig a temporary sheave, and wind the broken portion onto the drawworks sandreel. The wire failure cost 3-1/4 hr.

Core recovery and apparent penetration dropped sharply for Cores 150-905A-25H and -26H, so coring reverted to XCB mode at 219 mbsf. (The base of the slump unit was later found to be at 215 mbsf.) Good conditions for ROP and recovery prevailed in the more homogeneous silty clay, and nearly 100% of the section was recovered in the XCB interval from 219 to 655 mbsf. Though no hole problems had been experienced in coring to that depth, an important target horizon had been crossed, and coring was interrupted to log the upper portion of the hole before it deteriorated too far for good log quality.

As the wiper trip began, it was necessary to pull three stands of pipe before the drill string was free enough to set back the top drive. An additional tight spot was found at 290 mbsf as the bit was pulled back to 77 mbsf. Additional resistance was noted at various depths on the down trip, and the circulating head had to be rigged to advance the bit from 529 to 577 mbsf. Rotation with the top drive was required to wash and ream the hole to total depth. After a 40 bbl mud sweep, the bit was raised to 106 mbsf, and the SES and sheaves were rigged for logging.

Logging with the sonic-induction-gamma ray tool string again was far from routine. An attempt to log with the bit only about half-way down the hole was stopped by a bridge about 30 m below the bit. The logging tool then was pulled back inside the pipe, and the drill string was lowered to 634 mbsf, with circulation required to advance it below 545 mbsf.

Eventually a reasonably good log was recorded from 647 to 105 mbsf with the aid of the SES. A run with the litho-porosity tool string followed and logged from 581 to 81 mbsf. The caliper log showed most of the open-hole interval to be 12-15" in diameter, with the portion above about 165 mbsf washed out beyond the maximum 16" caliper reading. Several scattered tight zones from 1 to 8 m in vertical extent calipered in the 5-6" diameter range only minutes after the 10-1/8" bit passed through ahead of the logging tool.

Because hole stability was marginal and apparently time-dependent and because ROP remained high at 655 mbsf, the operating plan was modified to continue with XCB coring. When ROP declined significantly or when hole conditions forced discontinuation of operations, the hole would be plugged and a second (RCB) hole would be drilled quickly to the total depth of Hole 905A before coring resumed toward the 1300 m penetration target.

When the SES and logging tools had been rigged down, it was necessary to use the top drive to ream the tight hole from 577 mbsf to total depth. After another 40 bbl mud sweep, XCB coring resumed in a debris-flow lithologic unit. A homogeneous silty clay unit was entered at about 690 mbsf, but ROP remained high, and the anticipated 30-minute-per-core cutoff rate did not occur. Mud sweeps were pumped each third core because of the rapid penetration deep in the hole, and no signs of hole-cleaning difficulties were noted as coring progressed past 800 mbsf.

Cores had varied from moderately gassy to very gassy throughout the section. Below about 820 mbsf, the methane/ethane ratio, as measured by headspace chromatography, dropped to about 200. Traces of butane were detected consistently and isopentane occasionally in vacutainer samples. When the vacutainer from Core 150-905A-95X showed gases through hexane, a solvent cut was done on a sediment sample. When the solvent cut showed bright fluorescence, indicating aromatic liquid hydrocarbons, coring was suspended pending analysis of Core 150-905A-96X samples and evaluation of the situation with regard to the risk of pollution. Per guidelines of the JOIDES Pollution Prevention and Safety Panel (PPSP), ODP Management personnel in College Station were contacted, and shipboard supervisors consulted with the Co-Chief Scientists and the organic geochemist.

Counsel from shore was to core an additional ten meters to determine whether the trend toward liquid hydrocarbons continued with depth or was merely an isolated occurrence. By coincidence, hard drilling was encountered in the first meter. Two short core attempts penetrated just four meters with very low ROP and recovered only jammed core catchers.

Because refusal depth for the XCB had been reached and the operating plan for the site called for a second hole to be drilled with the RCB, the hole was filled with weighted mud prior to the pipe trip. Considerable difficulty was anticipated in pulling the BHA and bit back through the restrictions encountered during the earlier logging operations. Remarkably, the hole had stabilized during the subsequent coring, and the tight zones were not found at all. As the fate of continued coring hinged upon the results of the next ten meters and hole conditions were much improved, abandonment of the hole was reconsidered. When the bit reached the depth of the planned cement plug and no hole drag had been experienced, plans were altered to deepen Hole 905A. That was considered preferable to investing about 36 hours in drilling a new hole that might have to be abandoned after one core.

A free-fall reentry funnel (FFF) was moved into position in the moonpool, assembled around the drill string, and free-dropped to the seafloor. After the FFF had been allowed to fall a sufficient time, the string was pulled from the hole and tripped to the surface for conversion to a RCB bit and BHA.

Bit and VIT were lowered to reentry depth. The crater was filled to seafloor level with turbid water, and the only visible trace of the FFF was the pattern of three floating glass-ball reflectors, which had been attached to the funnel rim with six-foot tethers and appeared to float on the surface of the turbidity. A successful reentry stab was made into the center of the reflector triangle, and the VIT was pulled while pipe was tripped into the hole.

The pipe trip continued after recovery of the VIT with no impediment until a ledge or bridge was struck at 836 mbsf. When the top drive had been deployed, the hole was washed easily to total depth. RCB coring began with poor results, as only fragments of core were recovered from the initial five-meter core attempt. As only five additional meters remained from which to obtain a gas sample, the second core was a two-meter penetration with adjusted coring parameters. Full recovery was achieved. To provide a second sample interval, the ten-meter interval was completed with another core of two meters while the previous sample was analyzed. The results were inconclusive, and permission was received to penetrate an additional ten meters for analysis. Short cores were taken in that mode to 910.6 mbsf. Though indications of liquids and hexane gas had diminished, the C_1/C_2 and C_1/C_{2+} ratios continued to decline, and ODP, in consultation with PPSP, directed abandoning the hole.

Hole 905A was abandoned by the emplacement of cement plugs from 905-795, 600-450, and 240-210 mbsf. The drill string then was recovered to the BHA, which was given its once-per-leg electromagnetic inspection. *JOIDES Resolution* departed at 1300 on 14 July.

SITE 906

Site MAT-18a was proposed in the field as an alternate to MAT-13 after the early termination of Site 905 and because some of the MAT-13 objectives had been accomplished at other sites. The drilling location was on the continental slope less than 2 nmi north of Site 902 and in the thalweg of Berkeley Canyon. Drilling objectives were to compare the timing and nature of formation and infill of a buried Miocene valley with sedimentation on an interfluve between canyons (Site 902) over the same time period. The particular location was chosen because seismic records showed that the buried valley Thalweg could be reached with minimal Pleistocene overburden by drilling in the Thalweg of the modern Berkeley Canyon.

An eleven-hour arrival survey was conducted to pinpoint the drilling location and to relate the new site to nearby Sites 902 and 903. After the positioning beacon was dropped at 0330 hrs on 14 July, the vessel continued two miles past the drop point, recovered gear and returned to the beacon.

Hole 906A

An APC/XCB BHA was assembled and run to spud depth. Problems in deploying the APC cost one hour of operating time when the old, oversized aft coring line became fouled in the oilsaver. The wire finally was removed from service, and the new forward coring line (which had been installed during the move from Site 905) was used for the remainder of Leg 150 operations.

Seafloor depth was determined by the initial APC core to be 924.5 m from driller's datum. Continuous APC cores were taken through the Pleistocene section. Incomplete stroke was attained on Core 150-906A-5H at about 45 mbsf, a few meters into stiff Miocene clay. Difficulty in drilling down the shoulder for Core 150-906A-7H indicated firm sediment and a probable clay ball on the bit, so the coring mode was switched to XCB.

Core recovery was excellent from the beginning in silty clay with minor sands. A sandy interval from about 380 to 420 mbsf was the exception, producing poor to fair recovery. Coring proceeded without incident to about 552 mbsf, just above the contact with Eocene chalk. The marly chalk repeatedly jammed the XCB shoes despite all measures that could be taken, and both ROP and core recovery fell sharply. Due to the lack of satisfactory progress, coring was terminated at 602 mbsf--short of a secondary drilling objective but with primary goals achieved.

The hole then was conditioned for logging with a wiper trip and a mud sweep. Logging sheaves and the SES were rigged with the bit at 84 mbsf, and the induction-sonic-gamma ray tool string was assembled.

A failure in the telemetry cartridge forced interruption of the first logging run. After the tool string had been recovered and the cartridge replaced, a successful log was recorded from 590 to 84 mbsf. A good run with the litho-porosity combination tool followed, with the log from 583 to 103 mbsf.

The FMS tool was the third to be run. After an SES-assisted first pass, a bridge prevented lowering the tool for a second pass. On attempts to pull the tool inside pipe for a return to the bottom of the hole, the top of the tool would not enter the pipe. It was surmised that the float valve flapper had closed on the wire, and that pump circulation had succeeded in opening the flapper to permit entry. Logging personnel decided to retrieve the tool and check for damage before attempting a second FMS pass. A severe kink was found in the cable about 30 m above the tool, and marks on the "torpedo" connection near the cablehead confirmed contact with the float valve. A rehead of the cable was required, and plans for a second FMS pass were canceled due to time constraints. A final logging run then was made with the geochemical combination tool string from 569 to 146 mbsf.

When the logging equipment had been rigged down, the hole was plugged, the bit pulled clear of the seafloor, the two positioning beacons recalled, and the ship offset toward Site 903 in DP mode.

OCEAN DRILLING PROGRAM
OPERATIONS RESUME
LEG 150

Total Days (25 May - 25 July 1993)	60.7
Total Days in Port	3.0
Total Days Under Way	19.2
Total Days on Site	38.5

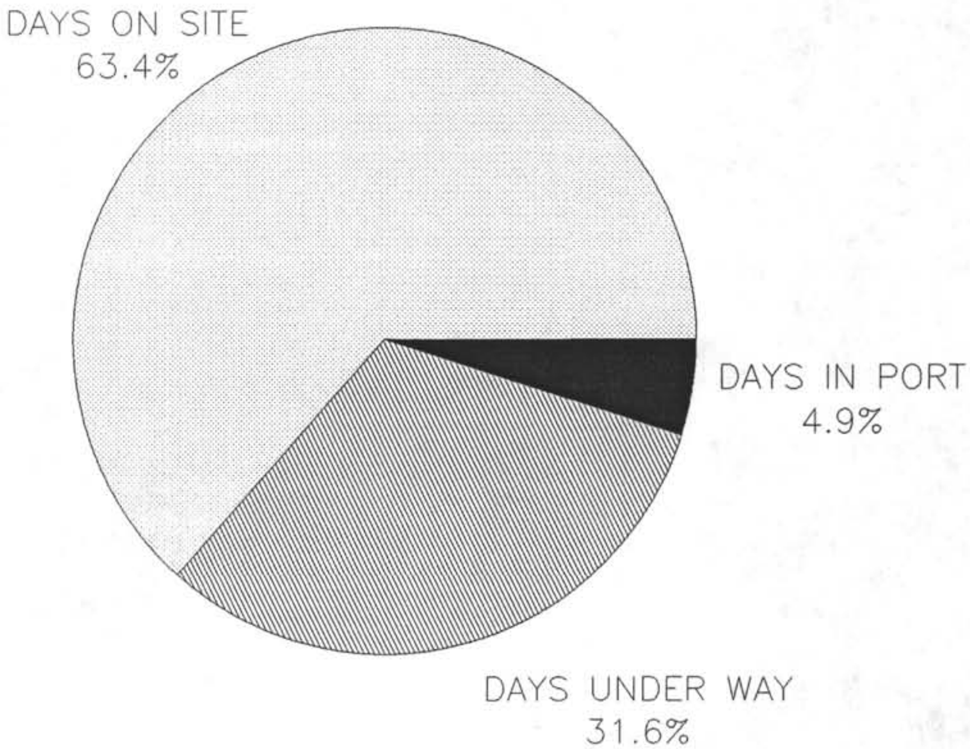
Trip Time	3.46
Coring Time	19.19
Drilling Time	1.46
Logging/Downhole Science Time	9.54
Reentry Time	0.38
Repair Time (Contractor)	0.08
Repair Time (ODP)	0.53
Casing and Cementing Time	0.58
Downhole Trouble Time	2.17
Other	2.08

Total Distance Traveled (nautical miles)	4291
Average Speed (knots)	9.2
Number of Sites	5
Number of Holes	11
Number of Reentries	2
Total Interval Cored (m)	4601.9
Total Core Recovery (m)	4034.5
Percent Core Recovered	87.6
Total Interval Drilled (m)	1442.9
Total Penetration (m)	6044.8
Maximum Penetration (m)	1149.7
Maximum Water Depth (m from drilling datum)	2709.0
Minimum Water Depth (m from drilling datum)	453.0

Table 1. Operations Summary

Hole	Latitude	Longitude	Seafloor Depth (meters)	No. of Cores	Interval Cored (meters)	Core Recovered (meters)	% Recovered (percent)	Intervals Drilled (meters)	Total Penetration (meters)	Time on Hole (hours)	Time on Site (days)
902A	38°56.08'N	72°46.35'W	826.0	4	31.0	31.4	101.4	0.0	31.0	13.5	
902B	38°56.08'N	72°46.36'W	822.0	1	9.5	9.9	104.2	1.0	10.5	4.3	
902C	38°56.08'N	72°46.36'W	822.0	16	130.0	135.9	104.5	0.0	130.0	15.3	
902D	38°56.08'N	72°46.38'W	819.0	82	736.6	677.0	91.9	3.5	740.1	141.0	
Site Totals:				103	907.1	854.2	94.1	4.5	911.6	174.0	7.25
903A	38°56.30'N	72°49.03'W	455.5	76	702.8	638.2	90.8	0.0	702.8	74.8	
903B	38°56.30'N	72°49.02'W	457.5	17	154.0	149.7	97.2	0.0	154.0	10.0	
903C	38°56.30'N	72°49.02'W	457.5	60	535.2	323.2	60.4	614.5	1149.7	205.8	
903D	38°56.30'N	72°49.04'W	453.0	25	233.1	163.5	70.1	803.9	1037.0	57.3	
Site Totals:				178	1625.1	1274.6	78.4	1418.4	3043.5	347.8	14.49
904A	38°51.81'N	72°46.08'W	1134.0	62	576.7	557.5	96.7	0.0	576.7	79.8	3.33
905A	38°36.83'N	72°17.02'W	2709.0	104	890.6	835.0	93.8	20.0	910.6	217.8	9.08
906A	38°57.90'N	72°46.00'W	924.5	68	602.4	513.2	85.2	0.0	602.4	104.0	4.33
Leg Totals				515	4601.9	4034.5	87.6	1442.9	6044.8	923.3	38.47

LEG 150
TOTAL TIME DISTRIBUTION



TOTAL DAYS OF LEG = 60.7

TECHNICAL REPORT

The following ODP Technical and Logistics personnel were aboard *JOIDES Resolution* for Leg 150 of the Ocean Drilling Program:

Laboratory Officer:	Burney Hamlin
Senior Marine Laboratory Specialist:	Don Sims
Marine Computer Specialists/System Managers:	Ed Garrett, Joel Huddleston
Marine Electronics and Downhole Tool Specialists:	Roger Ball, Eric Meisner
Marine Laboratory Specialist/Photography:	Barry Cochran
Marine Laboratory Specialist/Curatorial Representative:	Lorraine Southey
Marine Laboratory Specialist/Yeoperson:	Michiko Hitchcox
Marine Laboratory Specialist/Chemistry:	Chieh Peng, Philip Rumford
Marine Laboratory Specialist/X-ray:	Mary Ann Cusimano
Marine Laboratory Specialist/Thin Section:	"Gus" Gustafson
Marine Laboratory Specialist/Underway Geophysics:	Robert Kemp
Marine Laboratory Specialist/Physical Properties:	Claudia Müller, Taku Kimura
Marine Laboratory Specialist/Paleomagnetics:	Monica Sweitzer
Marine Laboratory Specialist:	Sebastian Mercier
Marine Laboratory Specialist:	Chuanwen Sun

PORT CALL

The needed components for the installation of a new MARISAT system were received and installed with few problems other than modifying the new mast. Difficulties developed establishing E-mail and fax communications with ODP via high speed modems. It was nearly three weeks into the leg before higher speeds were possible, with much of the gain attributed to installation of a new telephone exchange in College Station.

A nearly automatic satellite weather acquisition system was installed in place of the original Alden equipment, which required a weatherman's presence to receive and interpret the pictures. While the pictures today are similar, positioning grids and land masses are automatically registered and superimposed, and artificial colors can be used to enhance received information. Access to a wider group of weather satellites is also a benefit, particularly for the next couple of high latitude legs. The system's versatility will help keep track of pack ice for these legs. A GRAPE wipe test was conducted for the TAMU Radiation Safety Office.

The *JOIDES Resolution* sailed at 0745 on 28 May to begin the transatlantic transit to the continental shelf off New Jersey.

UNDER WAY

Navigation tapes were begun immediately, and underway watches were started after the ship left the river and the port's traffic pattern. The magnetometer was deployed, and the 12 kHz and 3.5 kHz depth recorders turned on; no seismic gear was used.

A seminar was conducted for TAMU employees and ship scientists to sensitize them to situations and conduct that can be construed as sexual harassment. A video was shown and a discussion conducted for most of the staff in conjunction with lab tours. Time on the long transit to the study area was filled with a series of presentations by the scientific party.

A pattern of weather fronts on the transit kept the ship speed at 9 knots. Heavy weather was encountered on two occasions, resulting in seawater leaks from the main deck hatch to the casing hold and into the lab stack stairwell at the main deck level. Winds to 63 knots were observed, and the seas temporarily forced a course change and reduced speed to protect the port side.

SURVEYS

To conserve ship time, an extensive 20 hour seismic survey was conducted to lace all the sites together. A single 200 $in.^3$ HAMCO water gun was used, and the streamer was deployed close to the ship to reduce refraction and to preserve vertically incident reflection raypaths in the shallow water on the shelf margin. A graphic demonstration showing the results and consequences of not matching the hydrophone array to the gun depth in shallow water was later prepared. Several of the sites were close together, and the ship was moved by DP to selected GPS coordinates.

Based on results from Sites 902 and 903, proposed site MAT-12 was moved ~2 nmi northeast. A second seismic line was needed to tie the new location to the other sites. The digital record was processed using SIOSEIS and printed to compare with seismic data brought aboard. The quality was very good. The line was reprocessed with less horizontal exaggeration to better satisfy publication needs.

A third survey was needed for a new site (Site 906) proposed at sea. Line three with the same seismic gear was generated by making four parallel tracks with several crossings, forming a grid that defined the course of a shallow buried canyon. Site 906 (MAT 17) was drilled in this feature.

Depth surveys were made between these sites with 5 minute navigation points. The AGC NAV display was well received and was valuable on one occasion, when drilling offsets from the beacon were incorrectly entered and which were immediately reflected in the display. A few pages of observations on the program are included with the manuals. The SMOOTH navigation program should be considered for retirement.

Survey lines were plotted for the scientists, sometimes with hydrographic underlays, using the GMT program on the SUN workstation. Development and system exploration was done, allowing the plots to be annotated with site positions. A continuing goal is to merge magnetometer and depth files with navigation data to generate magnetic or depth profiles vs. nautical miles using this program.

Limiting the output of this system to letter size pages remains annoying until the HP A-E size plotter is serviced and returned to the ship. While use is low, there are still applications in mapping, engineering and physical properties where size and color make a difference. Taping multiple pages together should not be necessary.

CURATION

The co-chiefs made the decision to do a minimum amount of sampling on the ship to protect critical intervals and to manage the high core flow. Sampling was deferred when critical intervals were identified with the exception of nannofossil toothpick samples. Approximately 2000 samples were deferred.

Gassy and expanding cores were regular features at these sites. Voids were collapsed when possible and noted. Expanded sediment, particularly when the liner was cut, was bagged and identified. These extra bits are expected to be packed in D-tubes and curated with the particular core.

A core box recycling effort was successfully accomplished; the only real problem was the softness of the cardboard and the occasional difficulty in getting the staples used to engage the second layer of cardboard. The many staple holes also made it harder to write on. It is the consensus of those using these boxes that core boxes, in good shape and that were not wet, could be re-used once.

Two shortages in supplies were worked around. Acetone used to fasten liner caps on cut sections was extended by mixing it 50/50 with propanol. This mix was only slightly less effective than pure acetone on dirty liner. Running out of plasticized labels had more implications, as the replacement paper labels used on the D-tubes may eventually have to be replaced. Two frozen shipments were prepared.

LABORATORIES

Core Lab

Soon after the first few days on site it was obvious that we would be recovering cores faster than the science staff could process them. A second core rack was assembled out of DEXION slotted metal and positioned on the forward end of the core receiving platform. This extra rack was fully utilized at two sites.

MST failures began immediately after running the heavy APC cores. The weak links continually released, the compumotor shaft adapter sheared at the 1/4" to 3/4" face (a new one was machined) and, occasionally, the run aborted as finished (motor seemed to stall) after moving the section a couple of inches.

There were two major problems with the present track as we began operation with the new natural gamma sensors in line -- too little compumotor torque and too weak a chain/boat link. Chain stretch and encoder backlash were also noted. The parameters menu controlling the Compumotor was changed to deliver 20% more torque, according to Edwin. He then reviewed the MST software and changed code checks to make the system less sensitive to the effects of chain stretch and recoil effects seen by the optical encoder. Tie wraps reinforced the weak links. Permatex silicone spray (heavier body than other sprays of this type) has been liberally used on the teflon track.

Over-diameter cores or misshapen liners that occur sometimes in short stroked APC or hard formations with XCB. May jam in the magnetics susceptibility loop or the throat of natural gamma, and can tear out the acetate barrier that keeps drips and dirt out of the scintillation detectors. Microswitch limiter problems and distorted liner caps, too, have resulted in torn chain and jammed cores. These problems are being addressed.

The natural gamma sensors software was advanced far enough to get some good counts beginning with the third site drilled. The data pleased the physical properties scientists, who are writing a technical note on its use. Total counts were of primary interest, but spectral analysis was also addressed by some scientists. The P-wave logger worked well, but velocities were only obtained in the uppermost few cores and the lower parts of the holes. This was due to the gassy sediments encountered. Magnetic susceptibility was trouble free.

We experienced a GRAPE alarm that halted MST operations for a couple of hours. This happened when the ARL detector was put on the bench next to the GRAPE device, MST operators had to push cores in order to prevent the MST from stalling. It was also found that radiation was considerably more intensive under the bench then on top of the GRAPE, where the detector is usually located. A survey was conducted with our Ludlum Model 14C Survey Meter at 1 X, and the results were compared to an old survey. MST operations were resumed. The report and survey were relayed to Radiation Safety at Texas A&M University for review. A statement was faxed from them stating that the unit was safe, and it was posted near the source.

Thermal conductivity operations were problematic for the operators, requiring them to call the ET's several times or others that understand their quirks. There are I/O errors that require rebooting and perception that units overheat. It is time to think about the replacement of the WHOI thermcon boxes. The units are custom made and are approaching 20 years old with components that are being discontinued. A folder is being assembled for the unit, with information and schematics to return to ODP. Current requirements and possible improvements will be reviewed and research conducted to locate a commercial replacement or verify the need for another custom design.

Other physical properties instruments worked well, although a key component in the resistivity system failed and was unrepairable. Various spreadsheets and databases were implemented, expanded or changed to meet the requirements of the leg. Staff representative Peter Blum was a contributor and has developed some ideas on modifying one of the PP benches to streamline core flow and perhaps integrate some of the instruments planned for the future half-core MST.

The cryogenic magnetometer worked well all leg, though the steady flow of cores precluded the use of other instruments. Magnetic signatures of the sediments were very low but were used to measure fields in 282 half sections and 245 minicore samples. Routine service and tuning were performed by the marine specialist and the ET's. Few problems were noted. New AF coils were received in Lisbon, and they were installed on the transit to St. John's. 2G, the company that built the coils, is scheduled to conduct a helium fill and will supervise the final tuning of the new coils.

The staff scientist and the scientific party reviewed possible use for the FAXITRON X-radiograph and requested that it be removed from the core lab. It was taken to the 2nd look lab with its peripheral paraphernalia. There is no room there to install the extension arms made for it nor provisions to shield the holes cut to allow cores to be moved through it.

The Lasentec particle analyzer was requested and set up. Testing indicated that the sand fraction values were the only ones that were believable, and it was retired. If there is no anticipated use for it on the following leg it will be returned to ODP for evaluation.

The Minolta color scanner was set up and calibrated and retired; values were too precise for the VCD software and not compatible with the Munsel color charts. The need for software to integrate the values into the ODP database has been identified on prior legs.

At Holes 902D and 904A runs were made in the open part of the holes with the LDEO Formation MicroScanner. The data were processed, creating image files, but they could not be printed, as a printer controller card was faulty or the software was corrupted. Schlumberger's real-time color plots of uncorrected FMS data looked fine, and it would be desirable to create compatible files to permit this enhanced presentation.

Taku Kimura joined the staff this leg as a new Marine Specialist and was introduced to the Physical Properties lab.

Chemistry Lab

The frequency of the incoming samples taken for safety and for science pressed the equipment and the staff time. With few exceptions, the instruments worked well, and good data were produced. A failure of the CARLE GC's power supply on the first site was disruptive, as the ET's were engaged in the heat flow effort. Routine was reestablished in a couple of hours.

Implementing OPSGAS for the Operations Superintendent with new people learning a new EXCEL extension generated frustration and confusion. Limits to the program and system in use were highlighted. The MAC SE used to display gas ratio plots in the Operations office was limited by the communications link to the chemistry lab or the EXCEL application and size of the screen.

This was reflected in the time lag between commands and implementation, which at times locked the link. Sometimes the graphs were off-screen, and the tools to move around on the screen were not available or unrecognized. Being on the subscribe end of Publish and Subscribe limits one to viewing instead of manipulating, which was annoying. Mixing headspace and vacutainer values in the files resulted in sawtooth graphs that were difficult to interpret. When two graphs were generated, the size of the files grew too big for the EXCEL template used. Running vacutainers on the NGA for C1/C2+ ratios was a departure from expected procedures, which caused confusion. Another go-around with OPSGAS would likely be smoother.

Other analyses and maintenance were routine. The Rock-Eval instrument was used and maintained by our ET, who ran about 50 samples.

X-ray Lab

The X-ray-diffraction unit was used to analyze 359 samples, primarily for bulk mineralogy. A few clay mineralogy preparations were also made. The instrument worked well, though there were occasional random spikes in the diffractograms.

The XRF was troublesome this leg, with numerous software and firmware problems persisting. Positioning and high voltage calibrations failed for goniometer 1. Communications with FISONS, our service representative, resulted in little progress. The calibration of goniometer 2 will be conducted on the transit to St. John's. This extremely busy leg and no demand for the instrument left little time for the marine specialists to troubleshoot. A service call has been requested.

Thin-section Lab

Thin sections this leg were made of sedimentary rocks. Billets require resin impregnation, and a new epoxy system by Reichold Plastics called Epotuf was tried. It is less viscous, making impregnation more complete. Its hardening characteristics are still being defined. The system uses a third component, a dilutent, that also works with Epo-tech. Many of the 63 thin sections prepared were carbonate stained at the request of the investigator.

Paleontology Lab

The lab was quite crowded this trip, and the assortment of video display devices and printers that would not be used were stored. Extra microscopes were removed or placed in a corner to make room. It was upsetting for one of the investigators, who discovered that there were no accessories for phase contrast or interference contrast lighting for the new microscopes. Accessories for a standard microscope were located, but a photoscope was eventually used. The deficiency was reported and corrected when possible.

The palynologist used one of the acid hoods for his work and had no problems with the facilities. He used two layers of the acoustic foam bought for a paleomagnetics project, to elevate his microscope to a preferred viewing height. A secondary result was reduction of vibration.

Computer Service

No significant changes were made in the computer environment. Few problems were encountered with the system or hardware other than the SCRATCH server, laser writers and a co-chief's Mac.

The new MARISAT communications system installed supported the use of high speed modems. Problems with the shore telephone lines and modem presets took nearly a month to overcome, and the implementation has since smoothed out. Traffic is relayed nearly 5 times faster than the old system, which should be a considerable savings.

Several crashes of the new weather system PC were noted when maps and annotation were added to image files. Backup tapes were used successfully to restore the program each time. No explanations were offered or discerned.

The new Schlumberger logging van houses some familiar VAXs which use a modern graphical interface and support color. DEC WINDOWS for the VAX could make our VAX cluster easier to use and may be less expensive and introduced faster than moving to new architecture.

Lab support eased some of the MST control problems experienced on the first site and made good progress toward integrating the new natural gamma sensors into the data stream. Time has been directed toward obtaining spectral gamma information, and testing continues.

SHIPSAM source code is not available to the ship staff, making it difficult by hours to make a "round-about program" that would allow sampling data to be printed to other-size labels. The rational for this policy will be reviewed.

Macintosh problems focused on the limited memory in many of the machines, a problem that will be taken care of on the following leg. The need for a PC-based graphics plotting program was mentioned again. There have been few recommendations, so a literature search will be made ashore for potential packages.

Photo Lab

This high recovery leg resulted in a record number of black and white prints (estimated 6000). The 4D program used to generate equipment reports was not tested on the Mac SE, due to the limited monitor size. The problem will be addressed on the following leg. A photo negative file was expanded with more pictures of the technical staff and the SEDCO crew. The effort is to produce an identification board with names and positions to help everyone to get acquainted as soon as possible. Few problems other than replacing failed photo lamps and retiring a jittery lightmeter were noted. Processing machines worked well with routine maintenance.

Microscopes

There was some concern when it was discovered that there were no phase contrast or differential contrast accessories available for the Axioskops/plan. The need for these accessories for the new microscopes was relayed to shore. No use was made of the video system or printers, and they were moved to the 2nd look lab for storage.

Electronic shop

The ET's handled the Adara heat flow program with measurements at two sites on every APC core until refusal. Some 40 profiles were collected at these sites with one loss. Problems with batteries were eliminated by ensuring that the tool was turned off between runs or that the batteries were removed from the tool.

Storekeeping

There were few problems experienced by our new Storekeeper, John Dyke. This was a relatively high recovery leg that illuminated some shortages. Rags were in short supply, but a ship contribution and a diligent washing effort eliminated the impact. Acetone and core labels were below the ROP from the previous legs. Work-arounds increased the usage of address labels and sample bags. A case of catwalk spatulas has apparently been misplaced; diligent scrubbing to clean the rust from the "SS" blades and patrols under the catwalk reduced demand. The cores were delivered to the East Coast Repository. The rest of the domestic freight from the ship and St. John's was backloaded onto emptied flats and into containers for the drive back to Texas.

Special Projects

A 4D database concept was tested, called "Laboratory Equipment Database," that allows staff scientists and interested personnel ashore to keep abreast of the state of the lab equipment/systems. After the initial survey of the equipment systems by the marine specialists at the beginning of the leg, a 10-page report was faxed and included weekly core box recovery. The following weekly reports were reduced to one or two pages. Eventually the weekly report will be part of our routine and sent as a text file. Reminding the specialists to review the systems regularly is necessary.

Pneumatic tools were installed on the core-receiving platform to drill holes in the core liner to relieve expanding gas, and another air drill with masonry bits to drill out packed XCB shoes. There will be maintenance needed after each site at which these tools are used. A Binks gun (air/water) was installed at the core-catcher bench to clean cutting shoes and Adara tools faster. An air/water washing wand was added to clean the core-receiving platform after sections are cut.

Hinged gates were built and installed to cordon off access to the casing hold hatch when open. There has been criticism of the effectiveness of the ropes or cables protecting curious visitors.

Framing was installed under the main hatch to support a loft to store bulk packing supplies and extra survival suits that had been stored on the acid cabinets. Hold fasts were rewelded to contain the new acid cabinet. A second fluorescent fixture was installed in this area to improve illumination; two fluorescent fixtures were added to the hold refrigerated storage area for the same reason.

The last of the four level winds was installed this leg, aft of the port magnetometer. The deck plate under the winch was thinned by corrosion in places. The thin places in the deck were fared with Red Hand two part epoxy and then painted before the winch was again welded down. It is anticipated that this piece of deck plate will be replaced in drydock.

The floor drain pan constructed on the aft end of the core-receiving platform was connected to a 4" overboard drain line to the starboard side. There is an isolation valve on the main deck to prevent use in port.

SAFETY

While accidents were few this leg, there were a noticeable number of specialists favoring limbs and wearing wrist bands or braces. Moving a ton of mud on a shift is very tiring and aggravates any number of old injuries. Shoulders, too, were stressed, by hammering out the core catchers on a far from routine shift. Fast-closing doors induced bruises.

The METS team was represented by three Marine Specialists this leg. A deference was shown to the many who worked the night shift.

TRANSIT TO ST. JOHN'S

The transit took 5 days, arriving at the harbor entrance at 0600 on the 25th. Underway watches were secured a day out of port in shallow banks water.

LEG 150 STATISTICS

General:

Sites:	5
Holes:	11
Meters Drilled:	6045
Meters Cored:	4602
Meters Recovered:	4034
Number of Samples:	12567; 2000 deferred
Number of Core Boxes:	593

Analysis

Magnetics Lab:	282
Discrete measurements:	245
Physical Properties:	
Index properties:	1671
Velocity:	1081
Therm con	1434
Chemistry Lab:	
CHNS	467
Coulometer	467
RockEval	100
AA	522
Dionex	348
Alkalinity	174
Xray Lab:	
XRD	359
Thin Sections:	63

Underway Geophysics:

Total Transit Nautical Miles:	(4346) est.
Bathymetry:	(4346)
Magnetics:	(4075)
XBT's	80