OCEAN DRILLING PROGRAM

LEG 150 SCIENTIFIC PROSPECTUS

THE NEW JERSEY CONTINENTAL SLOPE AND RISE

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March 1993

Scientific Prospectus No. 50
First Printing 1993

Distribution

Copies of this publication may be obtained from the Director, Ocean Drilling Program, Texas A&M University Research Park, 1000 Discovery Drive, College Station, Texas 77845-9547. Orders for copies may require payment for postage and handling.

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Academy of Sciences (Russia) - Inactive
Canada/Australia Consortium for the Ocean Drilling Program
Deutsche Forschungsgemeinschaft (Federal Republic of Germany)
Institut Français de Recherche pour l'Exploitation de la Mer (France)
Ocean Research Institute of the University of Tokyo (Japan)
National Science Foundation (United States)
Natural Environment Research Council (United Kingdom)
European Science Foundation Consortium for the Ocean Drilling Program (Belgium, Denmark, Finland, Iceland, Italy, Greece, The Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey)

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This Scientific Prospectus is based on pre-cruise JOIDES panel discussions. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Planning Committee and the Pollution Prevention and Safety Panel.

ABSTRACT

The "New Jersey sea-level/mid-Atlantic transect" is an integrated set of boreholes to be drilled in the U.S. mid-Atlantic region. The goal is to document the continental-margin record of the Oligocene-Holocene "Icehouse World" by determining the age of major unconformities, acquiring a database needed for modeling the amplitudes and rates of relative sea-level changes, and documenting facies variations associated with oscillations of sea level. Secondary objectives are to determine the ages of major Eocene "Doubthouse" unconformities and to evaluate the role of sea-level change on continental slope and rise sedimentation. This transect will encompass drilling in four settings with the following objectives:

1. Onshore coastal plain - to date Eocene-Miocene sequences and provide facies information on upper Oligocene-Miocene units landward of their clinoform inflection points. Drilling at Island Beach, Atlantic City, and Cape May, New Jersey, will occur between March and November 1993 in an ODP-related project involving Rutgers University, Lamont-Doherty Earth Observatory, the U.S. Geological Survey, and the New Jersey State Geological Survey.
2. Continental shelf - to recover the most complete record of relatively shallow-water facies deposited during the "Icehouse World." The TAMU safety panel has postponed shelf drilling by the *JOIDES Resolution* until pollution prevention and safety concerns are examined in detail.
3. Continental slope - to sample boundaries of depositional sequences that are imaged on the shelf but which can be dated with greater precision on the slope. Four sites will be drilled and logged during ODP Leg 150 in water depths between 345 and 1298 m; each has been chosen to recover an especially complete and thick part of the Oligocene-Holocene interval.
4. Uppermost continental rise - to compare the age and character of downslope and margin-parallel sediment transport events to the history of eustatic change. During Leg 150 one site at 2760 m will be drilled and logged.

INTRODUCTION

Global Sea Level and the NJ/MAT

The Second Conference on Scientific Ocean Drilling (COSOD II) met in July 1987 to formulate the major scientific problems to be addressed in the next decade of ocean drilling. Improved understanding of the history of global sea-level (eustatic) change was determined to be a primary goal. Subsequent discussions by the JOI/USSAC sea-level workshop (Watkins and Mountain, 1990) and the Sea-Level Working Group (Report of the SLWG, 1992) defined the role of ocean drilling in attaining this goal. The Ocean Drilling Program (ODP) is uniquely qualified to document the timing and magnitude of past eustatic changes because it is the only organization concerned with the collection and integration of data from the deep sea, carbonate platforms and atolls, and continental margins. Analysis of data from these settings provides three independent ways to measure sea-level change:

- Variations in foraminiferal $\delta^{18}O$ in deep-sea sediments provide a proxy for glacio-eustasy (e.g., Shackleton and Opdyke, 1973; Miller et al., 1987, 1991a);
- Stratigraphic markers (e.g., subaerial exposure surfaces) in carbonate platforms, atolls, and terraces record eustatic variations like oceanic dipsticks (e.g., Fairbanks and Matthews, 1978; Lincoln and Schlanger, 1991);
- Stratigraphic patterns within continental margin and epicontinental sediments preserve the record of changes in sea level relative to the continents (e.g., Sloss, 1963; Vail et al., 1977; Haq et al., 1987).

The continental-margin record of sea-level change can be deciphered in either of two ways: 1) through observations of transgressions/regressions of the shoreline or of changes in water depth inferred from facies successions (e.g., Bond, 1978; Hancock and Kauffman, 1979; Harrison, 1989); or 2) by analyzing regional unconformities either through physical and seismic stratigraphy (e.g., Vail et al., 1977; Vail, 1987; van Wagoner et al., 1987) or through hiatuses associated with them (e.g., Aubry, 1985; Miller et al., 1985). The chief advantage of the sequence stratigraphic approach is that the formation of stratal discontinuities requires the lowering of depositional base level and is therefore less sensitive to variations in sediment supply than is the position of the shoreline (Christie-Blick et al., 1990). This approach provides a great deal of information about the timing of relative sea-level changes, but less certain information about their magnitudes. It is essential to assess timing before magnitude to ensure that a given sea-level oscillation is of global rather than local origin.

The SLWG (1992) identified four issues that must be investigated to determine the complete history of eustatic variations: 1) timing; 2) amplitudes and rates; 3) stratigraphic response; and 4) causal mechanisms. A *transect* of holes across several passive continental margins was proposed as the best strategy for addressing the first three of these issues:

1. Timing. Sufficient chronostratigraphic precision (i.e., << 1 m.y.) can be attained only along a transect for the following reason: stratal geometry is most clearly expressed in the nearshore environment, but this is an environment in which key taxa for age determination are typically absent. Biostratigraphic markers and more continuous pelagic deposition are likely found in the bathyal setting of a continental slope, but sequence geometry that clearly relates to sea level control is lacking so far below depositional base level. The key to overcoming this shallow-water/deep-water paradox is having high-quality seismic data to establish the physical correlation between the two environments; one identifies the key sequence boundaries, while the other provides the definitive ages.
2. Amplitudes and rates. The amount of total subsidence (the sum of cooling, compaction, isostatic, and flexural changes through time) that has occurred on passive margins is larger than any eustatic oscillation. To estimate the amplitude and rates of sea-level changes, subsidence history must be known with considerable accuracy, and this can be achieved only by sampling along a dip line transect that has experienced a range of thermal, loading, and bending histories. In addition, paleobathymetric estimates based on faunal assemblages are an equally essential component in calculating the amplitudes of eustatic changes; their precision will be greatly enhanced by multiple samples along the transect of a single depositional surface.
3. Response. Recent sequence stratigraphic models (e.g., Posamentier et al., 1988) have generated considerable interest in the academic and industrial communities regarding the response of passive margin and epicontinental seas to sea-level variations. The detail and complexity of these facies models can be evaluated only by drilling a complete transect of boreholes from the coastal plain to the deep sea. While the response of deep-sea

sedimentation to sea-level fluctuations is not clear (e.g., Tucholke, 1981; see discussion below of MAT-14), the relationship is critical for understanding deep-sea processes and global sedimentary budgets.

COSOD II, the JOI/USSAC sea-level workshop, and the SLWG identified three time intervals for which sea-level studies would be especially valuable: the Oligocene to Holocene "Icehouse World," when eustasy was clearly driven by changes in the volume of high-latitude ice sheets; the middle Cretaceous "Greenhouse World," when significant ice sheets were lacking; and the Paleocene-Eocene "Doubthouse World," a time for which debate continues over the existence of ice sheets. The Oligocene to Holocene is an interval in which passive continental-margin records may be directly compared with eustatic estimates obtained from $\delta^{18}O$ studies.

Miller, Mountain, and Christie-Blick designed the "New Jersey sea level/mid-Atlantic transect" (NJ/MAT) to address the continental margin record of the "Icehouse World." This transect is the first drilling effort intended to examine the evidence of sea-level changes within the paradigm of sequence stratigraphy and the criteria established by COSOD II, the JOI/USSAC workshop, and the SLWG. The NJ/MAT will drill in four physiographic settings:

1. Three boreholes will be drilled on the onshore coastal plain at Island Beach, Atlantic City, and Cape May, New Jersey (Fig. 1). This drilling will take place as an ODP-related project in cooperation with the U.S. Geological Survey and the New Jersey State Geological Survey in March-November, 1993.
2. Eight boreholes have been proposed for future scientific coring of the continental shelf. We proposed to use the *JOIDES Resolution* in water depths where dynamic positioning is feasible (>35 m; Sites MAT-4 and -9) and to use a supplementary platform in water depths shallower than 35 m (Sites MAT-1 and -3). Sites MAT-1 and -9 were designed to sample prograding sequences now buried beneath the continental shelf where seismic profiles show that the geometry and facies of Neogene strata will best reveal stratal relationship to sea-level change. Each drill site was located on a profile that provided physical correlation to equivalent strata beneath the continental slope, where companion drill sites would best document the age of the key stratal boundaries.

3. Four boreholes will be drilled during Leg 150 on the continental slope (Sites MAT-10 and -13) to sample the pelagic correlatives to the sequence boundaries observed beneath the continental shelf.
4. One borehole will be drilled on Leg 150 on the uppermost continental rise (Site MAT-14) to compare the age and character of downslope and margin-parallel sediment transport events to the history of eustatic change.

Sites in water depth less than 90 m (MAT-1 and -8) were not approved by the Pollution Prevention and Safety Panel (PPSP) in October 1992 because of concerns about drilling in such shallow water with open circulation. Although sites in 90 m of water (MAT-8A and -9) were approved by PPSP, the TAMU safety panel decided that it was not prudent to drill these sites at this time. The remaining slope and rise sites were redesigned and approved by PCOM at its annual meeting in December 1992. The result is 5 sites on Leg 150 and 3 onshore sites that together constitute the end points of a margin-wide transect. Leg 150 drilling will provide the pelagic correlative needed to determine the timing of major stratal surface and sea-level history. It will not address direct stratal indicators of Neogene sea-level change now found beneath the continental shelf; this awaits future shelf drilling. We look forward to the day when the shallow-water portion of the NJ/MAT can be completed.

BACKGROUND

New Jersey Margin

The U.S. middle Atlantic margin (New Jersey-Delaware-Maryland; Fig. 2) is a classic passive margin ideally suited for recovering the record of Neogene glacio-eustatic changes. Rifting began in the Late Triassic (Grow and Sheridan, 1988), and seafloor spreading commenced by the Callovian (~165 Ma; Middle Jurassic; Sheridan, Gradstein, et al., 1983). The subsequent tectonic history has been dominated by simple thermal subsidence, sediment loading, and flexure (Watts and Steckler, 1979; Reynolds et al., 1991). The Jurassic section is composed of thick (typically 8-12 km) shallow-water limestones and shales. A barrier-reef complex fringed the margin until the middle Cretaceous (Poag, 1985). Regional sedimentation rates were generally low during Late

Cretaceous to Paleogene siliciclastic and carbonate deposition (Poag, 1985). Accumulation increased dramatically in the Oligocene to Miocene when siliciclastic sedimentation dominated (Poag, 1985). The cause of this large increase is not known, although it may reflect tectonics in the hinterland (Poag and Sevon, 1989; Sugarman et al., in press). This period coincides with overall global cooling and the appearance of high-latitude ice caps that continue to characterize the post-Eocene as the Earth's most recent "Icehouse" interval.

The middle Atlantic margin is especially suitable for the study of sea-level changes during the late Oligocene to Holocene "Icehouse World." High sedimentation rates during this period of simple thermal and flexural subsidence led to especially complete upper Oligocene to Holocene shelf sequences. Additional advantages of this section include:

- Sediments prograded across the margin throughout the Miocene and accumulated at rates high enough (10's to 100's of m/m.y.) to seismically resolve stratal relationships in unusually great detail (Poag, 1977; Schlee, 1981; Greenlee et al., 1988, 1992);
- the mid-latitude setting ensures good biostratigraphic control (Poag, 1985; Olsson and Wise, 1987; Poore and Bybell, 1988; Greenlee et al., 1992), and upper Eocene-Miocene sediments of this region have adequate carbonate to utilize strontium-isotope correlation techniques (Burke et al., 1982; DePaolo and Ingram, 1985; Hess et al., 1986; Miller et al., 1988, 1990, 1991a; see Sugarman et al., in press, for application to onshore boreholes);
- the eastern UnitedStates is an old, stable margin, and throughout the Cenozoic its tectonic subsidence has been along the relatively well-defined, nearly linear part of the thermal subsidence curve (Steckler and Watts, 1982);
- there is little seismic or outcrop evidence to suggest faulting, rotation, or other medium-large scale disturbances of the Cenozoic section (Poag, 1985), although some differential subsidence may have occurred between the Delmarva Peninsula and New Jersey (Owens and Gohn, 1985);
- because of these relatively slow Cenozoic thermal subsidence rates (<10 m/m.y.), eustatic effects on lateral facies changes and coastal onlap are likely to be well expressed (Mitchum et al., 1977); and

- a substantial body of useful data from seismics to wells to outcrops already exists on this margin (Figs. 2, 3) (Hathaway et al., 1976; Poag, 1978, 1980, 1985, 1987; Kidwell, 1984, 1988; Olsson et al., 1987; Greenlee et al., 1988, 1992; among others).

In recognition of many of these features of the New Jersey margin, DSDP Legs 93 and 95 were designed to begin a margin-wide transect that would document the stratigraphic record of eustatic change (van Hinte, Wise, et al., 1987; Poag, Watts, et al., 1987). However, the shallowest site drilled (612) was on the middle slope in 1400 m water depth where only indirect effects of sea-level change could be monitored. Furthermore, this and all other DSDP sites were poorly located for sampling Oligocene-Miocene sections (Miller et al., 1987). Leg 150 is the next step in the transect effort, and slope drilling will proceed concurrently with drilling the onshore coastal plain of New Jersey. While Leg 150 will not recover direct indicators of sea-level change, proposed slope sites as shallow as 345 m water depth have been placed on seismic lines that trace key marker horizons back onto the shelf. The final step in the transect will be drilling on the continental shelf.

The seismic grid that makes these slope-to-shelf correlations possible was developed in three ways: we obtained regional MCS profiles and log data from Exxon Production Research (EPR; Fig. 3); we collected a high-resolution MCS grid of our own (Fig. 1); and we integrated both sets of profiles with well logs, biostratigraphy, and Sr-isotope stratigraphy of boreholes, wells, and outcrops (Greenlee et al., 1992; Sugarman et al., in press).

The new seismic grid (cruise Ew9009, collected in Nov. 1990) comprises 3700 km of profiles (data archived in ODP databank). Two-thirds of these data (Fig. 1) are 120-channel, tuned air-gun array profiles across the shelf that complement the Exxon data and tie to their wells; the rest are single-channel water-gun data on the upper continental slope (Fig. 4), tying the shelf stratigraphy to a number of boreholes drilled previously and to outcrop samples collected in 1989 by the DSV *Alvin* (K.G. Miller, in prep.). These new profiles represent a clear improvement over older seismic data.

Seismic stratigraphic studies of the New Jersey continental shelf (Greenlee et al., 1988, 1992; Greenlee and Moore, 1988; G.S. Mountain, K.G. Miller, and N. Christie-Blick, in progress) reveal numerous Oligocene-Miocene depositional sequences. We evaluated the ages of six major

Miocene sequence boundaries of Greenlee et al. (1988; Tuscan to Bice-1; Figs. 5, 6) using available industry wells (Greenlee et al., 1992). Biostratigraphic resolution is coarse in these wells, and the age estimates have large uncertainties (±1 m.y. or worse). Two well-log transects tied to Exxon seismic data provide insight into the lithofacies and sequence stratigraphic architecture (Greenlee et al., 1992). Ew9009 profiles have better seismic resolution than do those from the Exxon grid, and thus were used to confirm the major sequence boundaries of Greenlee et al. (1988, 1992) and to identify several other surfaces as probable sequence boundaries (Fig. 5).

OBJECTIVES

We speculate that the major sequence boundaries identified on our seismic grids (Figs. 1, 3) correlate with oxygen-isotope increases linked to glacio-eustatic lowerings (Fig. 7). Furthermore, we propose that these sequence boundaries correlate with hiatuses on the coastal plain (Sugarman et al., in press) and continental slope (K.G. Miller, in prep.; Fig. 8). Stratal terminations observed in the Ew9009 seismic grid suggest that further study may locate additional sequence boundaries. Each of these confirmed and potential sequence boundaries can be traced directly from the continental shelf to our slope sites, where they can be dated in a pelagic setting.

The primary goal of Leg 150 is 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 are 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. This information will contribute to the final objectives of the entire NJ/MAT that will be completed with shelf drilling. At that time it will be possible to estimate the amplitudes and rates of the sea-level change and assess the stratigraphic response of glacio-eustatic forcing in terms of sequence architecture and facies successions.

PROPOSED DRILL SITES

The complexity of slope stratigraphy (e.g., Poag, Watts, et al., 1987) requires drilling in several locations to assemble a composite section as free of hiatuses as possible. Leg 150 slope drilling will recover the Oligocene-Holocene "Icehouse" interval on the slope with a composite, stacked section from the four sites MAT-10 through -13. Each borehole will recover different parts of the Oligocene-Holocene section; each has been selected for its optimum thickness, completeness, and clarity of seismic expression. MAT-10 and -12 will bottom in lower Eocene strata at the target reflector Red-3. Greenlee and Moore (1988) have correlated this surface with the 49.5-Ma sequence boundary of Haq et al. (1987). We have traced this reflector from Site 612, where it is associated with the top of a diagenetic front near the lower/middle Eocene boundary (Mountain, 1987). MAT-13 will concentrate on upper Neogene to Holocene stratal surfaces younger than 5.5 Ma.

Leg 150 will also sample the Oligocene-Holocene on the continental rise at Site MAT-14. The scientific objectives at this site differ from those at the slope sites, and we provide a more detailed discussion of this rise location below.

<u>Proposed Site MAT-10</u>

Site MAT-10 (at 806 m water depth on the slope) will penetrate to the top of the lower Eocene (Fig. 9). This site is located 2 km north (and slightly upslope) of the Continental Offshore Stratigraphic Test (COST) B-3 well, where the upper Miocene section above Tuscan (post ca. 10.5 Ma) is thicker than at the COST well. Stratigraphic details were limited at COST B-3 because samples came from cuttings, the first of which were not recovered until 329 m below the seafloor (mbsf; middle Miocene and older). MAT-10 will recover a thick post-Tuscan interval (400 ms), although erosional truncation by a late Neogene (Plio-Pleistocene) surface is indicated (Purple on Fig. 9). There is also a thick middle Miocene section between Tuscan and Pink-2 (200 ms; ~10.5-13.8 Ma; Fig. 9). The upper Oligocene-lower middle Miocene section at COST B-3 is thin and punctuated by hiatuses (Fig. 9). This section also thickens away from COST B-3 toward MAT-10, particularly between Pink-2 and Bice-1 (?16 Ma on Fig. 5, although the surface may actually be lower Miocene), and we anticipate a reasonably thick upper Oligocene to lower Miocene section. Recovery at COST B-3 indicates that the Eocene section should also be promising, although the upper Eocene section may be truncated between COST B-3 and MAT-10.

Proposed Site MAT-11

Site MAT-11 (at 430 m water depth on the slope) will penetrate to the top of the lower Eocene (Fig. 10). Like MAT-10, this site will recover a thick post-Tuscan interval (680 ms), again with some erosion in the upper Neogene (Plio-Pleistocene). The middle Miocene section between Tuscan and Bice-1 is locally thick (300 ms) with a particularly expanded Yellow-2 to Aqua interval (80 ms; 12-14 Ma.) This site offers the best opportunity to recover the lower Miocene because it has the thickest Bice-1 to Pink-3 section (~110 ms; ?16 Ma-?top Oligocene.) The lower Miocene section is otherwise thin on the slope. The Eocene to Oligocene section should be comparable to MAT-10.

Proposed Site MAT-12

Site MAT-12 (at 1298 m water depth on the slope) is 2 km north and slightly upslope from DSDP Site 612 (Leg 95; Poag, Watts, et al., 1987). The pre-Oligocene and post-middle Miocene stratigraphy should be identical to Site 612 (Poag, Watts, et al., 1987); however, Site 612 was drilled in a buried canyon thalweg and consequently missed the middle Miocene to lowermost Oligocene section into which this canyon is cut. Sampling in Carteret Canyon adjacent to Site MAT-12 has confirmed the presence of these strata missed at Site 612 (Figs. 4, 9). The middle Miocene to lowermost Oligocene strata thicken away from the canyon outcrop and reach a local maximum at Site MAT-12 (~80 ms; Fig. 9).

Proposed Site MAT-13

Site MAT-13 (at 340 m on the slope) is 31 km downdip from proposed site MAT-8A (COST B-2) (Fig. 1). The upper Neogene section on the slope above Pink-1 (?5.5 Ma) is uniformly thicker and more clearly imaged seismically in this region than it is at an equivalent water depth 35 km southwest near MAT-10 and -12. The cause is twofold: first, a ?Pleistocene canyon is incised into the shelf edge and is now buried in the vicinity of Line 1003 (Fig. 1), and post-Pink-1 strata have been removed. Second, post-Pink-1 slope defacement has been much more severe in the vicinity of MAT-10 and -12 than near MAT-13.

Numerous candidate sequence boundaries can be traced along MCS Line 1002 to proposed sites MAT-8A and -9 on the shelf. MAT-13 will focus on the upper Neogene section above Pink-1 (Fig. 11). The age and significance of Pink-1 and the numerous unconformities that overlie it are uncertain. Greenlee and Moore (1988) speculated that Pink-1 correlates with the 5.5-Ma sequence boundary of Haq et al. (1987), although our examination of data from industry wells in this region shows that the age of this reflector is unconstrained (Greenlee et al., 1992). We observe roughly 10 surfaces above Pink-1 that may constitute sequence boundaries; we are currently tracing each of these throughout the MCS grid to determine which are indeed related to lowering of depositional base level.

The numerous upper Neogene sequence boundaries to be sampled at MAT-13 are much better represented along Line 1002 than elsewhere in the grid of available seismic data. Determining their ages will provide a valuable upper Neogene component to our sea-level study. However, to thoroughly evaluate this younger part of the glacio-eustatic record poses two challenges: 1) there are relatively few profiles in the vicinity of Line 1002 to provide the optimal seismic control because we chose to focus our Ew90-09 MCS grid on lower-middle Miocene sequences revealed on the Exxon profiles; and 2) attaining requisite stratigraphic resolution of the many uppermost Miocene to Holocene sequences may prove to be difficult. While oxygen isotope stratigraphy is the preferred correlation tool for the past few millions of years, this ordinal technique is compromised by hiatuses and uncertain biostratigraphy. Biostratigraphic control may not be ideal for the uppermost Miocene to Holocene due to the absence of some low-latitude markers (e.g., Poag, Watts, et al., 1987). Despite this cautious assessment, Site MAT-13 will evaluate the feasibility of correlating the numerous uppermost Miocene to Holocene sequences to a glacio-eustatic proxy afforded by the oxygen-isotope record.

Proposed Site MAT-14

Since Heezen et al. (1966) showed that abyssal circulation shapes the U.S. continental rise, the relative roles of endogenous (e.g., currents) versus exogenous (e.g., sea-level) mechanisms of slope failure and rise sedimentation have been debated. Seismic stratigraphic studies (e.g., Poag, 1985; Mountain and Tucholke, 1985) have documented that canyons similar to those entrenched into the modern rise (e.g., Hudson and Wilmington canyons) are absent in the sub-bottom lower Neogene to Paleogene off North America. Consequently, if the adjacent shelf and slope contributed substantial volumes of sediment to the rise during eustatic lowstands, mechanisms of both transport and deposition are as yet unclear. Localized slope failure provides a source of rise sediments as well as potential conduits to deliver sediment to the rise, and may be attributable to mechanisms other than sea-level change, such as: 1) seismicity (Heezen and Ewing, 1952); 2) activity of bottom-dwelling fauna (Shepard and Dill, 1966); 3) undercutting by erosive bottom currents (Paull and Dillon, 1980); 4) groundwater sapping caused by changing in-situ pore pressure (Robb et al. 1981); 5) along-shelf transport and sediment buildup at the shelf edge (May et al., 1983); and 6) diagenesis leading to jointing and collapse (McHugh et al.,1993). Of these, only changes in terrestrial sediment supply and groundwater sapping are linked directly to changes in sea level. We speculate that these two mechanisms dominate the accumulation of slope sediment, and determine to a large degree the times of sediment transport to the upper continental rise. However, the abyssal currents that rework these sediments on the rise vary on time scales that may differ significantly from those of eustatic change. As a result, accumulation histories may contrast sharply across a short distance between the slope and rise. Sites MAT-10 and -13 and MAT-14 will compare these histories and allow us to evaluate causal mechanisms for sediment accumulation and erosion on the slope and rise, respectively.

Coastal plain, shelf, and slope drilling will provide a relative sea-level signal; MAT-14 will document the accumulation rate, source, and sedimentary structures of the coeval sediments on the rise. Due to site placement, Legs 93 and 95 did not recover Neogene sediments on the upper rise older than latest Miocene. Although Sites 105, 106, 388, and 603 cored a thick Miocene section, all were on the lower rise in water depths too deep for detailed biostratigraphic control. Thus, previous seismic stratigraphic studies of the margin have been hampered by a lack of age and lithologic data (e.g., Tucholke and Mountain, 1979; Poag, 1985; Mountain and Tucholke, 1985; Poag and Sevon, 1989; Poag and Mountain, 1987; McMaster et al., 1989). Site MAT-14 is the same location as Site NJ-6 from DSDP Leg 95, but because of time constraints it was never drilled. Continental rise Site MAT-14 will provide both the biostratigraphic and lithostratigraphic control for the Miocene sections that will also be sampled on the shelf and slope; it will address two major issues related to the response of continental-rise sedimentation to sea-level change.

The first issue to be evaluated by MAT-14 is how and when sediment was deposited on the continental rise, and what the relationship of this history is to relative sea-level change. Numerous studies have suggested that increased sedimentation on the rise and abyssal plains was caused by increased terrigenous input during late Pleistocene lowstands (e.g., Horn et al, 1971; Weaver et al., 1986). However, this conclusion has not been tested with samples from the older record. Three questions need to be answered:

1. Is the transport of terrestrial sediments to the rise constant or episodic?
2. By what process does sediment accumulate on the rise?
3. What is the relative contribution of slope sediments to the rise?

MAT-14 will address a second important issue by evaluating the role of deep-sea currents in shaping the upper continental rise. Seismic studies have shown that more than 2 km of Neogene sediments account for the general shape of the rise off the eastern United States. Three widespread reflectors -- Au, Merlin, and Blue -- have been traced along the rise and subdivide this thick interval (Mountain and Tucholke, 1985; Fig. 12). Each of these reflectors provides evidence for deep-sea erosion resulting from strongly circulating deep waters originating in the high-latitude North Atlantic or Nordic Seas (i.e., Northern Component Water (NCW) analogous to modern North Atlantic Deep Water). While their exact ages are uncertain, it is clear that Au is latest Eocene to earliest Oligocene, Merlin is late middle Miocene, and Blue is Pliocene; more precise dates are needed. Mountain and Tucholke (1985) interpreted these seismic features as elements of current-controlled deposition. In this model, only the few hundred meters of stratified sediments at the base and at the top of the post-Au interval at MAT-14 are predicted to be downslope transported sediments. The rest of MAT-14 will sample the "hummocky" and the "back-slope" acoustic facies of the Chesapeake Drift.

Thus, MAT-14 will not only address the effects of sea-level change on continental-rise deposition, but will also evaluate the timing and role of deep-water circulation changes in reshaping these deposits. While it is likely that pulses of NCW correlate with sea-level changes, we lack sufficient age control to test this important linkage. MAT-14 will provide improved geochronology of the three marker horizons Au, Merlin, and Blue, and will allow us to evaluate the causal relationship between deep-water changes, glaciation, and sea-level history (e.g., Broecker and Denton, 1989).

OPERATIONS

Site Priority

Sites MAT-10 and -11 are highest priority, and will be drilled first and in that order. If Oligocene to lower Miocene recovery is adequate at both sites, MAT-13 and its upper Neogene objectives will be drilled next. Alternatively, MAT-12 will be the third site drilled to ensure recovery of the critical Oligocene-lower Miocene section. MAT-14 on the upper rise will be the fourth site, and we intend to drill to the target reflector Au, which is presumably an erosional hiatus that now juxtaposes upper Oligocene/lower Miocene over pre-middle Eocene strata. If time permits after reaching Au, we will drill the remaining slope site, which will be MAT-12 or -13, depending on the previous choice at the completion of MAT-11. However, if the remaining slope site is MAT-13, and continuing to Au at MAT-14 would preclude a return to the slope, the decision will be made at MAT-14 as to when coring must be halted to leave time for drilling to at least below Pink-1 (770 ms) at MAT-13.

We plan to APC/XCB each site, and when refusal depth is reached and the hole is open, to log each with both the standard Schlumberger suite and the FMS tool. After tripping to set a new BHA, each site will be continued to TD using the RCB. A second set of logs will then be run before abandoning the hole. A second APC/XCB hole will be drilled at MAT-11, and if time permits at MAT-13 (if we encounter no difficulties at our first site, MAT-10, we would consider double APC/XCB holes there). In addition, we plan two other downhole measurements: VSP at Sites MAT-11 and -14, and the APC heat-flow tool at Sites MAT-10 and -11. These latter two downhole techniques will be done as long as they do not jeopardize the chance of completing our primary coring and logging objectives.

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TABLE 1. SUMMARY SITE INFORMATION, LEG 150

Site	Lat./Long.	Water Depth (m)	Seismic Profile	Sediment Penetration TWT(ms)	Sediment Thickness (Km)
MAT-10	38°55.93'N 72°46.05'W	806	Ew9009 MSC Line 1027 (and 1005)	925	10
MAT-11	38°56.22'N 72°49.00'W	430	Ew9009 MCS Line 1005 (and 1026)	1225	10
MAT-12	38°50.00'N 72°44.98'W	1298	Ew9009 MCS Line 1027 (and 1006)	525	10
* MAT-13	39°12.50'N 72°26.60'W	345	Ew9009 MCS Line 1002; Exxon MCS Line 77-8	950	10
* MAT-14	38°37.00'N 72°17.30'W	2761	BGR 201 MCS; USGS 25 MCS	1400	10
* MAT-15†1	38°51.60'N 72°50.40'W	862	Ew9009 SCS Line 5 and MCS Line 1006		10
* MAT-16†2	38°52.70'N 72°52.50'W	562	Ew9009 SCS Line 3 and MCS Line 1006		10
* MAT-17†3	38°31.80'N 72°05.50'W	2858	SP 4380 on USGS Line 25		10

* Subject to Pollution Prevention and Safety Panel approval in April 1993.
†1 Alternate site for MAT-10.
†2 Alternate site for MAT-11.
†3 Alternate site for MAT-14.

TABLE 2. TIME ESTIMATES, LEG 150

Site	Water Depth (m)	Penetration (mbsf)	Drill (hours)	Log* (hours)	On Site (hours)	Transit (days)	Total (days)
LISBON PORT TO MAT-10						12.0	12.0
FIRST PRIORITY SITES:							
MAT-10	806	925	145	39	184	0.0	7.7
MAT-11	430	1225	242	47	289	0.2	12.0
SECOND PRIORITY SITES:							
MAT-13	345	950	140	38	178	0.2	7.6
MAT-14	2761	1400	288	54	342	0.0	14.4
LAST SITE TO ST. JOHN'S PORT						4.3	4.3
Total Days							58.0
CONTINGENCY AND ALTERNATIVE SITES:							
MAT-12	1298	525	63	29	92	0.2	4.0
MAT-15	862						
MAT-16	562						
MAT-17	2858						

* Including Seismic-Statigraphy, Litho-Porosity, Geochemical, and FMS strings. Time will be saved by omitting Geochemical and/or FMS runs at some of the sites.

FIGURES

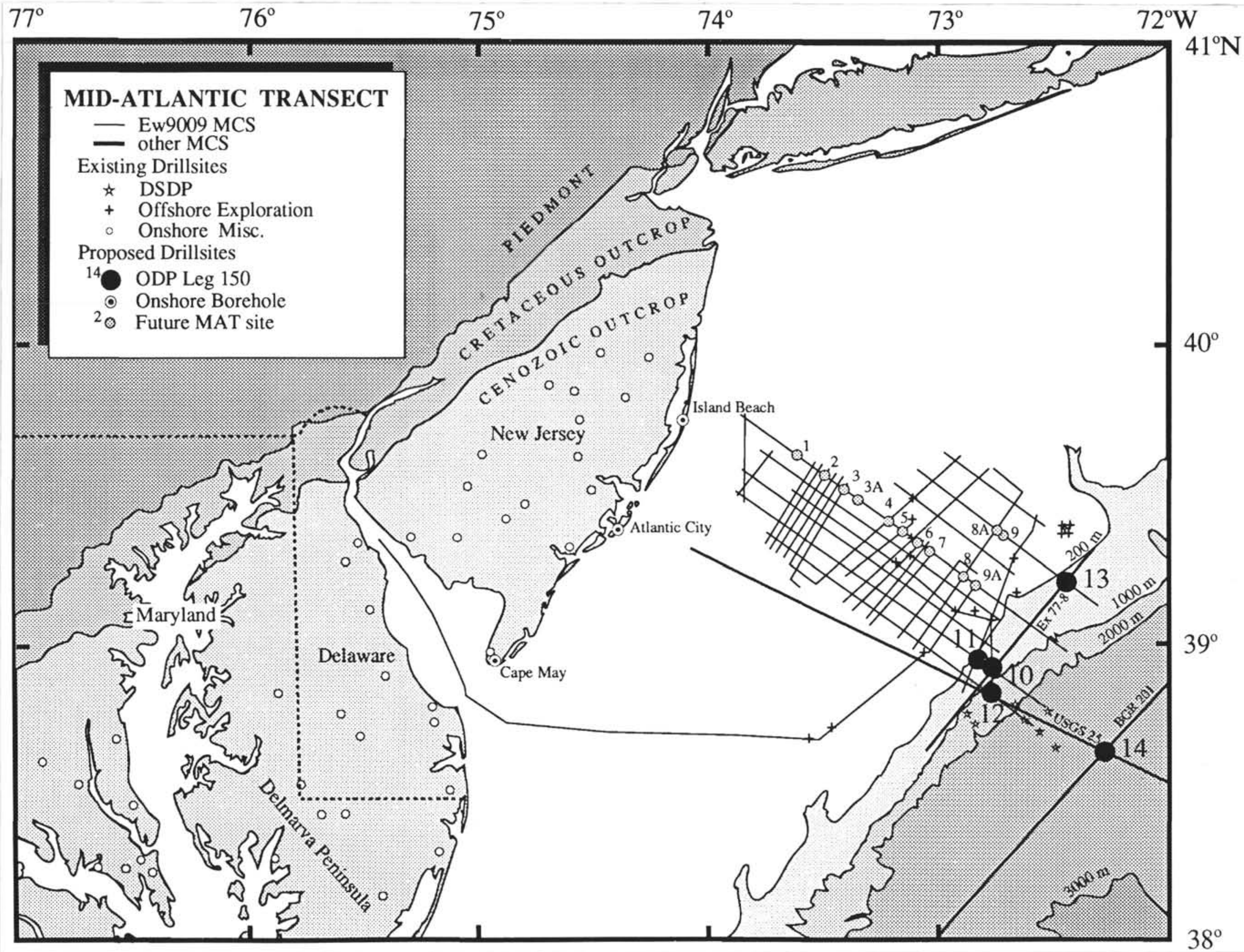

77°
76°
75°
74°
73°
72°W
41°N
40°
39°
38°
MID-ATLANTIC TRANSECT
Ew9009 MCS
other MCS
Existing Drillsites
DSDP
Offshore Exploration
Onshore Misc.
Proposed Drillsites
ODP Leg 150
Onshore Borehole
Future MAT site
PIEDMONT
CRETACEOUS OUTCROP
CENOZOIC OUTCROP
New Jersey
Island Beach
Atlantic City
Cape May
Maryland
Delaware
Delmarva Peninsula
1
2
3
3A
4
5
6
7
8A
9
8
9A
10
11
12
13
14
200 m
1000 m
2000 m
3000 m
Ex 77-8
USGS 25
BGR 201

Figure 1

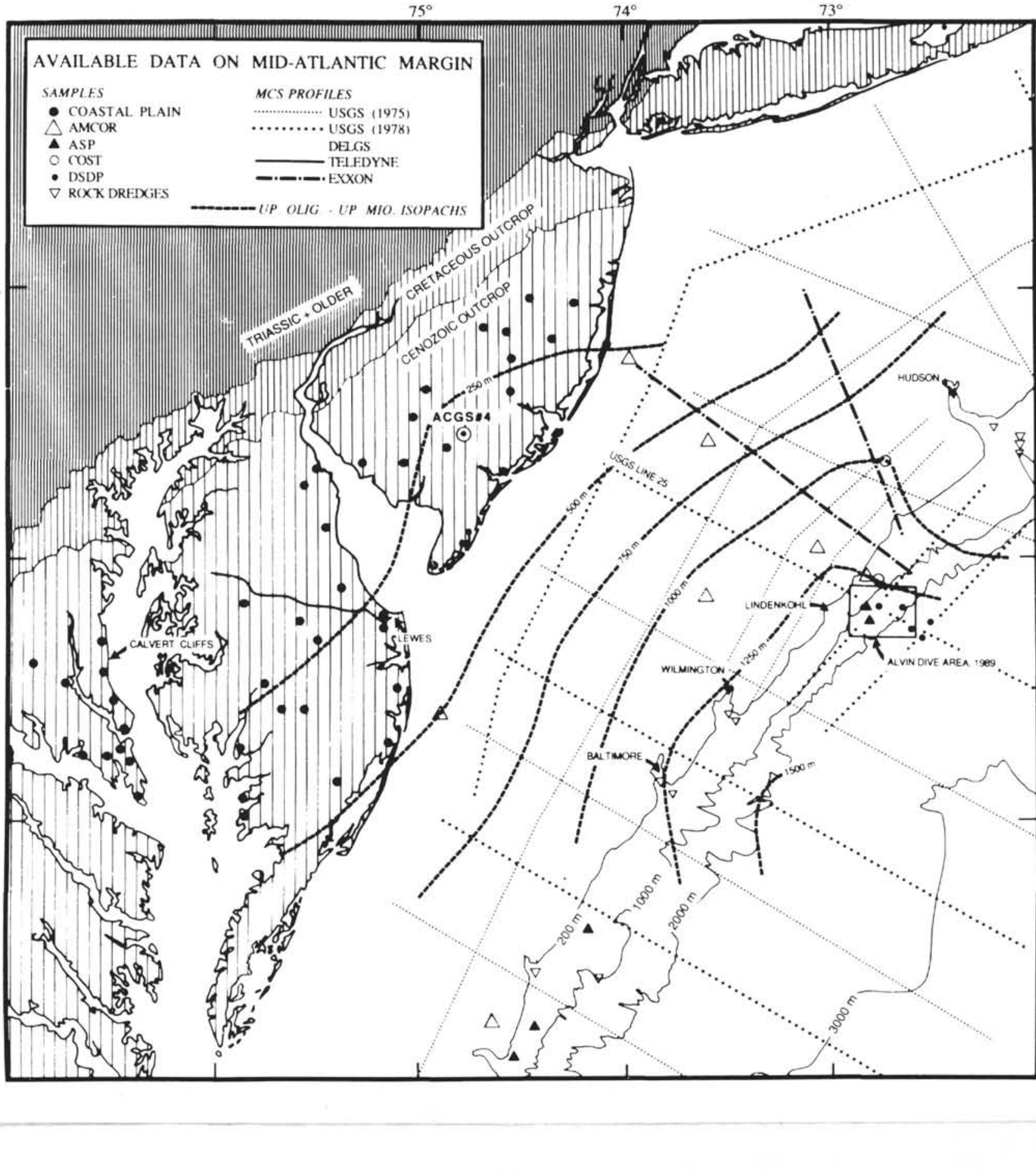
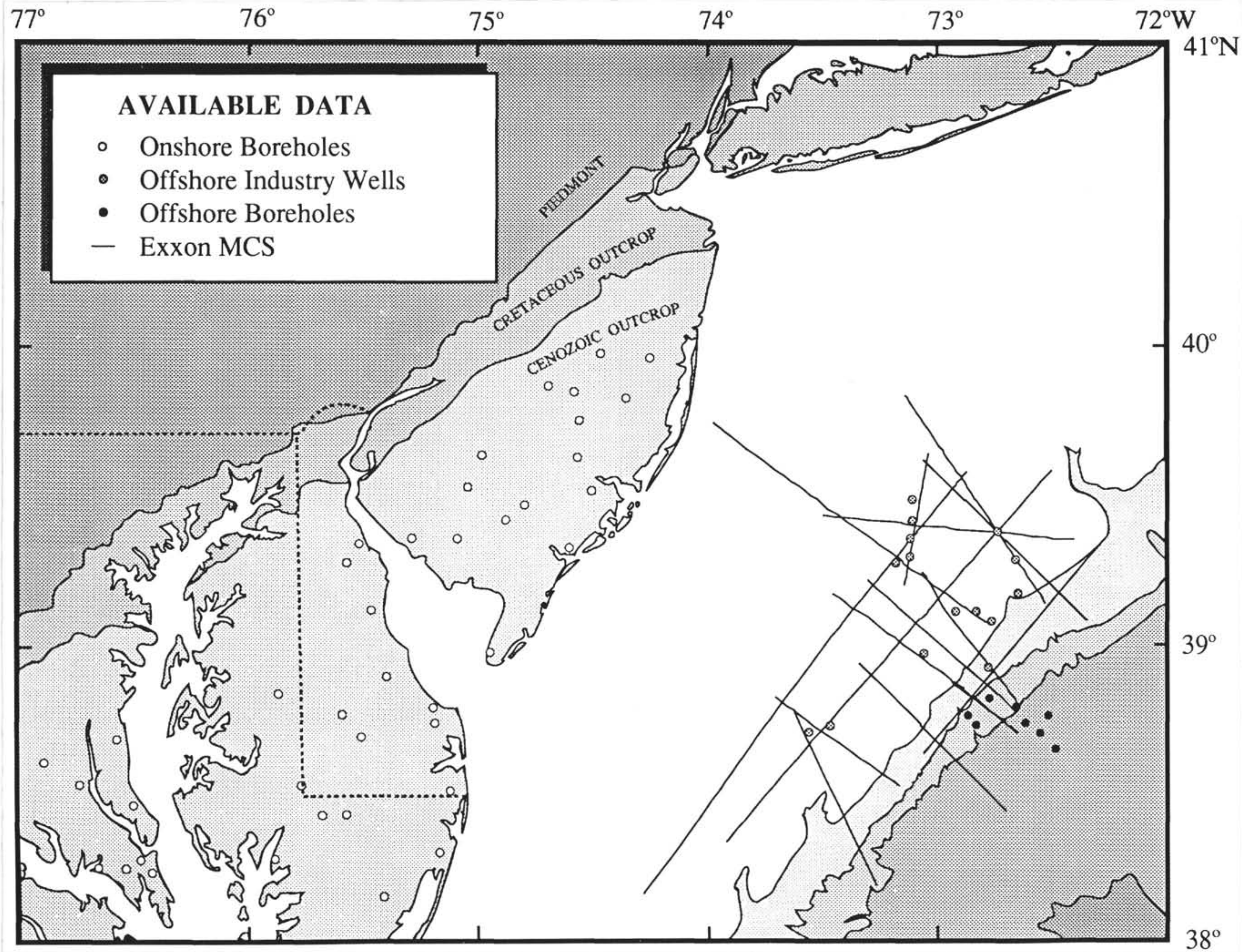

AVAILABLE DATA ON MID-ATLANTIC MARGIN
SAMPLES
COASTAL PLAIN
AMCOR
ASP
COST
DSDP
ROCK DREDGES
MCS PROFILES
USGS (1975)
USGS (1978)
DELGS
TELEDYNE
EXXON
UP. OLIG. - UP. MIO. ISOPACHS
75°
74°
73°
40°
39°
38°
TRIASSIC + OLDER
CRETACEOUS OUTCROP
CENOZOIC OUTCROP
ACGS#4
CALVERT CLIFFS
LEWES
USGS LINE 25
HUDSON
LINDENKOHL
ALVIN DIVE AREA 1989
WILMINGTON
BALTIMORE
250 m
500 m
750 m
1000 m
1250 m
1500 m
200 m
1000 m
2000 m
3000 m

Figure 2


77°
76°
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72°W
41°N
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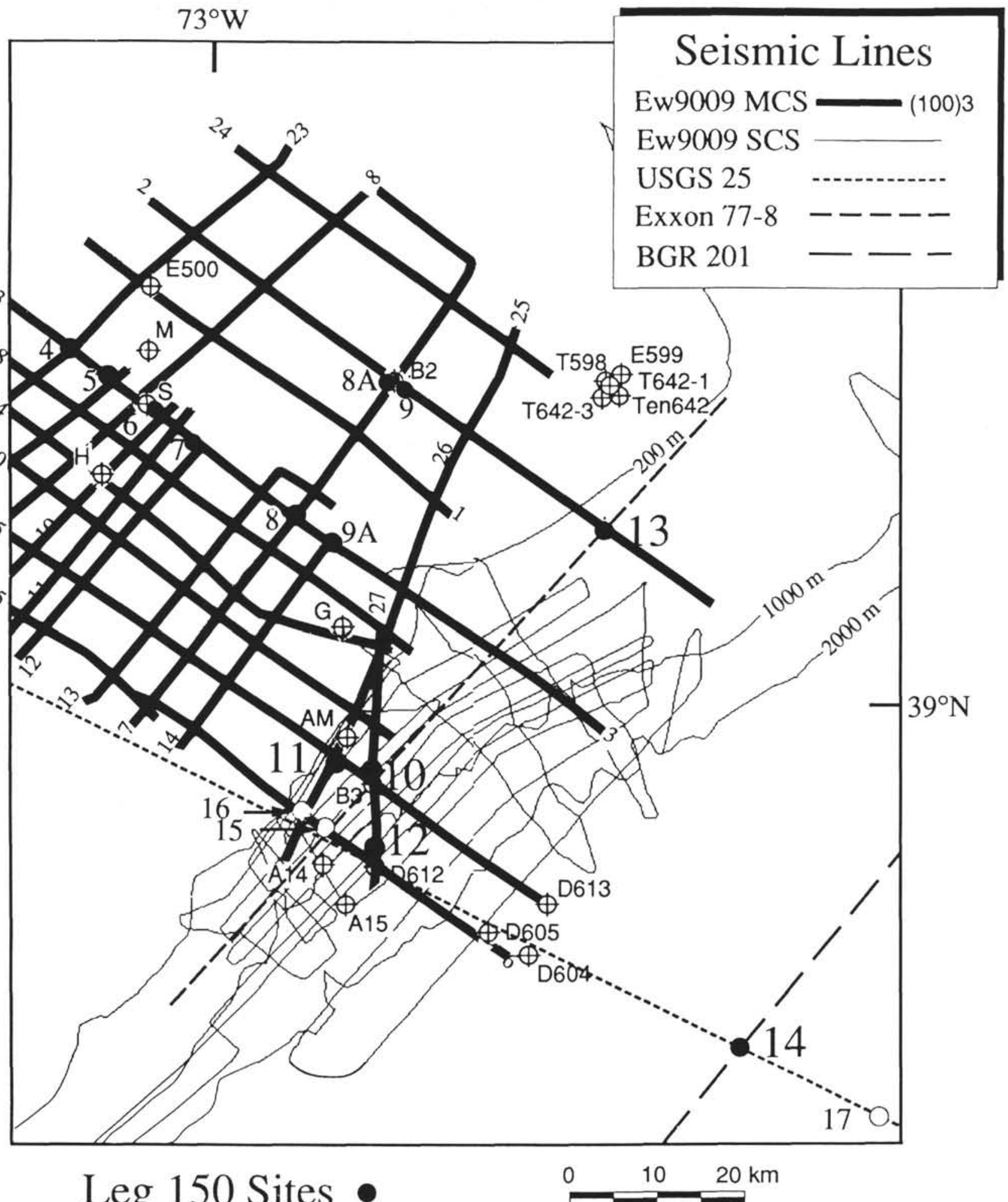
AVAILABLE DATA
Onshore Boreholes
Offshore Industry Wells
Offshore Boreholes
Exxon MCS
PIEDMONT
CRETACEOUS OUTCROP
CENOZOIC OUTCROP

Figure 3



Key to wells ⊕ E 500 & 599 = Exxon 500-1 & 599-1 M = Mobil 544-1
S = Shell 632-1 H = HOM 676-1 G = Gulf 857-1 Ten642 = Tenneco 642-2
T - 598, 642-1, 642-3 = Texaco 598-1, 642-1, & 642-3 AM = Amcor6021
B2 = Cost B2 B3 = Cost B3 A14 = ASP14 A15 = ASP15
D604, 605, 612, & 613 = DSDP604, 605, 612, & 613

Figure 4

Oligocene-Miocene Biostratigraphy and Age Estimates

Sequence Boundaries & Ages	COST B-2 298' (91 m) 98' kb	EXXON 684-1 399' (122m) kb	SHELL 273-1 292' (89 m) 84' kb	EXXON 902-1 433' (132 m) 72' kb	COST B-3 2686' (819 m) 42' kb	Interpreted Age	$\delta^{18}O$ Zones	
	Gt. plesiotumida 810[1] *B. elongata* 880[4] 1345	*B. elongata* 1964[4] 2365	1210	*B. elongata* 2810[4] 2910				
PINK-1 "5.5"			1660	*S. seminulina* 2990[4] (N21; ~3 Ma) 3110	N.D.	?3 Ma ? 9-3 Ma		Pliocene?
YELLOW-1 "6.3"	ONLAPPED OUT N.D.	N.D.	*Gt. margaritae* 2220[4] (3.4 Ma) *B. elongata* 2220[4] 2430		N.D.	?		upper Miocene
RED "8.2"	ONLAPPED OUT N.D. 1500	N.D. 2810	*Gt. mayeri* 2640[4] (10.4 Ma) 2860	N.D. 3475	N.D. Reflector M1 of Miller et al, 1987 ~3700?	?	?Mi 7 (8.5 Ma)	upper Miocene
TUSCAN "10.5"	*Gt. mayeri* 1510[1] (10.4 Ma) 2000	*Gt. mayeri* 2940[4] 3230	*Gt. fohsi lobata* 3030[4] (11.6 Ma) 3050	*Gt. mayeri* 3590 (10.4 Ma) *Gt. fohsi robusta* 3650[5] (11.5 Ma) 3800	*Gt. fohsi lobata* 3800[6] (11.6 Ma) *Gt. mayeri* 3800[4,7] *Gt. fohsi fohsi* 3990[4] (12.3 Ma) ~4100	10 Ma ~11-9 Ma	Mi 6 (9.6 Ma)	middle Miocene
YELLOW -2 "DLS" FLESH YELLOW-3 INDIGO	*Gt. fohsi fohsi* 2800[3] (12.3 Ma) *Gt. peripheroronda* 2860[1] (~N10; 14.6 Ma?) 2920	3330	*Gt. fohsi fohsi* 3120[4] (12.3 Ma) 3260	4030	*P. glomerosa* 4160[6] (~15 Ma) 4335	11.7 Ma 12.2-11.2 Ma	Mi 5 (11.3 Ma)	middle Miocene
AQUA "12.5" TERRA COTTA PINK-2	3080	3445	*Gt. peripheroronda* 3420[4] (~14.6 Ma?) 3470?	4170	*G'lla insueta* 4430[6] (~15 Ma) 4480	13.5 Ma 14.9-12.8 Ma	Mi 4 (12.6 Ma)	middle Miocene
RED-2 "13.8" VIOLET	3280	*Gt. peripheroronda* 3630[4] (~14.5 Ma?) 3640	3950	*G'lla insueta* 4250[4] (~lower N9; ~15 Ma) 4270	*C. dissimilis* 4490[6] (17.6 Ma) possibly miscorrelated on log 4650	14.5 Ma 15.3-13.5 Ma	Mi 3 (13.6 Ma)	middle Miocene
BICE-1 "15.5" OCHRE SAND BLUE PINK-2 BICE-2 RED-3 RED-4	*C. stainforthi* 3580[4] (~mid N7; ~17 Ma) *Gt. kugleri* 3610[1,2] (21.7 Ma) *P. opima opima* 3850[5] (28.2 Ma)	*P. opima* cf. *opima* 3690[4] (?28.2 Ma)	*G. ciperoensis* 3990[4] (~23 Ma) *P. opima opima* 4230[4] (28.2 Ma)	*Gt. peripheroronda* 4406[4] (~14.6 Ma) (premature LO ?) *P. opima opima* 4422[4] (28.2 Ma)	*Gt. kugeri* 4670[6] (21.7 Ma) *P. opima opima* 4760[8] (28.2 Ma)	16 Ma? ~19-14.8 Ma	Mi 2 (16.1Ma)	? up. OL.- lo. Mio.

Figure 5

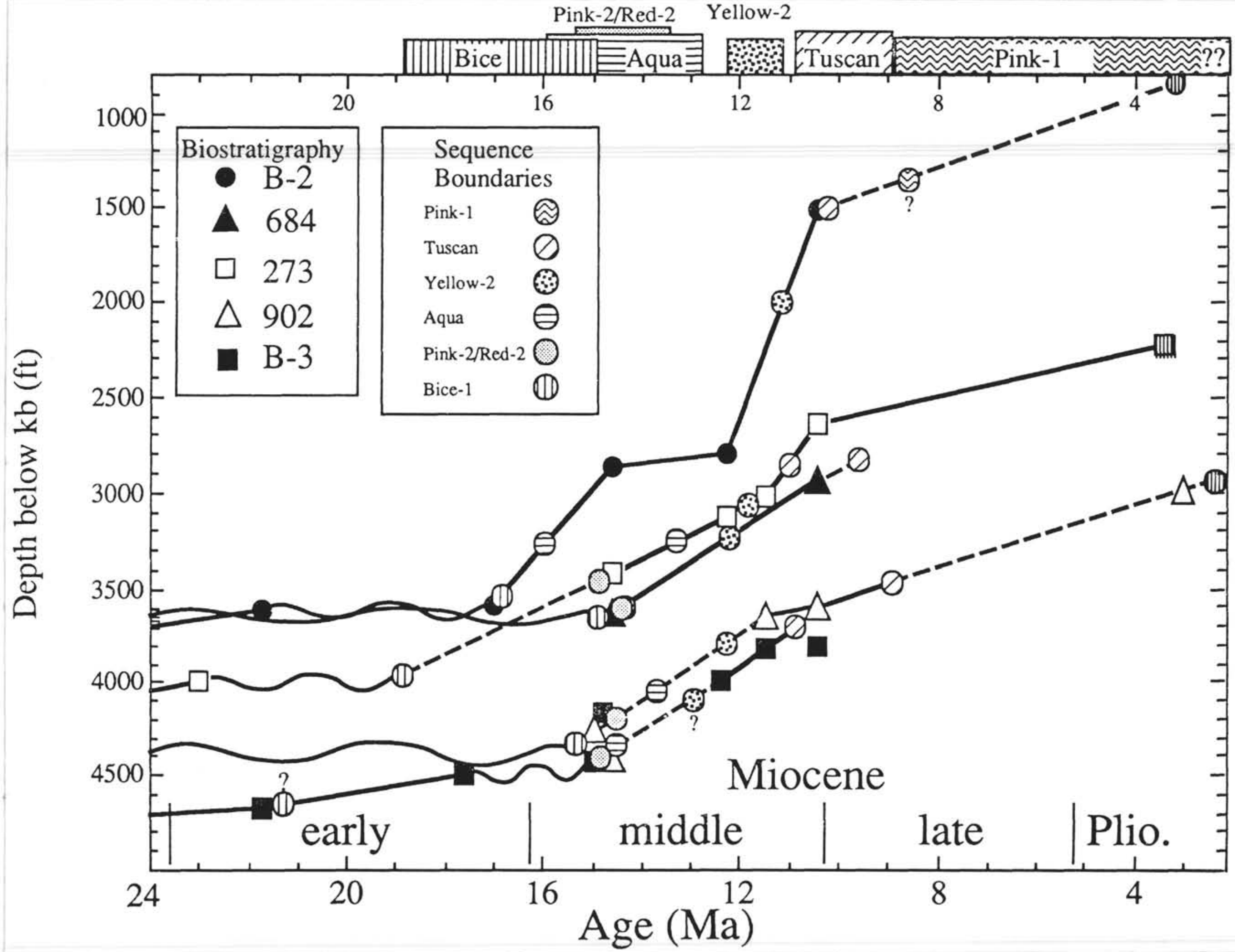

Pink-2/Red-2
Yellow-2
Bice
Aqua
Tuscan
Pink-1
??
Biostratigraphy
B-2
684
273
902
B-3
Sequence Boundaries
Pink-1
Tuscan
Yellow-2
Aqua
Pink-2/Red-2
Bice-1
Depth below kb (ft)
1000
1500
2000
2500
3000
3500
4000
4500
Miocene
early
middle
late
Plio.
24
20
16
12
8
4
Age (Ma)

Figure 6

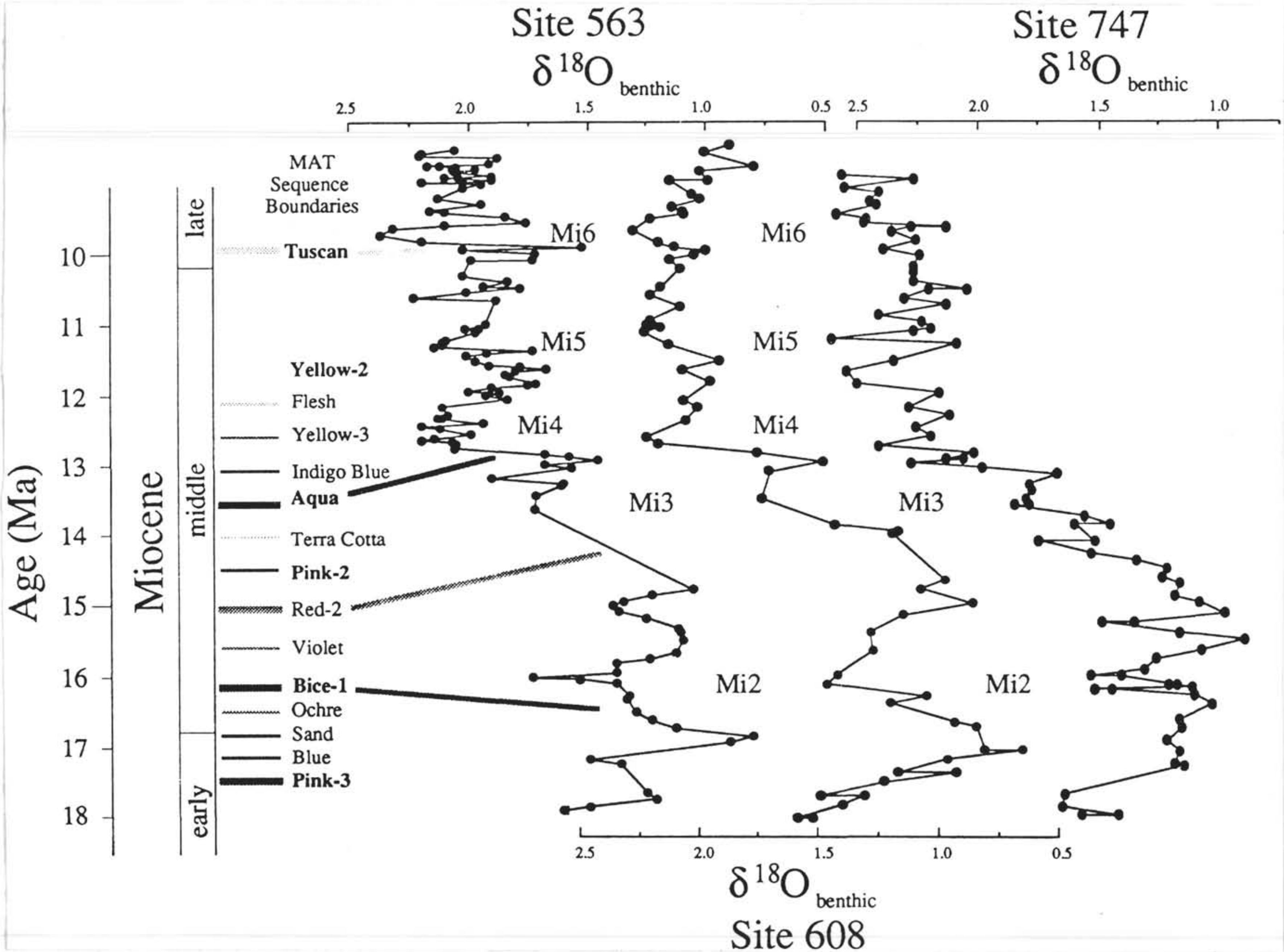

Site 563
δ18O benthic
Site 747
δ18O benthic
2.5
2.0
1.5
1.0
0.5
MAT
Sequence
Boundaries
Age (Ma)
Miocene
late
middle
early
Tuscan
Yellow-2
Flesh
Yellow-3
Indigo Blue
Aqua
Terra Cotta
Pink-2
Red-2
Violet
Bice-1
Ochre
Sand
Blue
Pink-3
Mi6
Mi5
Mi4
Mi3
Mi2
10
11
12
13
14
15
16
17
18
δ18O benthic
Site 608

Figure 7

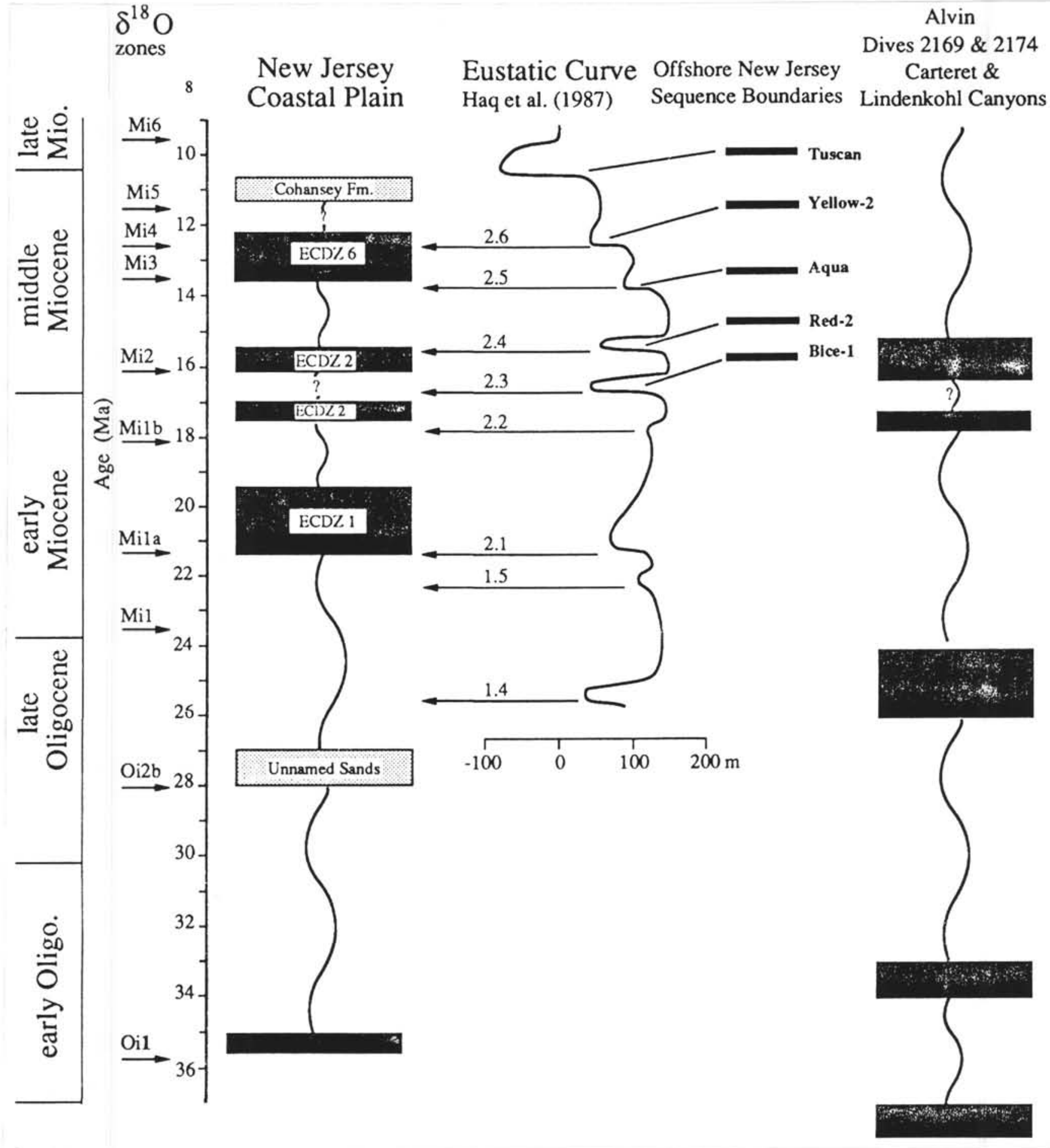

δ18O zones
New Jersey Coastal Plain
Eustatic Curve
Haq et al. (1987)
Offshore New Jersey Sequence Boundaries
Alvin
Dives 2169 & 2174
Carteret &
Lindenkohl Canyons
late Mio.
middle Miocene
early Miocene
late Oligocene
early Oligo.
Age (Ma)
Mi6
Mi5
Mi4
Mi3
Mi2
Mi1b
Mi1a
Mi1
Oi2b
Oi1
Cohansey Fm.
ECDZ 6
ECDZ 2
ECDZ 2
ECDZ 1
Unnamed Sands
2.6
2.5
2.4
2.3
2.2
2.1
1.5
1.4
Tuscan
Yellow-2
Aqua
Red-2
Blce-1
-100
0
100
200 m

Figure 8

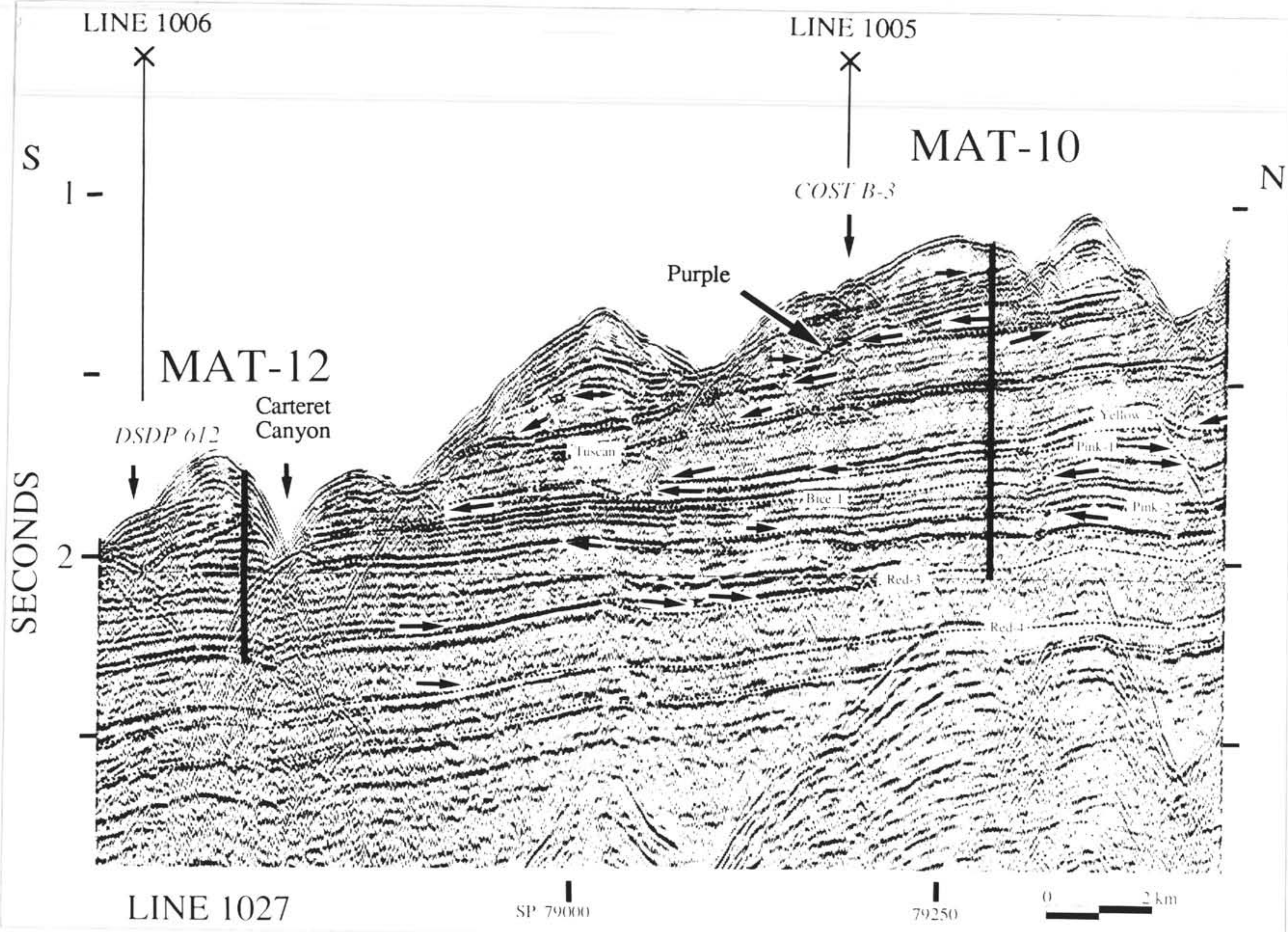

LINE 1006
LINE 1005
S
MAT-10
N
1
COST B-3
Purple
MAT-12
Carteret
Canyon
DSDP 612
SECONDS
2
Yellow-2
Pink-1
Tuscan
Blue-1
Pink-2
Red-3
Red-4
LINE 1027
SP 79000
79250
0
2 km

Figure 9

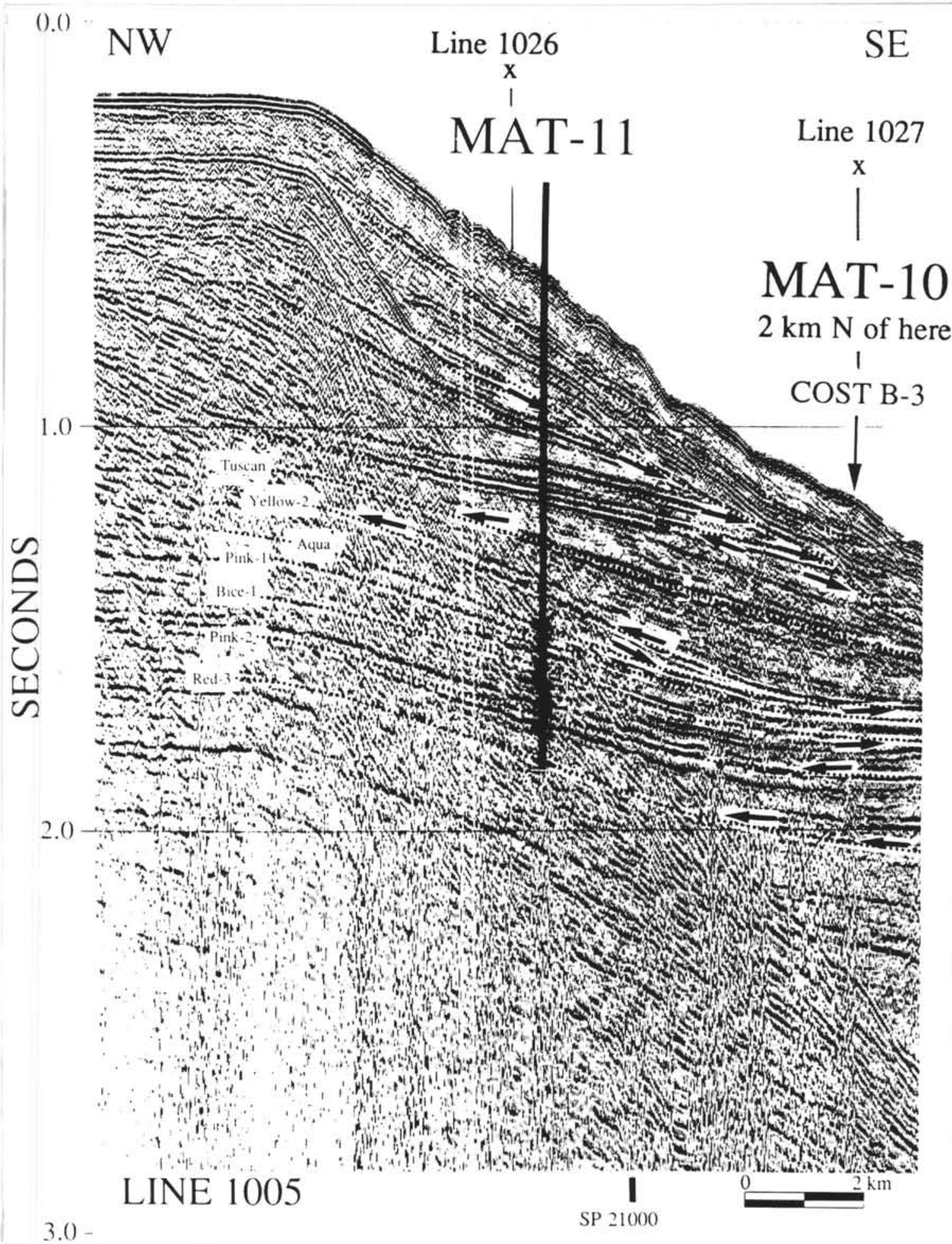

0.0
NW
Line 1026
x
MAT-11
SE
Line 1027
x
MAT-10
2 km N of here
COST B-3
1.0
Tuscan
Yellow-2
Aqua
Pink-1
Bice-1
Pink-2
Red-3
SECONDS
2.0
LINE 1005
SP 21000
0
2 km
3.0

Figure 10

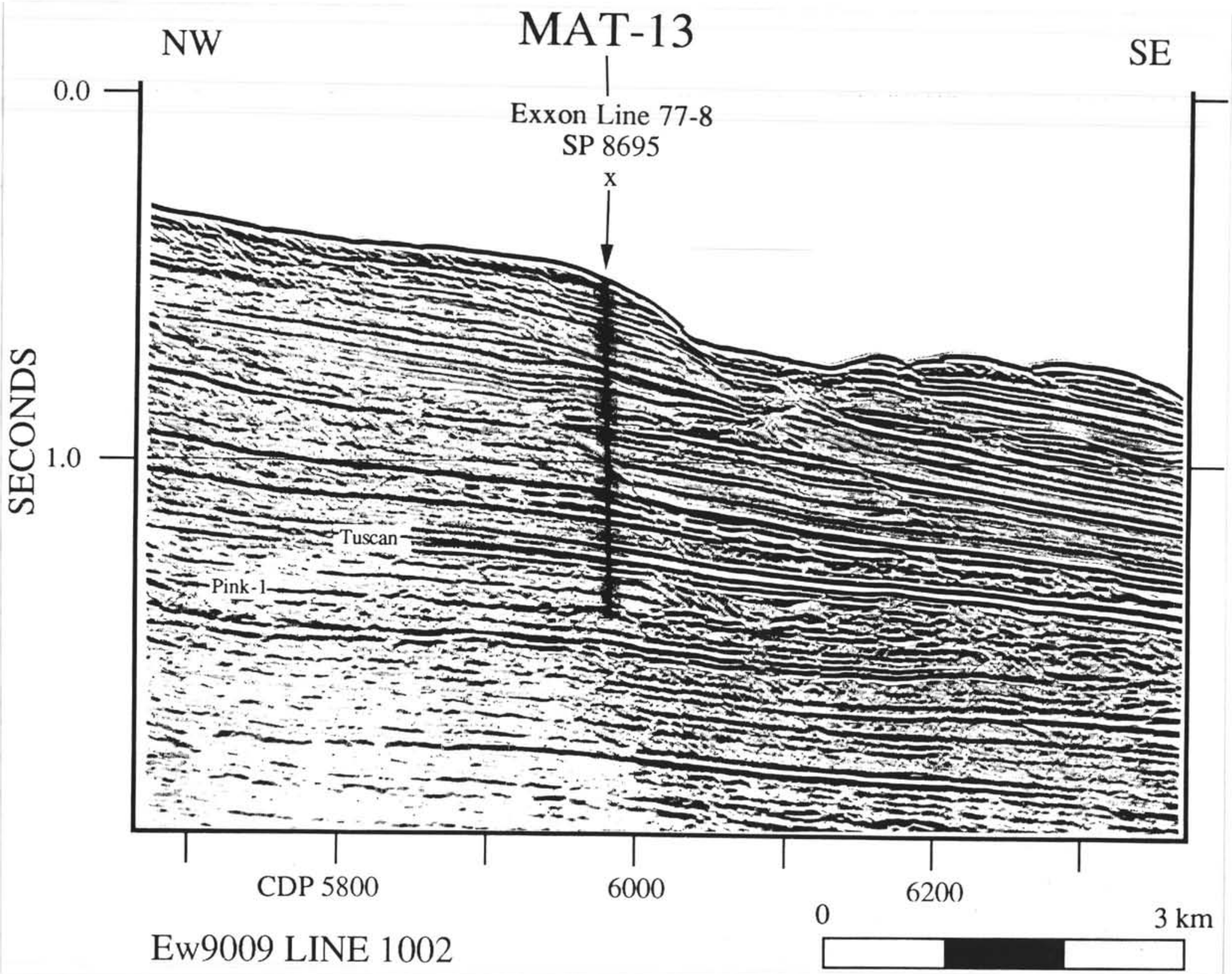

MAT-13
NW
SE
Exxon Line 77-8
SP 8695
x
0.0
1.0
SECONDS
Tuscan
Pink-1
CDP 5800
6000
6200
0
3 km
Ew9009 LINE 1002

Figure 11

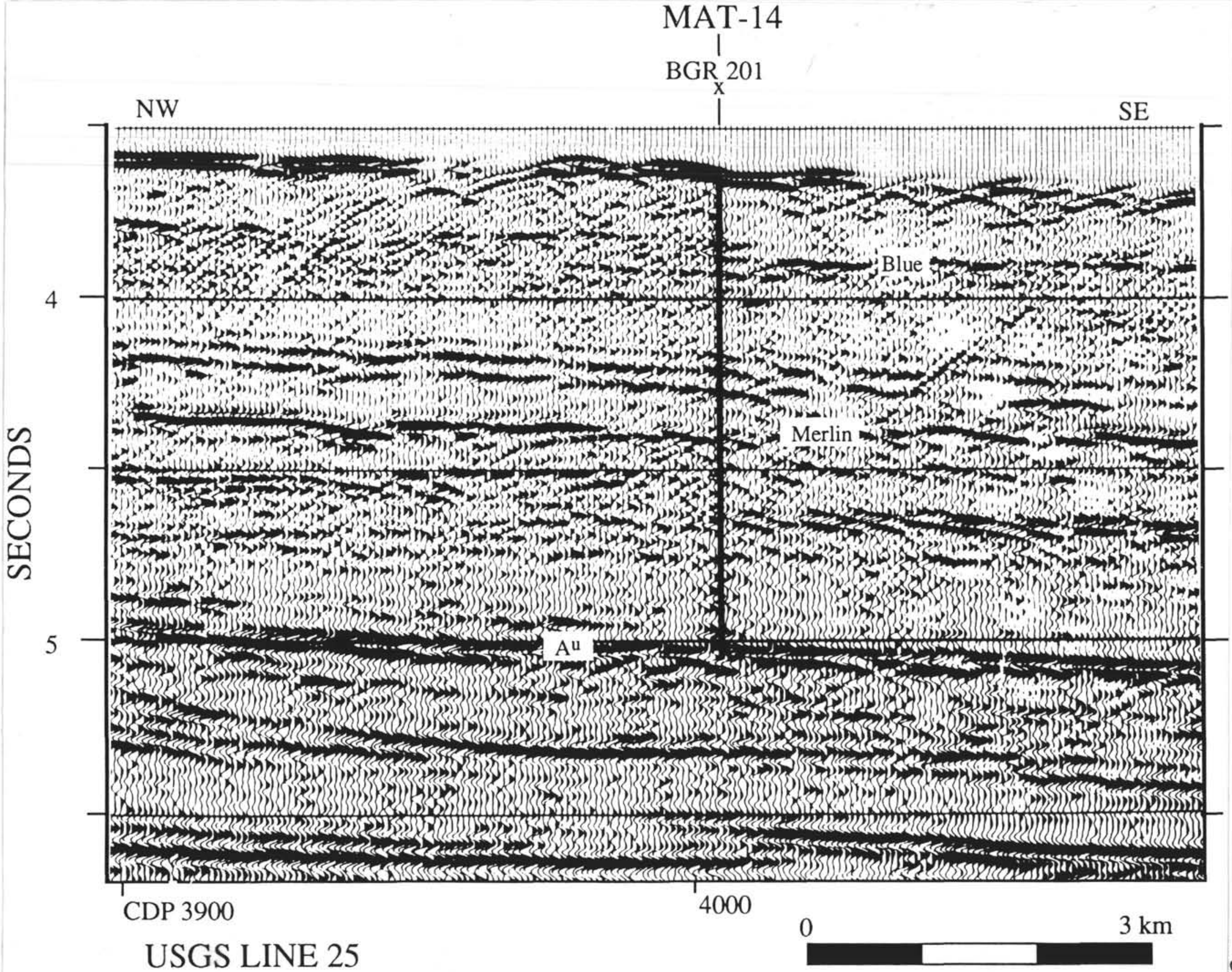

MAT-14
BGR 201
x
NW
SE
Blue
Merlin
A^u
4
5
SECONDS
CDP 3900
4000
0
3 km
USGS LINE 25

Figure 12

Site: MAT-10

Priority: 1

Position: 38°55.93'N, 72°46.05'W

Water Depth: 806 m

Sediment Thickness: ~ 10 km

Total Penetration: 908 m

Seismic Coverage: Ew9009 Line MCS 1027; miscellaneous air gun, water gun, including Exxon MCS

Objectives: Determine age of pelagic correlatives to sequence boundaries Tuscan (10 ± 1 Ma) to Red-3 (?49.5 Ma) sampled on the continental shelf.

Drilling Program: APC and XCB coring.

Logging and Downhole Operations: 1) Schlumberger suite: standard quad combo and geochemical log; 2) Formation Microscanner.

Nature of Rock Anticipated: Silty clays and pebbly mudstones (0-760 m), chalk (760-875 m), and procellanitic limestone (875-908 m).

Site: MAT-11

Priority: 1

Position: 38°56.22'N, 72°49.00'W

Water Depth: 430 m

Sediment Thickness: ~ 10 km

Total Penetration: 1271 m

Seismic Coverage: Ew9009 MCS Lines 1005 (and 1026); Ew9009 water gun; USGS 40 in.^{3} air gun; miscellaneous regional, including Exxon MCS

Objectives: Determine age of pelagic correlatives to sequence boundaries Tuscan (10 ± 1 Ma) to Red-3 (?49.5 Ma) sampled on the continental shelf.

Drilling Program: APC, XCB, RCB coring.

Logging and Downhole Operations: 1) Schlumberger suite: standard quad combo and geochemical log; 2) Formation Microscanner.

Nature of Rock Anticipated: Silty clays and pebbly mudstones.

Site: MAT-12

Priority: 2

Position: 38°50.00'N, 72°49.98'W

Water Depth: 1298 m

Sediment Thickness: ~ 10 km

Total Penetration: 477 m

Seismic Coverage: Ew9009 MCS Line 1027; miscellaneous air gun, water gun

Objectives: Determine age of pelagic correlatives to sequence boundaries Pink-2 (?17.5 Ma) through Red-3 (?49.5 Ma) sampled on the continental shelf.

Drilling Program: APC, XCB, RCB coring.

Logging and Downhole Operations: 1) Schlumberger suite: standard quad combo and geochemical log; 2) Formation Microscanner.

Nature of Rock Anticipated: Silty clays and pebbly mudstones (0-250 m), chalk (250-450 m), and procellanitic limestone (450-477 m).

Site: MAT-13

Priority: 2

Position: 39°12.50'N, 72°26.60'W

Water Depth: 345 m

Sediment Thickness: ~ 10 km

Total Penetration: 937 m

Seismic Coverage: Ew9009 MCS Line 1002; Exxon MCS Line 77-8; miscellaneous regional water-gun and air-gun lines.

Objectives: To focus on upper Neogene sequence boundaries (especially post-Pink-1, ?5.5 Ma) and to provide "ground truth" on pre-late Neogene sequences on the slope adjacent to MAT-8A and -9.

Drilling Program: APC, XCB, and RCB coring.

Logging and Downhole Operations: 1) Schlumberger suite: standard quad combo and geochemical log; 2) Formation Microscanner.

Nature of Rock Anticipated: Silty clays and pebbly mudstones.

Site: MAT-14

Priority: 2

Position: 38°37.00'N, 72°17.30'W

Water Depth: 2761 m

Sediment Thickness: ~ 10 km

Total Penetration: 1300 m

Seismic Coverage: BGR 201 MCS; USGS 25 MCS; C2502 water gun; C1903 large air gun

Objectives: To determine response of continental-rise sedimentation to sea-level change during "ice-house" interval and to link deep-sea record with shallow- and intermediate-water sea-level studies. Determine age of three major continental-rise unconformities (reflectors Blue, Merlin, and AU)

Drilling Program: APC, XCB, RCB coring and reentry.

Logging and Downhole Operations: 1) Schlumberger suite: standard quad combo and geochemical log; 2) Formation Microscanner.

Nature of Rock Anticipated: Silty clays and mudstones.

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