Integrated Ocean Drilling Program
Expedition 313 Scientific Prospectus

New Jersey shallow shelf

Shallow-water drilling of the New Jersey continental shelf: global sea level and architecture of passive margin sediments

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Abstract

During Integrated Ocean Drilling Program Expedition 313, proposed Sites MAT-1, MAT-2, and MAT-3 will be drilled on the New Jersey shallow shelf to

1. Date Paleogene–Neogene sequences and compare ages of the unconformable surfaces bracketing these sequences with times of sea level lowerings predicted from the $\delta^{18}O$ glacio-eustatic proxy;
2. Estimate the corresponding amplitudes, rates, and mechanisms of sea level change; and
3. Evaluate sequence stratigraphic facies models that predict depositional environments, sediment compositions, and stratal geometries in response to sea level change.

The New Jersey Coastal Plain and continental shelf/slope are a “natural laboratory” for unraveling eustasy and margin sedimentation by providing the chance to drill a series of linked boreholes as part of the “New Jersey/Mid-Atlantic Transect” (NJ/MAT). This margin has been the focus of previous drilling both onshore and offshore (Ocean Drilling Program [ODP] Legs 150X, 174AX, 150, and 174A). Each of these efforts has successfully dated sequence boundaries and tied them to the $\delta^{18}O$ proxy of glacioeustasy, but all have fallen short of the ultimate objectives because the region most sensitive to sea level change (the shallow shelf) has not been sampled and the technology aboard the ODP drilling platform (the R/V *JOIDES Resolution*) had not been well suited for recovering sand-prone shelf sediments. Consequently, a critical gap remains in the NJ/MAT that limits our knowledge of global sea level change and its imprint in the geologic record. The drilling we propose will use a mission-specific platform to obtain subseafloor samples and downhole logging measurements in this crucial shallow shelf region. Sites MAT-1 to MAT-3 represent the most sensitive and accessible locations for bringing the NJ/MAT to a successful conclusion.

Schedule for Expedition 313

Expedition 313 is based on Integrated Ocean Drilling Program drilling proposal number 564 (available at **www.eso.ecord.org/docs/564.pdf**). Following ranking by the IODP Scientific Advisory Structure, the expedition was scheduled for the drilling platform LB *Kayd,* operating under contract with the European Implementing Organization. The expedition is currently scheduled to start at Atlantic City, NJ (USA), on 2 May 2009 and to end in Atlantic City on 22 July 2009 (estimate). An estimated 80 days will be available for the drilling, coring, and downhole measurements described in this report (for the current detailed schedule, see **www.iodp.org/**).

Introduction

Eustasy as a global phenomenon

Understanding the history, cause, and impact of sea level fluctuations is a compelling goal of Earth system research. Not only are worldwide effects of encroaching shorelines evident today—the rate of this change is clearly increasing. Whereas global sea level rise during the previous century was ~1.8 mm/y (Church and White, 2006), today that rate is ~3.25 mm/y (Cazenave et al., 2009), in part due to anthropogenic influences (Barnett, 1990). Furthermore, in many coastal regions the rate is still higher because of the additional effect of local subsidence. The geologic record shows that global sea level has fluctuated by well over 100 m (summaries in Donovan et al., 1979) at rates as high as 20–40 mm/y (Fairbanks, 1989; Stanford et al., 2006). The importance of carefully examining the geologic record for eustatic variations goes beyond preparing for a sea level rise of 0.4 m or more during this century. Indeed, Integrated Ocean Drilling Program (IODP) Expedition 313 will not address the centennial timescale; for that, strategies synthesizing tide gauge and Holocene marsh records are required. Instead, this study leads toward a broader understanding of the long-term behavior and wide-ranging effects of the divide between land and ocean. Throughout Earth's history, the transfer of energy and material across this boundary has profoundly influenced the interactions among the lithosphere, biosphere (e.g., Katz et al., 2005), and atmosphere and continues to affect the balance of these systems today. Weathering rates, sediment distribution, stratal architecture, carbon burial, and glaciation are just a few of the myriad processes that are intertwined with eustatic change.

Despite its importance, knowledge of the basic amplitudes and rates of sea level variations on timescales of tens of thousands to millions of years is surprisingly limited. Our goal is to address this deficiency in the way endorsed by numerous study groups (e.g., Imbrie et al., 1987; JOIDES Pollution Prevention and Safety Panel, 1992): by sampling key facies across the prograding deposits of a passive continental margin at proposed Sites MAT-1, MAT-2, and MAT-3.

Unraveling eustasy from the effects of subsidence and sediment supply requires a fundamental understanding of passive margin response to sedimentation. Deposits adjacent to the shoreline are replete with stratal discontinuities on all spatial scales, including sequence boundaries and regional unconformities associated with evidence for base-level lowering (Vail et al., 1977; Posamentier et al., 1988). Sequence boundaries provide a means to objectively subdivide the stratigraphic record (Christie-Blick et al., 1990; Christie-Blick, 1990), and the intervening sedimentary sequences provide the basis for evaluating controls on sedimentary architecture and predicting sedimentary facies and societally important resource distributions (e.g., hydrocarbons and potable water) (Vail et al., 1977; Sugarman et al., 2006). Remarkably similar sequence architecture occurs on margins of widely contrasting tectonic and sedimentary histories (e.g., Bartek et al., 1991), emphasizing the fact that eustasy exerts a fundamental, worldwide control on the stratigraphic record. Nevertheless, it is clear that tectonism and changes in sediment supply also have molded the stratigraphic record (e.g., Reynolds et al., 1991); the challenge is to isolate the imprint of each of these influences.

Sequence stratigraphy provides a powerful tool for deciphering margin records, but many of its fundamental assumptions have not been tested. For example, although the facies models of Exxon Production Research Company (e.g., Posamentier et al., 1988) are widely applied, the nature of facies associated with prograding clinoforms has not been publicly documented (although Ocean Drilling Program [ODP] Legs 166 and 174A made good contributions). Furthermore, the timing and phase relationships of facies distributions with respect to sea level change have not been evaluated (e.g., Reynolds et al., 1991). More importantly, the sequence stratigraphic record has been used to extract a eustatic history, despite the fact that critical assumptions (e.g., the water depth at the lowest point of onlap; Greenlee and Moore 1988, see discussion below) have not been tested.

Eustatic unknowns: amplitude, response, and mechanism

Measuring the geologic record of amplitudes of eustatic change is a difficult task. Although deep-sea $\delta^{18}O$ records provide precise timing of glacio-eustatic changes (Miller et al., 1991, 1996a, 2005a), eustatic amplitudes can be estimated using $\delta^{18}O$ to no better than ±20% for the past few million years and ±50% prior to that because of assumptions about paleotemperature and application of the Pleistocene sea level/δ_w calibration of Fairbanks and Matthews (1978) to the older record (Miller et al., 2005a). Carbonate atolls have been sampled as fossil "dip sticks" (e.g., ODP Legs 143 and 144), and although this approach has been successful for the Pleistocene (Fairbanks, 1989), recovery and age control for records older than the late Pleistocene have posed very large challenges. As noted above, continental margin sediments have long been regarded as a viable source for extracting eustasy (e.g., Vail, 1977; Watts and Steckler, 1979; Haq et al., 1987; Greenlee and Moore, 1988), provided the effects of total subsidence (compaction, loading, and cooling), as well as changes in sediment supply, could be removed.

Drilling into the New Jersey shallow shelf as we propose will allow us to evaluate the several controls on the stratigraphic record at passive margins. It was known that drilling on the New Jersey continental slope during ODP Leg 150 (Mountain, Miller, Blum, et al., 1994) would yield virtually no information concerning amplitudes. By contrast, it was expected that the coastal plain drilling during ODP Leg 150X (Miller et al., 1994, 1996b) and later ODP Leg 174AX (Miller et al., 1998, 2003, 2004, 2005a; Miller, Sugarman, Browning, et al., 1998; Kominz et al., 2008) would provide valuable constraints on how high sea level rose during the last 100 m.y. Although onshore analyses have borne this out (Fig. **F1**), they have been based on incomplete Miocene and younger sections dating from times when the shoreline was frequently seaward of its current position (Kominz et al., 1998). By contrast, the Late Cretaceous to Oligocene shoreline was often landward of the coastal plain wells and, as a result, eustatic amplitudes from these sections have been shown to be as large or larger than those of the Miocene (Fig. **F1**) (Miller et al., 2005a). Analyses from ODP Leg 194 on the Marion Plateau (John et al., 2004) clearly show that the New Jersey onshore sites do not capture the full amplitude of Miocene sea level change. Though backstripping the Marion Plateau data provided a relatively precise estimate of 56.5 ± 11.5 m for a late middle Miocene fall (John et al., 2004), it did not address estimates of other Miocene events. The New Jersey continental shelf, particularly the inner to middle shelf where we propose to drill Sites MAT-1 to MAT-3, is much better suited for estimating late Oligocene–Miocene eustatic amplitudes because sediments at this location are stratigraphically more complete, record the full range of water depth variations, and provide the facies needed to estimate eustatic amplitudes.

Various facies models have been proposed to explain shelf sedimentation in response to eustatic changes (e.g., Posamentier et al., 1988; Galloway, 1989), but the fact remains the response of passive margin sedimentation to large, rapid sea level changes is not well known. One of the main reasons for this situation is the scarcity of direct sampling of well-imaged seismic sequences in the regions most affected by sea level change. Understanding the amplitude of sea level change and sedimentation response requires knowledge of the depositional setting of strata that onlap sequence boundaries, but without samples it cannot be known if this onlap is coastal, marginal marine, or deep marine (~100 m or more, as suggested by Greenlee and Moore, 1988). Furthermore, the depositional significance (e.g., shoreface versus midshelf) of the clinoform inflection point, a critical constraint in facies interpretation, has been inferred mostly through forward models, although tantalizing evidence recovered from Leg 174A Hole 1071F suggests a marginal marine setting ~3.5 km landward of one late middle Miocene clinoform inflection point (Austin, Christie-Blick, Malone, et al., 1998). Continued analysis of Leg 174A sequences will shed new light on shelf facies models and their predictions from seismic data, but these data were limited by low core recovery and penetration of only upper middle Miocene and younger strata, hampering efforts to establish reliable facies models. Drilling at proposed Sites MAT-1 to MAT-3 will provide the information needed to properly evaluate depositional facies models.

Glacioeustasy (Donovan et al., 1979) is the only known mechanism for producing the large, rapid eustatic changes that have been reported for the past 200 m.y. (Miller et al., 2005a). Previous studies of the New Jersey margin have shown that changes in ice volume are the dominant mechanism causing eustatic changes in the last 42 m.y. (Miller et al., 1996a, 1998). Most researchers have assumed that Earth was ice-free during Cretaceous to Eocene times; however, Stoll and Schrag (1996) and Miller et al. (1999, 2004, 2005a, 2005b) have argued that there were ice sheets during the Cretaceous to early Eocene. One of the sites we plan to drill, Site MAT-1, is intended to recover a Paleocene–Eocene record that will address this fundamental issue.

The importance of eustasy versus tectonism to the formation and preservation of sequences is a long-standing debate that our proposed drilling will address. Tectonism in this context includes phenomena that operate across a large range of scales in both time and space (i.e., from rapid, narrowly focused “active” processes such as faulting and salt intrusion to the slower and more laterally extensive "passive" process of flexural loading). We have backstripped seven onshore boreholes (Kominz et al., 1998, 2008; Van Sickle et al., 2004; see summary in Miller et al., 2005b) and have shown that active tectonics has played a minimal role in Cenozoic onshore deposition. By contrast, backstripping has shown that flexural loading led to ~30 m of excess subsidence at onshore Delaware wells versus those in New Jersey beginning at ~21–12 Ma. This enhanced subsidence is attributed to a local flexural response to the load of thick sequences prograding offshore Delaware (Browning et al., 2006). Based on this, we hypothesize that

- Eustatic change is a first-order control on accommodation space and provides a simultaneous imprint on all continental margins;
- Tectonic change due to movement of the crust can overprint the record and result in large gaps, though this effect is not apparent in New Jersey Miocene sequences; and
- Second-order differences in sequences can be attributed to local flexural loading effects, particularly in regions experiencing large-scale progradation.

Sites MAT-1 to MAT-3 (Fig. **F2**) provide the crucial link in the onshore–offshore transect (Fig. **F3**) required to evaluate eustasy versus local lithospheric flexure on the development of prograding late Oligocene–Miocene sequences.

The New Jersey margin: its suitability, results, and promise

The New Jersey margin is an ideal location to investigate the history of sea level change and its relationship to sequence stratigraphy for several reasons: rapid depositional rates, tectonic stability, and well-preserved, cosmopolitan fossils suitable for age control characterize the sediments of this margin throughout the time interval of interest (see summary in Miller and Mountain, 1994). In addition, there exists a large set of seismic, well log, and borehole data with which to frame the general geologic setting from the coastal plain across the shelf to the slope and rise (Miller and Mountain, 1994) (Figs. **F2, F3**).

Drilling into the New Jersey slope (ODP Sites 902–904 and 1073) and the Coastal Plain (Island Beach, Atlantic City, Cape May, Bass River, Ancora, Oceanview, Bethany Beach, Millvile, Fort Mott, Sea Girt, and Cape May Zoo) has provided a chronology for sea level changes over the past 100 m.y. (Miller and Snyder, 1997; Miller et al., 1998, 2005a). Sequence boundaries from 10 to 42 Ma have been shown to correlate (within ±0.5 m.y.) both regionally (onshore–offshore) and interregionally (New Jersey–Alabama–Bahamas), as well as globally, with glacio-eustatic lowerings inferred from the $\delta^{18}O$ record (Fig. **F4**). These correlations establish a firm link between late middle Eocene to middle Miocene glacio-eustatic change and margin erosion on the million year scale. Oxygen isotopic studies of slope Site 904 provide prima facie evidence for a causal connection between Miocene $\delta^{18}O$ increases (inferred glacio-eustatic falls) and sequence boundaries (Miller, Sugarman, Browning, et al., 1998). Results of these studies are consistent with the general number and timing of Late Cretaceous to middle Miocene sequences initially published by Exxon (Vail and Mitchum, 1977), although the Exxon group's sea level amplitudes are substantially higher than those derived in New Jersey studies (Miller et al., 1996b, 2005a; Miller, Sugarman, Browning, et al., 1998; Van Sickel et al., 2004).

Aided by easier access to older strata than is found downdip/offshore, New Jersey Coastal Plain drilling (Miller et al., 1994, 1996b; Miller, Sugarman, Browning, et al., 1998) has sampled "Greenhouse" (Cretaceous to Eocene) sequences and addressed their relationship to global sea level changes. One surprising result has been to extend the history of ice sheets back to a time previously considered to be ice-free (Late Cretaceous–middle Eocene, Browning et al., 1996; mid-Maastrichtian, Miller et al., 1999, 2005a, 2005b). Late Cretaceous to middle Eocene comparisons of onshore hiatuses/sequence boundaries and $\delta^{18}O$ indicate that growth and decay of small ice sheets (<30 m sea level equivalent) also occurred in this supposedly ice-free world (Browning et al., 1996; Miller et al., 1998, 2003, 2005a, 2005b).

ODP drilling in the Bahamas (Leg 166 and supplementary platform drilling; Eberli, Swart, Malone, et al., 1997) complements the results from New Jersey by providing a chronology of base-level lowerings (Fig. **F4**) and an evaluation of prograding carbonate sequences.

Published results of drilling at the New Jersey and Bahamas margins validate the approaches outlined by COSODII (Imbrie et al., 1987) and the JOIDES Seal Level Working Group (Loutit, 1992). In particular,

- Each region has proved the age of sequence boundaries on margins can be determined to better than ±0.5 m.y.;
- Both regions have validated the "transect" approach of drilling passive continental margins (arrays of holes: onshore, shelf, and slope);

- The siliciclastic New Jersey margin and the carbonate Bahamas margin yield correlatable records of base-level change, as deduced from definitions of the chronostratigraphy of seismically observed stratal discontinuities; and
- Orbital-scale stratigraphic resolution has been achieved on continental slopes and carbonate platforms.

Despite these advances in dating sequences and linking them to glacioeustasy, there are major gaps in our understanding of amplitudes, response of sedimentation, and mechanisms that drive eustatic change. Only by drilling in the region most sensitive to sea level change, the paleo-nearshore zone to inner shelf region of a passive margin, can these gaps be filled.

Scientific objectives

1. *Provide a testable record of eustatic variations.*

Backstripping is a proven method for extracting amplitudes of global sea level from passive margin records (e.g., Watts and Steckler, 1979). One-dimensional backstripping is a technique that progressively removes the effects of sediment loading (including the effects of compaction) and paleowater depth from basin subsidence. By modeling thermal subsidence on a passive margin, the tectonic portion of subsidence can be assessed and a eustatic estimate obtained (Kominz et al., 1998, 2008; Van Sickel et al., 2004). Backstripping requires knowing relatively precise ages, paleodepths, and porosities of sediments, and each of these criteria are best obtained from borehole transects. Such transects also allow application of two-dimensional backstripping techniques that account for lithospheric flexural effects, increasing the precision of the eustatic estimates (Steckler et al., 1999; Kominz and Pekar, 2001). The eustatic component obtained from backstripping needs to be verified by comparing sea level records with other margins and those derived from $\delta^{18}O$ estimates.

Drilling at Sites MAT-1 to MAT-3 will allow us to make precise late Oligocene to early middle Miocene eustatic estimates using one- and two-dimensional backstripping as described above. One- (Kominz et al., 1998; Van Sickel et al., 2004) and two-dimensional (Kominz and Pekar, 2001) backstripping of onshore New Jersey sites have provided preliminary amplitude estimates of 10–60 m for million year–scale variations, but the estimates are incomplete, particularly for the Miocene, because most lowstand deposits are generally not represented (Miller, Sugarman, Browning, et al., 1998; Miller et al., 2005a, and fig. F2 therein). Amplitude estimates derived from $\delta^{18}O$ studies require assumptions about temperature and the sea level/δ_w calibration; although the uncertainties are large, initial eustatic estimates based on $\delta^{18}O$ records are consistent with backstripping results (Fig. **F1**). Sites MAT-1 to MAT-3 are precisely located to recover as nearly a complete set of late Oligocene–middle Miocene sequences as possible and, through backstripping, provide a much more direct measure of the full range of amplitudes for this time interval.

Once we have obtained precise eustatic estimates from late Oligocene to early middle Miocene records at Sites MAT-1 to MAT-3, we will be able to extend our results to the older and younger records. Middle Miocene through recent sediments record similar clinoform geometries on the New Jersey shelf; by applying calibrations of seismic profiles and facies developed as part of this work, we should be able to derive eustatic estimates for the interval 16–0 Ma. In particular, deriving a firm, independent eustatic estimate from margin sediments will

- Allow us to test temperature assumptions needed to make glacio-eustatic estimates from $\delta^{18}O$ records (Fig. **F1**),
- Provide an estimate of the Tertiary sea level/δ_w calibration, and
- Evaluate the Pekar (1999) and Pekar et al. (2002) calibration of 0.09‰/10 m (versus 0.11‰/10 m for the late Pleistocene) that was based on backstripping an incomplete coastal plain record.

Whereas both backstripping and $\delta^{18}O$ methods make inherently large assumptions, the convergence of the two methods (Fig. **F1**) suggests that we will be able to produce a testable eustatic model for the past 42 m.y. and perhaps for the older record as well.

2. *Test models of sedimentation on siliciclastic shelves.*

Shallow-water records contain unconformities observed in outcrop or in the subsurface at all spatial scales, whether they divide beds or basins. Unconformably bounded sequences are the fundamental building blocks of the shallow-water record (Sloss, 1963; Van Wagoner et al., 1990; Christie-Blick, 1991). Researchers at the Exxon Production Research Company (Vail et al., 1977; Haq et al., 1987; Van Wagoner et al., 1988; Posamentier et al., 1988) claimed that similarities in the ages of stratal unconformities pointed to global sea level (eustasy) as the overriding control. The resulting "eustatic curve" has remained controversial (e.g., Christie-Blick et al., 1990; Miall, 1991), largely because of basic assumptions about the stratigraphic response to eustatic change and because the work relies in part on unpublished data. In response to this controversy, Christie-Blick and Driscoll (1995), among others, pointed out that the fundamental enterprise of interpreting the origin of layered rocks does not really require any assumptions about eustasy. They emphasized that sequence boundaries attest to changes in depositional base level. The timing of many of the Exxon Production Research Company sequence boundaries has been validated onshore New Jersey and correlated to the $\delta^{18}O$ proxy of eustatic change (Miller et al., 1998, 2005a), though other sequence boundaries on this and other margins may be tectonically derived. Whether sequence boundaries are caused by changes in eustasy, local tectonism, or sediment supply (Reynolds et al., 1991), disconformable surfaces irrefutably divide the shallow-water record into sequences. Whatever their cause, these stratal breaks are real and they provide an objective means of analyzing the rock record.

Facies between sequence boundaries vary in a coherent fashion, and various facies models have been proposed for shelf sedimentation (e.g., Posamentier et al., 1988; Galloway, 1989). Much work has been done by the exploration and academic communities in testing and applying these models, and much has been learned. For example, flooding surfaces (particularly maximum flooding surfaces) can be used to unravel stratigraphic stacking patterns (e.g., Galloway, 1989), whereas highstand deposits are generally regressive and commonly serve as reservoirs for oil or water resources (e.g., Posamentier et al., 1988; Greenlee et al., 1992; Sugarman and Miller, 1997; Sugarman et al., 2006). Nonetheless, predictions of facies models have not been widely successful because they are the products of many unevaluated processes (Reynolds et al., 1991).

One major reason that models are still poorly constrained is that there has been no publicly available study of continuous cores across a prograding clinoform deposit that constitutes the central element of many facies models. As a result, the water depths in which clinoforms form and the distribution of lithofacies they contain are not well known. It is widely debated whether clinoform tops ever become subaerially exposed during sea level lowstands and whether the shoreline ever retreats to (or perhaps moves seaward of) the clinoform rollover (Fulthorpe and Austin, 1998; Austin et al., 1998; Steckler et al., 1999; Fulthorpe et al., 1999). Settling these controversies will have significant implications on our understanding of how sequence boundaries develop and how much of the facies distribution within clinoforms can be attributed to eustasy. Some workers assume that the shoreline is always located at the clinoform rollover (e.g., Posamentier et al., 1988; Van Wagoner et al., 1990; Lawrence et al., 1990). Others have presented models of basin evolution that suggest the shoreline and the clinoform rollover can move independently of each other (e.g., Steckler et al., 1993, 1999). The sea level estimates of Greenlee and Moore (1988) argue that sea level falls expose an entire continental shelf and that strata onlapping clinoform fronts are coastal plain sediments deposited during the beginning of the subsequent sea level rise. Many researchers (e.g., Steckler et al., 1993) stress that if strata onlapping clinoform fronts were deposited at or near sea level, then the clinoform heights dictate that sea level occasionally fell hundreds of meters in less than a million years; such magnitudes and rates are beyond the reasonable scales of any known mechanism for eustatic change. Extracting the amplitude of sea level fluctuations from sequence architecture is critically dependent on whether the lowest point of onlap onto sequence boundaries is truly coastal or is deeper marine. Determining water depths at the clinoform edge is essential to sequence stratigraphic models and understand this basic element of the dynamic land-sea interface. It can only be established by sampling, such as proposed here.

Proposed drill sites

Optimal locations of Sites MAT-1, MAT-2, and MAT-3

The region between the paleo-shoreline and the paleo-inner to middle shelf is the most sensitive region for studying past sea level variations and *must* be sampled to obtain estimates of eustatic amplitudes. Reliability of these estimates depends on the precision of paleowater depths determined by lithologic and benthic foraminiferal criteria. Both of these are optimal indicators in nearshore to middle neritic facies but become less precise in facies deeper than middle neritic (>100 m) paleodepths (see examples in Miller and Snyder, 1997). Sections deposited in nearshore to inner neritic environments (<30 m paleodepth) are difficult to date, even though the facies associations may be clearer and the paleodepth resolution is best. Work onshore New Jersey has shown that the best results can be obtained by targeting sequences deposited between 0 and 60 m paleodepth (Kominz and Pekar, 2001). Following these guidelines, as well as concepts developed by the JOIDES Sea Level Working Group (Loutit, 1992), the ideal drilling locations are outlined in Figure **F5.**

Sites MAT-1 to MAT-3 target upper Oligocene to middle Miocene seismically imaged prograding clinoforms that were deposited in inner–middle neritic paleodepths (based on coeval onshore strata deposited in nearshore/prodelta settings). We have obtained excellent seismic profiles of these clinoforms (Fig. **F6**) across the regions that record the full amplitude of sea level change: immediately landward of and near the toes of the clinoforms (i.e., across the clinoform inflection point). Modern water depths at Sites MAT-1 to MAT-3 are ~34 m (Fig. **F7;** Table **T1**), a fortunate "crossover" depth between being too far landward for detailed control on sequence geometry (i.e., thorough seismic control on land is not possible) and too far seaward for affordable commercial drill rigs.

Site location

Three sites have been selected that lie along a dip-line transect (Fig. **F7**) roughly 45 to 60 km offshore New Jersey in 32–35 m water depths; primary locations are Sites MAT-1A, MAT-2D, and MAT-3A (Table **T1**).

Available site survey data at Sites MAT-1 to MAT-3

Three MCS surveys have passed within 1 km of proposed Sites MAT-1 to MAT-3 (**IODP Site Survey Databank**):

1. A reconnaissance grid using a 120-channel, 6-air gun system aboard the R/V *Maurice Ewing* in 1990 was the first demonstration that Oligocene–Miocene clinoforms were well developed at this location.
2. The R/V *Oceanus* returned with 48-channel, generator-injector gun, high-resolution seismic equipment in 1995 and collected remarkably improved images of these same features along Line 529.
3. In 1998 the R/V *Cape Hatteras* concentrated on three grids of 150–600 m line spacing designed to provide detailed three-dimensional control on clinoform geometries, as well as to meet the guidelines established by the JOIDES Pollution Prevention and Safety Panel (1992).

These data have been studied to determine the location of any subsurface features that may pose a hazard to drilling (amplitude anomalies suggesting trapped gas, faults that could serve as conduits for deep-seated hydrocarbons, or indicators of unstable settings for a jack-up rig).

A Simrad EM1000 swath-bathymetry/acoustic backscatter survey passed over the proposed drill sites during an U.S. Office of Naval Research–supported STRATAFORM study in 1996. In June 1999 Joint Oceanographic Institutions, Inc./U.S. Science Advisory Committee (USSAC) supported the collection of additional Simrad EM3000 bathymetry and seafloor grab samples across Sites MAT-1 to MAT-3. A review of all data, including reprocessing of the *Cape Hatteras* seismic data, was carried out by an independent site survey company (Guardline) for a gas hazard report. No significant gas hazards were found to affect any of the potential drilling locations. Finally, as a final examination for seabed hazards and characterization, additional profiling, magnetometer, and vibracore data were collected by Alpine Geophysical in Spring 2008 and each proposed site was determined safe for drilling.

Coring strategy

The "New Jersey/Mid-Atlantic Sea Level Transect" (NJ/MAT) was designed as a series of boreholes from the onshore New Jersey Coastal Plain across the shelf to the slope and rise (Miller and Mountain, 1994) (Figs. **F1, F2**) with the following goals:

1. Date major "Icehouse" (Oligocene–recent) sequences, a time of known glacio-eustatic change (Miller et al., 1991), and compare ages of the unconformable surfaces bracketing these sequences with times of sea level lowerings predicted from the $\delta^{18}O$ glacio-eustatic proxy;
2. Estimate the amplitudes, rates, and mechanisms of sea level change; and
3. Evaluate sequence stratigraphic facies models (e.g., systems tracts) (Posamentier et al., 1988, Catuneanu, 2006) that predict depositional environments, sediment compositions, and stratal geometries in response to sea level change.

Leg 174A shelf drilling (Austin, Christie-Blick, Malone, et al., 1998) targeted similar upper Miocene–Pliocene clinoforms beneath the modern outer shelf, demonstrated that the multiple-site transect strategy is valid, and attempted to yield precise eustatic estimates across one upper Miocene sequence. Success was hampered by unstable hole conditions that led to moderate to poor recovery and the inability to reach sediments older than 12 Ma. Proposed shallow shelf Sites MAT-1 to MAT-3 (Figs. **F6, F7**) are ideally located to sample sequence boundaries both landward and seaward of several clinoform inflection points and to test the amplitudes of, and facies models for, late Oligocene to middle Miocene sea level changes. Prime targets include sequence-bounding late Oligocene reflection "o1" to middle Miocene "m4" (~28–14 Ma) (Monteverde et al., 2000).

Site location details

For site location details, see Tables **T2, T3,** and **T4.** Total sediment penetration for the three New Jersey margin sites is 2250 m.

Operational strategy

Drilling platform

The required depth of the boreholes below seabed is 750 m. The water depth at all the sites is shallow (35 to 40 m), and thus a jack-up type rig has been selected to carry out the coring for the project. The drilling platform, chosen by the contractor and inspected by European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO), is the LB *Kayd*, which is a 245 class liftboat. Essentially this is a three-legged, self propelled jack-up.

The coring rig will be cantilevered off the bow of the liftboat, between the two forward jacking legs.

The *Kayd* will have sufficient capacity by way of food and accommodation for 24 h operation but will require frequent resupply, which will be carried out by a contractor-arranged supply boat provisionally on a 7 day cycle. Exact scheduling will be controlled by coring requirements and, particularly, the freshwater requirements of the rig.

Coring rig

The coring rig is an Atlas Copco CS4002 mining rig utilizing flush-jointed mining drill strings sized to allow the larger ones to act as casings if the coring requires it. The rig has a mast capable of handling 6 m string lengths, and coring is done with a top drive system installed in the mast. Wireline operation of the core barrel is conducted through the top drive.

Coring methodology

A conductor pipe will be run to the seabed to protect the first drill string from excessive movement and vibration. Initially it may not be run into seabed to allow core collection from the seabed, but following this it can be run to a suitable depth to maintain top-hole stability for the rest of the coring.

The first coring string will be a Deep Observation and Sampling of the Earth's Continental Crust (DOSECC) lake drilling system with a wireline core barrel and a PHD (mining pipe) or HWT (mining casing) flush-jointed drill string (114.3 mm outer diameter [OD], 101.6 mm inner diameter [ID]). This system has interchangeable inner core barrels. The outer core bit size will be ~160 mm, and the core collected will be ~62 mm diameter. This is the "standard" IODP core size and is collected in identical liners.

The annulus between the hole and drill string is small, which is key to obtaining a stable borehole in delicate formations. The outer core barrel is able to accept a variety of inner core barrels, which will help to maximize core recovery in unconsolidated and consolidated formations. The inner core barrel bit or cutting shoe is interchangeable with the inner core barrel, allowing a good degree of flexibility to ensure that best core recovery and quality are obtained.

The maximum core run length will be 3 m. However, the length of a core run will be geared to maximize the core recovery and maintain hole stability, even if this reduces overall penetration speed. In unconsolidated, sandy, or silty formations, these core runs could well be less than the 3 m maximum length.

Drilling mud will be used to condition the borehole as dictated by the circumstances and the driller's requirements. Fluorescent microspheres will be added to the mud to assist the evaluation of contamination of samples for microbiology studies.

Should it be impossible to reach the required total depth (TD) with a single drill string, the first string will be used as a casing for the completed part of the borehole. With the inner core barrel removed, sufficient clearance through the outer core barrel bit will be made available to allow a second string and core barrel to pass through and thus progress the borehole. This second drill string will also be a flush-jointed mining system (HQ; 96.0 mm OD, 63.5 mm ID) and has a matched HQ-size mining core barrel. The core is also collected in a liner and, because the hole diameter and annulus spacing are smaller, the core collected is essentially the same size as the first core (61 mm diameter).

The liner is standard mining type and different from the IODP liner. Both types of liner were provided to the curation and petrophysics teams for calibration.

Drilling mud will also be used to condition this section of the borehole and to ensure the top of the section does not deteriorate further than the point when it caused the second string to be deployed.

Appropriate systems for gas monitoring will be used throughout the expedition. They will be contractor- and ESO-supplied. Note that although such systems will be able to detect and identify gas, they are empirical or semiquantitative at best and are not analytical instruments.

Core on deck

Once the drilling operation commences and core begins to arrive on deck and after initial labeling of cores, the operations team will be responsible for delivering the cores to the curation container. The operation will proceed using a changeover of inner core barrels to ensure continuity of the coring operation in as timely a fashion as possible. The deck operators will deploy an empty core barrel immediately after the previous one has been retrieved and then address the core removal and subsequent readying of that core barrel for reuse. As the cores will be collected in a plastic liner, the usual IODP curation procedures will be followed and will be documented in an ESO Handbook.

Downhole logging

During all expeditions the downhole logging program will be integrated with the scientific objectives to ensure maximum scientific output. This may include the use of specialist third-party tools.

To facilitate downhole measurements and core petrophysics for mission-specific platforms, the European Petrophysics Consortium (EPC) has been developing protocols for use both offshore and as part of the Onshore Science Party.

Unlike the D/V *Chikyu* and riserless vessels where the pipe size will be constant and allows a standard set of logging tools to be deployed, mission-specific platforms have variable pipe sizes and drill in a variety of water depths, each of which provides constraints on the anatomy of logging operations. Pipe diameter is the controlling factor, and it is envisaged that a wide range, from slim-line memory-mode tools to standard oilfield tool suites, may be utilized. Water depth is also an important constraint because some mission-specific platform expeditions will operate in very shallow territorial waters where the deployment of nuclear sources may be prohibited or be severely restricted.

This service will be contracted as part of the services for the New Jersey shallow shelf expedition and will be managed by the EPC. The logging equipment and team will be interfaced for a seamless operation on the platform, ready to undertake any requirements as the project progresses.

Priorities and potential program of work

All aspects of the following work program are subject to change as our knowledge of hole conditions and the timing of operational activities improves.

The New Jersey sites will be attempted in the following order: MAT-1, MAT-2, and MAT-3. Site MAT-2 is considered to be the most scientifically critical site. Site MAT-3 is considered to be the least scientifically critical site and may not be cored in its entirety if time runs out toward the end of the operation. If coring at Site MAT-1 is problematic and slow, the Eocene section below the "o1" reflector at Site MAT-1 will not be cored, as it is considered to be a low-priority interval.

In all holes, we will core to TD (750 m) or the maximum depth possible, using the PHD string. Before continuing with the smaller diameter HQ string if required, a total gamma ray log will be taken through the PHD casing. After HQ coring, a total gamma ray log will be taken through the HQ-cased section of the hole. Drilling will be paused to take in situ borehole temperature measurements if borehole conditions are favorable.

Open-hole logging will commence after coring, most probably in increments to reduce the risk of hole instability halting the logging runs. The exact pull-back increments will be defined on site when we will have better knowledge of the formations. If HQ coring is utilized, the minimum pull-back of the first increment is at the depth where HQ coring commenced.

Normally, and where hole stability allows, five wireline logging tools will be run at each site in this order: induction resistivity, magnetic susceptibility, sonic measurements, spectral and total gamma ray, and mechanical caliper. The induction tool is the most robust tool in this suite and, with minimal risk of damage, will confirm whether the hole is open for additional logging tools while providing information about porosity and formation fluids.

Vertical seismic profile (VSP) logging will commence over the entire open hole after all wireline logging is finished. If an unstable hole is indicated, a wiper trip to recondition the hole will be conducted before VSP logging is attempted. If the hole is found to be very unstable during the wireline logging runs, VSP logging will be attempted in increments, essentially as the fifth tool in the logging suite.

VSP logging of Site MAT-2 is critical to meet the scientific objectives of the expedition. If VSP logging of the first hole at Site MAT-2 is unsuccessful, a dedicated hole for VSP logging may be drilled using a full-face bit (no coring) despite the potential reduction in available coring time this might cause at Site MAT-3. This will only be undertaken if VSP logging was successful at Site MAT-1, which will have demonstrated that the expedition can run VSP logging in difficult, sand-prone formations. If Sites MAT-1 and MAT-2 both prove too challenging for VSP logging, then VSP logging will be attempted at Site MAT-3, which is suspected to be the least sand-prone site.

If the borehole remains open after VSP logging, and if time allows, a second low-priority suite of wireline tools may be run: hydrogeological, and acoustic imaging (including acoustic caliper).

Marine mammal observation will be conducted by trained observers during VSP surveying.

Science operations

A sampling and measurements plan for Expedition 313 (see the **"Appendix"**) was prepared to meet the scientific objectives of IODP Proposal 564 following the recommendations of the Science Advisory Structure (SAS).

Offshore science operations

After due consideration, it has been decided that there will be no splitting of the cores at sea, as it will be more efficient to carry out most of the scientific analysis during the Onshore Science Party at Bremen. Therefore, only limited scientific analysis will be carried out on board, and only a limited number of scientists will be required to sail. It is currently planned that core will be cut on board into 1.5 m lengths and curated (**www.marum.de/en/Offshore_core_curation_and_measurements.html**). The core catcher sample will be split and a visual description recorded. Samples will be taken from appropriate lithologies at spot intervals for (1) preliminary mineralogy, (2) $^{87}Sr/^{86}Sr$ dating of shell fragments, and (3) dinocyst stratigraphy. These will be sent ashore when possible for preparation and analysis by members of the Science Party at Rutgers and Brock Universities. Results of these analyses will be made available to the

Science Party in advance of the Onshore Science Party. Samples for microbiology and interstitial water analysis will be taken and suitably stored. Some preliminary microbiology and pore water ephemeral property measurements will be conducted offshore (see **"Microbiology"** and **"Inorganic geochemistry"** in the "Appendix"). All cores will be run through a multisensor core logger (MSCL) offshore, which measures gamma-derived density, *P*-wave velocity, electrical resistivity, and magnetic susceptibility (see the **"Appendix"**).

Staffing

Scientific staffing is decided on the basis of task requirements and nominations from the ECORD Science Support Advisory Committee (ESSAC), USSAC, Japan Drilling Earth Science Consortium (JDESC), and Ministry of Science and Technology (MOST). ESO staffing is based on the need to carry out the drilling and scientific operations efficiently and safely.

The following ESO and science staffing amounts to a maximum of 18 participants and is the total for staff onboard at any one time:

ESO:

- 1 Operations Superintendent
- 1 Staff Scientist
- 1 Petrophysics Staff Scientist
- 1 ESO Petrophysicist
- 1 Curator
- 1 Curatorial representative (ESO technician)
- 2 Drilling Coordinators
- 1 ESO Geochemist
- 1 Database Manager
- 1 Electronics Engineer
- 2 Logging Contractors

Offshore science team:

- 1 Co-Chief Scientist
- 1 Geochemist
- 1 Microbiologist (first site only)

- 1 Petrophysicist
- 1 Sedimentologist

Platform science activities

Science activities on the platform are confined to those essential for early sampling and logging and for safety and curation (see the **"Appendix"**). Scientific activities will be as follows (please also refer to the online tutorial at **www.marum.de/en/Offshore_core_curation_and_measurements.html**):

- Basic curation and labeling of core.
- Shoe sample (core catcher [CC]) description and sampling for initial sedimentological and micropaleontological analysis, including taking a CC image.
- Core storage.
- All cores will be run on the MSCL (gamma density, *P*-wave velocity, electrical resistivity, and magnetic susceptibility) (see the **"Appendix"**).
- Pore water sampling and preservation, and analyses of ephemeral properties.
- Microbiological sampling and preservation.
- Associated data management of all activities (see below).

In order to carry out the science requirements on the platform with a small crew, a staffing plan will be devised. The plan will require flexibility of approach from all participants, with priority to safety, core recovery, curation, and procedures for the measurement of ephemeral properties.

Report preparation will take place on board as required by IODP Management International, Inc. (IODP-MI); the reports to be compiled include

- Daily and weekly operations and science reports to IODP-MI, Science Party members, and relevant parties. Scientific reports are provided by the Co-Chief Scientists.
- Site summary reports to IODP-MI.
- Technical Operations Report (submission to IODP-MI due 60 days postexpedition).
- Completion of the offshore sections of the Expedition Reports section of the *Proceedings* volume (primarily the "Methods" chapter).
- Operational Review report (submission to IODP-MI due 2 months postexpedition).
- Press releases in line with IODP-MI outreach policy.
- Information for posting on the ESO expedition Web site.

New Jersey logging operations

The following is a generic list of minimum and additional logging tools that are intended to be run at each of the three proposed sites. The tools are listed by the formation properties which they measure, and not by "operator"-based trademark names.

High-priority suite:

- Total through-pipe gamma ray intensity: for log-log and core-log correlation.
- Induction resistivity: multiple usages, a robust measurement even under poor borehole conditions for the evaluation of porosity.
- Sonic measurements: for core-log correlation, borehole-seismic integration, quality control, etc.
- Spectral and total gamma ray: for log-log and core-log correlation (total), clay typing, and mineralogy determination (spectral).
- Magnetic susceptibility: for lithologic determination and core-log correlation.
- Caliper: for quality control and borehole corrections.
- VSP: direct measurement of acoustic traveltime for core/borehole-seismic integration.
- In situ borehole temperature: an IODP minimum measurement to be measured during drilling operations.

Lower-priority suite:

- Hydrogeological (pH, eH, and temperature): borehole fluid characterization to detect fluid circulation.
- Acoustic imaging (including acoustic caliper): for core-log correlation, stratigraphic analyses, and oriented sedimentological and structural information.

Wireline logging will be carried out at all sites and will include the measurements listed above, as hole conditions allow. As the borehole conditions that will be encountered in New Jersey are anticipated to result in challenging conditions for wireline logging, total gamma ray logs will be run though the drill pipe in order to obtain continuous (although attenuated) data. The open-hole sections where wireline logging measurements are acquired will be carefully selected based on scientific objectives and borehole stability, and time will be spent to ensure the optimum data quality is acquired. Please see **"Priorities and potential program of work,"** above, for more details on how the logging program will be implemented.

Onshore science activities

The Onshore Science Party is to be conducted under the supervision of Dr. Ursula Röhl, the manager of the IODP Bremen Core Repository. The scientific work will follow that required by the prospectus and measurements plan to be developed in due course in conjunction with the Co-Chief Scientists.

Details of the facilities that will be available for the Onshore Science Party at the Bremen IODP Core Repository located in the MARUM building on the campus of the University of Bremen can be found in the **"Appendix."** Additional facilities can be made available through continuing close cooperation with additional laboratories at the MARUM-Center for Marine Environmental Sciences and the Department of Geosciences at Bremen University, as well as the Max Planck Institute for Marine Microbiology, all of which are situated nearby on campus.

A staffing plan will be developed with the Co-Chief Scientists in order to ensure that all required analyses and subsampling can be carried out efficiently. The measurement plan will take account of IODP specifications for quality assurance/quality control (QA/QC) procedures, which are being developed.

In view of the proposed geographical distribution of all Deep Sea Drilling Project (DSDP)/ODP/IODP cores, it is understood that the Bremen Core Repository will be the long-term location for these Atlantic Ocean cores.

Report preparation will take place during the Onshore Science Party as required by IODP-MI; the reports to be compiled include

- Twice-weekly operations and science reports to IODP-MI and relevant parties. Scientific reports are provided by the Co-Chief Scientists.
- *Preliminary Report* (submission to IODP Publication Services 1 week after Onshore Science Party).
- Completion of the Expedition Reports section of the *Proceedings* volume (submission to IODP Publication Services as soon as practically possible after the Onshore Science Party).

Staffing

ESO:

- 1 Superintendent (Curation and Laboratory Manager)
- 1 Staff Scientist

- 1 Assistant Superintendent (Assistant Curation and Laboratory Manager)
- 2 Petrophysics Staff Scientists
- 1 ESO Petrophysicist
- 2 Curators
- 2 Database Operators
- 1 Trainee Staff Scientist
- 1 Publications Specialist
- Laboratory Team (provided by University of Bremen predominantly for nonpetrophysics stations/laboratories and by the EPC for petrophysics-related stations).

Expedition scientists:

- 2 Co-Chief Scientists
- 6 sedimentologists
- 4 modelers (backstripping)/stratigraphic correlators
- 3 petrophysicists/physical property specialists
- 1 paleomagnetist
- 2 inorganic geochemists
- 1 dinocyst specialist
- 1 planktonic foraminifer specialist
- 1 benthic foraminifer specialist
- 1 terrestrial palynologist
- 1 nannofossil specialist
- 1 microbiologist

Data management strategy

A data management plan for the expedition will be developed once the data requirements and operational logistics are finalized. The outline plan is as follows:

- The primary data capture and management system will be the ExpeditionDIS (Drilling Information System). This is a relational database. It will capture drilling, curation, and geoscience metadata and data during the offshore and onshore phases of the expedition.
- The ExpeditionDIS includes tools for data input, visualization, report generation, and data export.

- The database can be accessed directly by other interpretation or decision-making applications if required.
- A file server will be used for the storage of data not captured in the database (for example, documents and image files) and the inputs/outputs of any data processing, interpretation, and visualization applications used during the expedition.
- The EPC will manage the capture of downhole-log data, MSCL data, and physical properties data. Logging metadata and MSCL data will be stored in the ExpeditionDIS. Downhole logging data will be stored separately by the EPC for processing and compositing.
- Upon completion of the offshore phase of the expedition, the ExpeditionDIS database and the file system will be transferred to Bremen to continue data capture during the Onshore Science Party.
- Between the end of the offshore phase and the start of the Onshore Science Party, the expedition scientists will have access to the data via a password-protected Web site.
- Upon completion of the Onshore Science Party, expedition scientists will continue to have access to all data through a password-protected Web site throughout the moratorium period.
- During the moratorium, all metadata and data, apart from downhole-log data, will be transferred to WDC-MARE/PANGAEA for long-term data archive.
- The downhole-log data will be transferred to the Lamont-Doherty Earth Observatory for long-term archive.
- Cores and samples will be archived at the IODP Bremen Core Repository.
- After the moratorium, all the expedition data will be made accessible to the public.

Definition of New Jersey shallow shelf Expedition Results data

Expedition Results data for Expedition 313 (Table **T5**) include

- All data collected on the drilling platform during the expedition.
- All data derived from samples taken on the drilling platform that are defined as minimum measurements by the IODP Science and Technology Panel (STP).
- All data derived from preliminary shore-based analyses of core catcher samples.
- All data collected onshore during the Onshore Science Party.

Sampling (and data sharing) requests

The IODP Sample, Data, and Obligations policy is available on the IODP Web site (**www.iodp.org/program-policies/**) and will apply to Expedition 313. This document outlines the policy for distributing IODP samples and data and defines the obligations that sample and data recipients incur. A primary obligation is that all members of the scientific party must conduct expedition-related scientific research and publish their results by the determined deadline.

Access to data and core samples for specific research purposes during the expedition and the subsequent 1 y moratorium must be approved by the sample allocation committee (SAC). The moratorium for Expedition 313 will extend 12 months from the completion of the expedition, which in the case of mission-specific platform expeditions is defined as the end of the Onshore Science Party.

All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the expedition objectives. Some redundancy of measurement may be unavoidable, but minimizing the duplication of measurements among the Science Party (which may include approved shore-based collaborators) will be a factor in evaluating sample requests.

Based on research requests (sample and data) submitted, the SAC will work with the Science Party to formulate a formal expedition-specific sampling and data sharing plan for shipboard and postcruise activities. This plan will be subject to modification depending on the actual material/data recovered and collaborations that may evolve between scientists before and during the expedition. Modifications to the sampling plan (i.e., new plans, research objectives, new collaborations, etc.) during the expedition and postcruise moratorium require the approval of the SAC.

Sampling to acquire essential ephemeral data types, to describe and characterize the recovered section, and to achieve essential sample preservation will be conducted during the expedition. Although some sampling for individual scientist's postcruise research may be conducted during the offshore phase of the expedition, the majority of sampling may be deferred to the Onshore Science Party.

The SAC has agreed that the detailed review of sample requests will be deferred until after the offshore operations are completed, so that sample requests can be reviewed within the context of the known core recovery and lithology.

For Expedition 313, it is presumed that all drilled intervals will be unique; therefore, it is expected that all intervals will be designated as permanent archives. It should be stressed that the availability of archive halves for sampling depends on the presence of equivalent sedimentary sequences in adjacent holes that can be directly correlated and thereby identified as duplicate material. In the drilling of corals, similar to the situation in hard rock environments, the paucity of replicate material may severely limit the availability of nonpermanent archive-half material.

The SAC comprises:

Gregory Mountain: Co-Chief Scientist

Jean-Noël Proust: Co-Chief Scientist

Ursula Röhl: ESO Curation Manager/IODP Curator (or shipboard representative)

David McInroy: ESO Staff Scientist

References

Austin, J.A., Jr., Christie-Blick, N., Malone, M.J., et al., 1998. *Proc. ODP, Init. Repts.,* 174A: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.174a.1998**

Barnett, T.P., 1990. Recent changes in sea level: a summary. *In* National Research Council (Ed.), *Sea-Level Change:* Washington, DC (National Academy Press), 37–51.

Bartek, L.R., Vail, P.R., Anderson, J.B., Emmet, P.A., and Wu, S., 1991. Effect of Cenozoic ice sheet fluctuations in Antarctica on the stratigraphic signature of the Neogene. *J. Geophys. Res., [Solid Earth],* 96(B4):6753–6778. **doi:10.1029/90JB02528**

Browning, J.V., Miller, K.G., and Pak, D.K., 1996. Global implications of lower to middle Eocene sequence boundaries on the New Jersey Coastal Plain—the icehouse cometh. *Geology,* 24(7):639–642. **doi:10.1130/0091-7613(1996)024<0639:GIOLTM>2.3.CO;2**

Browning, J.V., Miller, K.G., McLaughlin, P.P., Kominz, M.A., Sugarman, P.J., Monteverde, D., Feigenson, M.D., and Hernández, J.C., 2006. Quantification of the effects of eustasy, subsidence, and sediment supply on Miocene sequences, mid-Atlantic margin of the United States. *Geol. Soc. Am. Bull.,* 118(5):567–588. **doi:10.1130/B25551.1**

Catuneanu, O., 2006. *Principles of Sequence Stratigraphy:* Amsterdam (Elsevier).

Cazenave, A., Dominh, K., Guinehut, S., Berthier, E., Llovel, W., Ramillien, G., Ablain, M., and Larnicol, G., 2009. Sea level budget over 2003–2008: a reevaluation from GRACE space gravimetry, satellite altimetry and Argo. *Global Planet. Change,* 65(1–2):83–88. **doi:10.1016/j.gloplacha.2008.10.004**

Christie-Blick, N., 1991. Onlap, offlap, and the origin of unconformity-bounded depositional sequences. *Mar. Geol.,* 97(1–2):35–56. **doi:10.1016/0025-3227(91)90018-Y**

Christie-Blick, N., and Driscoll, N.W., 1995. Sequence stratigraphy. *Annu. Rev. Earth Planet. Sci.,* 23(1):451–478. **doi:10.1146/annurev.ea.23.050195.002315**

Christie-Blick, N., Mountain, G.S., and Miller, K.G., 1990. Seismic stratigraphic record of sea-level change. *In* National Research Council (Ed.), *Sea-Level Change:* Washington, DC (National Academy Press), 116–140.

Church, J.A., and White, N.J., 2006. A 20th century acceleration in global sea level rise. *Geophys. Res. Lett.,* 33(1):L01602. **doi:10.1029/2005GL024826**

Donovan, D.T., Jones, E.J.W., Ridd, M.F., and Hubbard, J.A.E.B., 1979. Causes of world-wide changes in sea level. *J. Geol. Soc. (London, U. K.),* 136(2):187–193. **doi:10.1144/gsjgs.136.2.0187**

Eberli, G.P., Swart, P.K., Malone, M.J., et al., 1997. *Proc. ODP, Init. Repts.,* 166: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.166.1997**

Fairbanks, R.G., 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature (London, U. K.),* 342:637–642. **doi:10.1038/342637a0**

Fairbanks, R.G., and Matthews, R.K., 1978. The marine oxygen isotope record in Pleistocene coral, Barbados, West Indies. *Quat. Res.,* 10(2):181–196. **doi:10.1016/0033-5894(78)90100-X**

Fulthorpe, C.S., and Austin, J.A., Jr., 1998. Anatomy of rapid margin progradation: three-dimensional geometries of Miocene clinoforms, New Jersey margin. *AAPG Bull.,* 82:251–273.

Fulthorpe, C.S., Austin, J.A., Jr., and Mountain, G.S., 1999. Buried fluvial channels off New Jersey: did sea-level lowstands expose the entire shelf during the Miocene? *Geology,* 27(3):203–206. **doi:10.1130/0091-7613(1999)027<0203:BFCONJ>2.3.CO;2**

Galloway, W.E., 1989. Genetic stratigraphic sequences in basin analysis, I. Architecture and genesis of flooding-surface bounded depositional units. *AAPG Bull.,* 73(2):125–142.

Greenlee, S.M., Devlin, W.J., Miller, K.G., Mountain, G.S., and Flemings, P.B., 1992. Integrated sequence stratigraphy of Neogene deposits, New Jersey continental shelf and slope: comparison with the Exxon model. *Geol. Soc. Am. Bull.,* 104(11):1403–1411. **doi:10.1130/0016-7606(1992)104<1403:ISSOND>2.3.CO;2**

Greenlee, S.M., and Moore, T.C., 1988. Recognition and interpretation of depositional sequences and calculation of sea-level changes from stratigraphic data—offshore New Jersey and Alabama Tertiary. *In* Wilgus, C.K., Hastings, B.S., Ross, C.A., Posamentier, H., Van Wagoner, J.C., and Kendall, C.G.St.C. (Eds.), *Sea-Level Changes: An Integrated Approach.* Spec. Publ.—Soc. Econ. Paleontol. Mineral., 42:329–353.

Haq, B.U., Hardenbol, J., and Vail, P. R., 1987. Chronology of fluctuating sea levels since the Triassic. *Science,* 235(4793):1156–1167. **doi:10.1126/science.235.4793.1156**

Imbrie, J., Barron, E.J., Berger, W.H., Bornhold, B.D., Cita-Sironi, M.B., Diester-Haass, L., Elderfield, H., Fischer, A.G., Lancelot, Y., Prell, W.L., Toggweiler, J.R., and Van Hinte, J.E., 1987. Scientific goals of an Ocean Drilling Program designed to investigate changes in the global environment. In *Report of the Second Conference on Scientific Ocean Drilling (COSOD II):* Strasbourg (European Science Foundation), 15–36. **http://www.odplegacy.org/PDF/Admin/Long_Range/COSOD_II.pdf**

John, C.M., Karner, G.D., and Mutti, M., 2004. $\delta^{18}O$ and Marion Plateau backstripping: combining two approaches to constrain late middle Miocene eustatic amplitude. *Geology,* 32(9):829–832. **doi:10.1130/G20580.1**

JOIDES Pollution Prevention and Safety Panel, 1992. Ocean Drilling Program guidelines for pollution prevention and safety. *JOIDES J.,* 18(7):24. **http://www.odplegacy.org/PDF/Admin/JOIDES_Journal/JJ_1992_V18_No7.pdf**

Katz, M.E., Wright, J.D., Miller, K.G., Cramer, B.S., Fennel, K., and Falkowski, P.G., 2005. Biological overprint of the geological carbon cycle. *Mar. Geol.,* 217(3–4)323–338. **doi:10.1016/j.margeo.2004.08.005**

Kominz, M.A., Browning, J.V., Miller, K.G., Sugarman, P.J., Misintseva, S., and Scotese, C.R., 2008. Late Cretaceous to Miocene sea-level estimates from the New Jersey and Delaware coastal plain coreholes: an error analysis. *Basin Res.,* 20(2):211–226. **doi:10.1111/j.1365-2117.2008.00354.x**

Kominz, M.A., Miller, K.G., and Browning, J.V., 1998. Long-term and short-term global Cenozoic sea-level estimates. *Geology,* 26(4):311–314. **doi:10.1130/0091-7613(1998)026<0311:LTASTG>2.3.CO;2**

Kominz, M.A., and Pekar, S.F., 2001. Oligocene eustasy from two-dimensional sequence stratigraphic backstripping. *Geol. Soc. Am. Bull.,* 113(3):291–304. **doi:10.1130/0016-7606(2001)113<0291:OEFTDS>2.0.CO;2**

Lawrence, D.T., Doyle, M., and Aigner, T., 1990. Stratigraphic simulation of sedimentary basins: concepts and calibration. *AAPG Bull.,* 74(3):273–295.

Loutit, T.S. (Ed.), 1992. *JOIDES Sea Level Working Group (SLWG) Report:* Woods Hole, MA (Woods Hole Oceanographic Institute).

Miall, A.D., 1991. Stratigraphic sequences and their chronostratigraphic correlation. *J. Sediment. Res.,* 61(4):497–505.

Miller, K.G., Barrera, E., Olsson, R.K., Sugarman, P.J., and Savin, S.M., 1999. Does ice drive early Maastrichtian eustacy? *Geology,* 27(9):783–786. **doi:10.1130/0091-7613(1999)027<0783:DIDEME>2.3.CO;2**

Miller, K.G., Browning, J.V., Sugarman, P.J., McLaughlin, P.P., Kominz, M.A., Olsson, R.K., Wright, J.D., Cramer, B.S., Pekar, S.J., and Van Sickel, W., 2003. 174AX leg summary: sequences, sea level, tectonics, and aquifer resources: coastal plain drilling. *In* Miller, K.G., Sugarman, P.J., Browning, J.V., et al., *Proc. ODP, Init. Repts.,* 174AX (Suppl.): College Station, TX (Ocean Drilling Program), 1–38. **doi:10.2973/odp.proc.ir.174AXS.104.2003**

Miller, K.G., et al., 1994. *Proc. ODP, Init. Repts.,* 150X: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.150X.1994**

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N., and Pekar, S.F., 2005a. The Phanerozoic record of global sea-level change. *Science,* 310(5752):1293–1298. **doi:10.1126/science.1116412**

Miller, K.G., Liu, C., Browning, J.V., Pekar, S.F., Sugarman, P.J., Van Fossen, M.C., Mullikin, L., Queen, D., Feigenson, M.D., Aubry, M.-P., Burckle, L.D., Powars, D., and Heibel, T., 1996a. Cape May site report. *Proc. ODP, Init. Repts.,* 150X (Suppl.): College Station, TX (Ocean Drilling Program), 5–28. **doi:10.2973/odp.proc.ir.150XS.014.1996**

Miller, K.G., and Mountain, G.S., 1994. Global sea-level change and the New Jersey margin. *In* Mountain, G.S., Miller, K.G., Blum, P., et al., *Proc. ODP, Init. Repts.,* 150: College Station, TX (Ocean Drilling Program), 11–20. **doi:10.2973/odp.proc.ir.150.102.1994**

Miller, K.G., Mountain, G.S., Browning, J.V., Kominz, M., Sugarman, P.J., Christie-Blick, N., Katz, M.E., and Wright, J.D., 1998. Cenozoic global sea level, sequences, and the New Jersey transect: results from coastal plain and continental slope drilling. *Rev. Geophys.,* 36(4):569–602. **doi:10.1029/98RG01624**

Miller, K.G., Mountain, G.S., the Leg 150 Shipboard Party, and Members of the New Jersey Coastal Plain Drilling Project, 1996b. Drilling and dating New Jersey Oligocene–Miocene sequences: ice volume, global sea level, and Exxon records. *Science,* 271(5252):1092–1095. **doi:10.1126/science.271.5252.1092**

Miller, K.G., and Snyder, S.W. (Eds.), 1997. *Proc. ODP, Sci. Results,* 150X: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.sr.150X.1997**

Miller, K.G., Sugarman, P.J., Browning, J.V., et al., 1998. *Proc. ODP, Init. Repts.,* 174AX: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.174AX.1998**

Miller, K.G., Sugarman, P.J., Browning, J.V., Kominz, M.A., Olsson, R.K., Feigenson, M.D., and Hernandez, J.C., 2004. Upper Cretaceous sequences and sea-level history, New Jersey Coastal Plain. *Geol. Soc. Am. Bull.,* 116(3):368–393. **doi:10.1130/B25279.1**

Miller, K.G., Wright, J.D., and Browning, J.V., 2005b. Visions of ice sheets in a greenhouse world. *In* de la Rocha, C.L., and Paytan, A. (Eds.), *Ocean Chemistry over the Phanerozoic and its Links to Geological Processes.* Mar. Geol., 217(3–4):215–231. **doi:10.1016/j.margeo.2005.02.007**

Miller, K.G., Wright, J.D., and Fairbanks, R.G., 1991. Unlocking the ice house: Oligocene–Miocene oxygen isotopes, eustasy, and margin erosion. *J. Geophys. Res.,* 96(B4):6829–6848. **doi:10.1029/90JB02015**

Monteverde, D.H., Miller, K.G., and Mountain, G.S., 2000. Correlation of offshore seismic profiles with onshore New Jersey Miocene sections. *Sediment. Geol.,* 134(1–2):111–127. **doi:10.1016/S0037-0738(00)00016-6**

Mountain, G.S., Miller, K.G., Blum, P., et al., 1994. *Proc. ODP, Init. Repts.,* 150: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.150.1994**

Pekar, S., 1999. Extracting an eustatic record from the western equatorial Pacific $\delta^{18}O$ records and onshore New Jersey Oligocene sequence stratigraphy [Ph.D. thesis]. Rutgers Univ., Piscataway, NJ.

Pekar, S.F., Christie-Blick, N., Kominz, M.A., and Miller, K.G., 2002. Calibration between eustatic estimates from backstripping and oxygen isotopic records for the Oligocene. *Geology,* 30(10):903–906. **doi:10.1130/0091-7613(2002)030<0903:CBEEFB>2.0.CO;2**

Posamentier, H.W., Jervey, M.T., and Vail, P.R., 1988. Eustatic controls on clastic deposition, I. Conceptual framework. *In* Wilgus, C.K., Hastings, B.S., Ross, C.A., Posamentier, H.W., Van Wagoner, J., and Kendall, C.G.St.C. (Eds.), *Sea-Level Changes: An Integrated Approach.* Spec. Publ.—Soc. Econ. Paleontol. Mineral., 42:109–124.

Reynolds, D.J., Steckler, M.S., and Coakley, B.J., 1991. The role of the sediment load in sequence stratigraphy: the influence of flexural isostasy and compaction. *J. Geophys. Res., [Solid Earth],* 96(B4):6931–6949. **doi:10.1029/90JB01914**

Seeberg-Elverfeldt, J., Schlüter, M., Feseker, T., and Kölling, M., 2005. Rhizon sampling of porewaters near the sediment-water interface of aquatic systems. *Limnol. Oceanogr.: Methods,* 3:361–371.

Sloss, L.L., 1963. Sequences in the cratonic interior of North America. *Geol. Soc. Am. Bull.,* 74(2):93–114. **doi:10.1130/0016-7606(1963)74[93:SITCIO]2.0.CO;2**

Stanford, J.D., Rohling, E.J., Hunter, S.E., Roberts, A.P., Rasmussen, S.O., Bard, E., McManus, J., and Fairbanks, R.G., 2006. Timing of meltwater pulse 1a and climate responses to meltwater injections. *Paleoceanography,* 21(4):PA4103. **doi:10.1029/2006PA001340**

Steckler, M.S., Mountain, G.S., Miller, K.G., and Christie-Blick, N., 1999. Reconstruction of Tertiary progradation and clinoform development on the New Jersey passive margin by 2-D backstripping. *Mar. Geol.,* 154(1–4):399–420. **doi:10.1016/S0025-3227(98)00126-1**

Steckler, M.S., Reynolds, D.J., Coakley, B.J., Swift, B.A., and Jarrard, R., 1993. Modelling passive margin sequence stratigraphy. *In* Posamentier, H.W., Summerhayes, C.P., Haq, B.U., and Allen, G.P. (Eds.), *Sequence Stratigraphy and Facies Associations.* Spec. Publ.—SEPM (Soc. Sediment. Geol.), 18:19–41.

Stoll, H.M., and Schrag, D.P., 1996. Evidence for glacial control of rapid sea level changes in the Early Cretaceous. *Science,* 272(5269):1771–1774. **doi:10.1126/science.272.5269.1771**

Sugarman, P.J., and Miller, K.G., 1997. Correlation of Miocene sequences and hydrogeologic units, New Jersey Coastal Plain. *In* Segall, M.P., Colquhoun, D.J., and Siron, D.L. (Eds.), *Evolution of the Atlantic Coastal Plain—Sedimentology, Stratigraphy, and Hydrogeology.* Sediment. Geol., 108(1–4):3–18. **doi:10.1016/S0037-0738(96)00046-2**

Sugarman, P.J., Miller, K.G., Browning, J.V., Kulpecz., A.A., McLaughlin, P.P., Jr., and Monteverde, D.H., 2006. Hydrostratigraphy of the New Jersey coastal plain: sequences and facies predict continuity of aquifers and confining units. *Stratigraphy,* 2(3):259–275.

Vail, P.R., and Mitchum, R.M., Jr., 1977. Seismic stratigraphy and global changes of sea level, Part 1. Overview. *In* Payton, C.E. (Ed.), *Seismic Stratigraphy: Applications to Hydrocarbon Exploration.* AAPG Mem., 26:51–52.

Vail, P.R., Mitchum, R.M., Jr., and Thompson, S., III, 1977. Seismic stratigraphy and global changes of sea level, Part 3. Relative changes of sea level from coastal onlap. *In* Payton, C.E. (Ed.), *Seismic Stratigraphy: Applications to Hydrocarbon Exploration.* AAPG Mem., 26:63–81.

Van Sickel, W.A., Kominz, M.A., Miller, K.G., and Browning, J.V., 2004. Late Cretaceous and Cenozoic sea-level estimates: backstripping analysis of borehole data, onshore New Jersey. *Basin Res.,* 16(4):451-465. **doi:10.1111/j.1365-2117.2004.00242.x**

Van Wagoner, J.C., Mitchum, R.M., Campion, K.M., and Rahmanian, V.D., 1990. *Siliciclastic Sequence Stratigraphy in Well Logs, Cores, and Outcrops: Concepts for High-Resolution Correlation of Time and Facies.* AAPG Methods Explor., 7.

Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Jr., Vail, P.R., Sarg, J.F., Loutit, T.S., and Hardenbol, J., 1988. An overview of the fundamentals of sequence stratigraphy and key definitions. *In* Wilgus, C.K., Hastings, B.S., Ross, C.A., Posamentier, H.W., Van Wagoner, J., and Kendall, C.G.St.C. (Eds.), *Sea-Level Changes: An Integrated Approach*. Spec. Publ.—Soc. Econ. Paleontol. Mineral., 42:39–45.

Watts, A.B., and Steckler, M.S., 1979. Subsidence and eustasy at the continental margin of eastern North America. *In* Talwani, M., Hay, W., and Ryan, W.B.F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment*. Maurice Ewing Ser., 3:218–234.

Table T1. Primary and alternate sites.

Proposed site	Latitude	Longitude	Water depth (m)
MAT-1A	**39°38′02.728″N**	**73°37′17.926″W**	**32**
MAT-1B	39°38′06.238″N	73°37′14.880″W	32
MAT-1C	39°38′21.908″N	73°36′59.828″W	32
MAT-2D	**39°33′56.592″N**	**73°29′50.158″W**	**35**
MAT-2E	39°34′01.499″N	73°29′45.780″W	35
MAT-2F	39°34′16.320″N	73°29′32.341″W	34
MAT-3A	**39°31′10.319″N**	**73°24′47.657″W**	**34**
MAT-3B	39°30′50.738″N	73°25′05.318″W	34
MAT-3C	39°31′30.133″N	73°24′28.890″W	34

Note: Bold text indicates primary site.

Table T2. Site MAT-1.

Proposed site	Water depth (m)	Sediment penetration (m)	Longitude	Latitude	Target
MAT-1A	32	750	73°37′17.926″W	39°38′02.728″N	Middle–upper Oligocene
MAT-1B	32	750	73°37′14.880″W	39°38′06.238″N	Middle–upper Oligocene
MAT-1C	32	750	73°36′59.828″W	39°38′21.908″N	Middle–upper Oligocene
Total penetration:		750			

Table T3. Site MAT-2.

Proposed site	Water depth (m)	Sediment penetration (m)	Longitude	Latitude	Target
MAT-2D	35	750	73°29′50.158″W	39°33′56.592″N	Middle–upper Oligocene
MAT-2E	35	750	73°29′45.780″W	39°34′01.499″N	Middle–upper Oligocene
MAT-2F	34	750	73°29′32.341″W	39°34′16.320″N	Middle–upper Oligocene
Total penetration:		750			

Table T4. Site MAT-3.

Proposed site	Water depth (m)	Sediment penetration (m)	Longitude	Latitude	Target
MAT-3A	34	750	73°24′47.657″W	39°31′10.319″N	Middle–upper Oligocene
MAT-3B	34	750	73°25′05.318″W	39°30′50.738″N	Middle–upper Oligocene
MAT-3C	34	750	73°24′28.890″W	39°31′30.133″N	Middle–upper Oligocene
Total penetration:		750			

Table T5. Types of data collected off- and onshore to be included in *Proceedings* volume.

Location of measurement	
Drilling platform	Onshore Science Party, Bremen
Core catcher description (lithology/core catcher photographs)	Visual core description (including smear slides, thin sections, and descriptions of both where appropriate)
MSCL (gamma density, *P*-wave velocity, electrical resistivity, and magnetic susceptibility)	Core photographs
Sampling for microbiology, mineralogy,* micropaleontology,* and $^{87}Sr/^{86}Sr$ dating*	Micropaleontology
Pore water sampling and initial analyses	Inorganic geochemistry
In-situ downhole temperature	X-ray diffraction (XRD) analysis
Downhole logging	Repeat whole-core petrophysical measurements (QA/QC) if required
Vertical Seismic Profiling (VSP)	Split-core MSCL measurements (if required)
	Natural gamma ray logging (whole core)
	Discrete sample index properties
	Color reflectance/digital line-scan imaging (line-scans)
	X-ray CT scanner of cores (limited number if required)

Notes: * = shore-based analyses to be conducted by Science Party members in advance of the Onshore Science Party. MSCL = multisensor core logger, QA/QC = quality assurance/quality control, CT = computed tomography.

Figure F1. Global sea level (light blue) for the interval 7–100 Ma derived by backstripping data from onshore boreholes along the New Jersey Coastal Plain. Global sea level (purple) for the interval 0–7 Ma is derived from $\delta^{18}O$. Benthic foraminiferal $\delta^{18}O$ synthesis from 0 to 100 Ma (red; reported to *Cibicidoides* values [0.64‰ lower than equilibrium]) is shown for comparison. Pink box at ~11 Ma = sea level estimate derived from the Marion Plateau (see text). Black line = long-term fit to the backstripped curve. Pale green boxes = times of spreading rate increases on various ocean ridges. Dark green box = opening of the Norwegian-Greenland Sea and concomitant extrusion of the Brito-Arctic basalts. (After Miller et al., 2005a.) NHIS = Northern Hemisphere ice sheets.

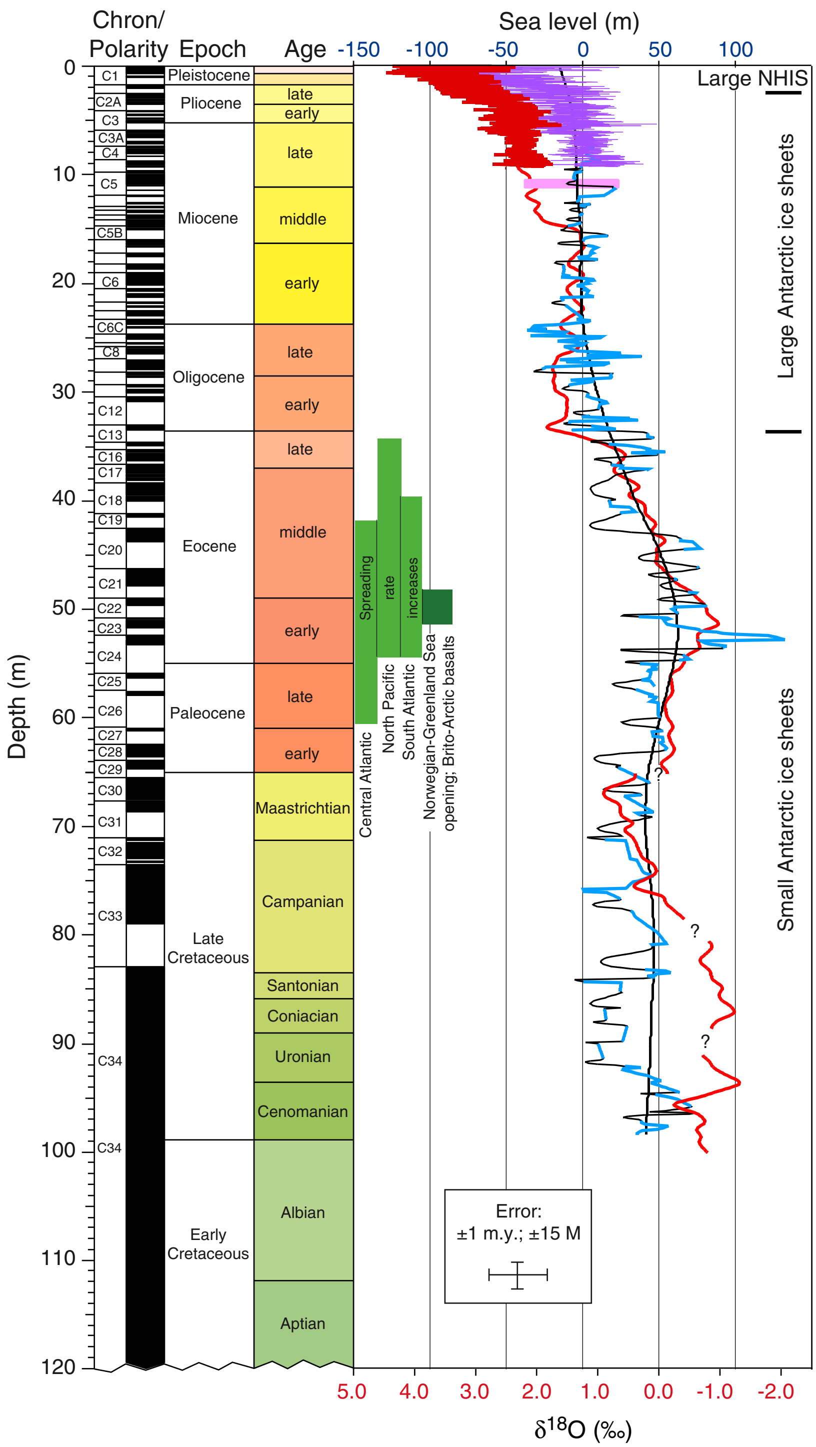


Figure F2. Map of the New Jersey continental margin showing proposed Sites MAT-1, MAT-2, and MAT-3 plus other completed boreholes both on- and offshore. Tracks of reconnaissance seismic lines relevant to the goals of this expedition are also shown.

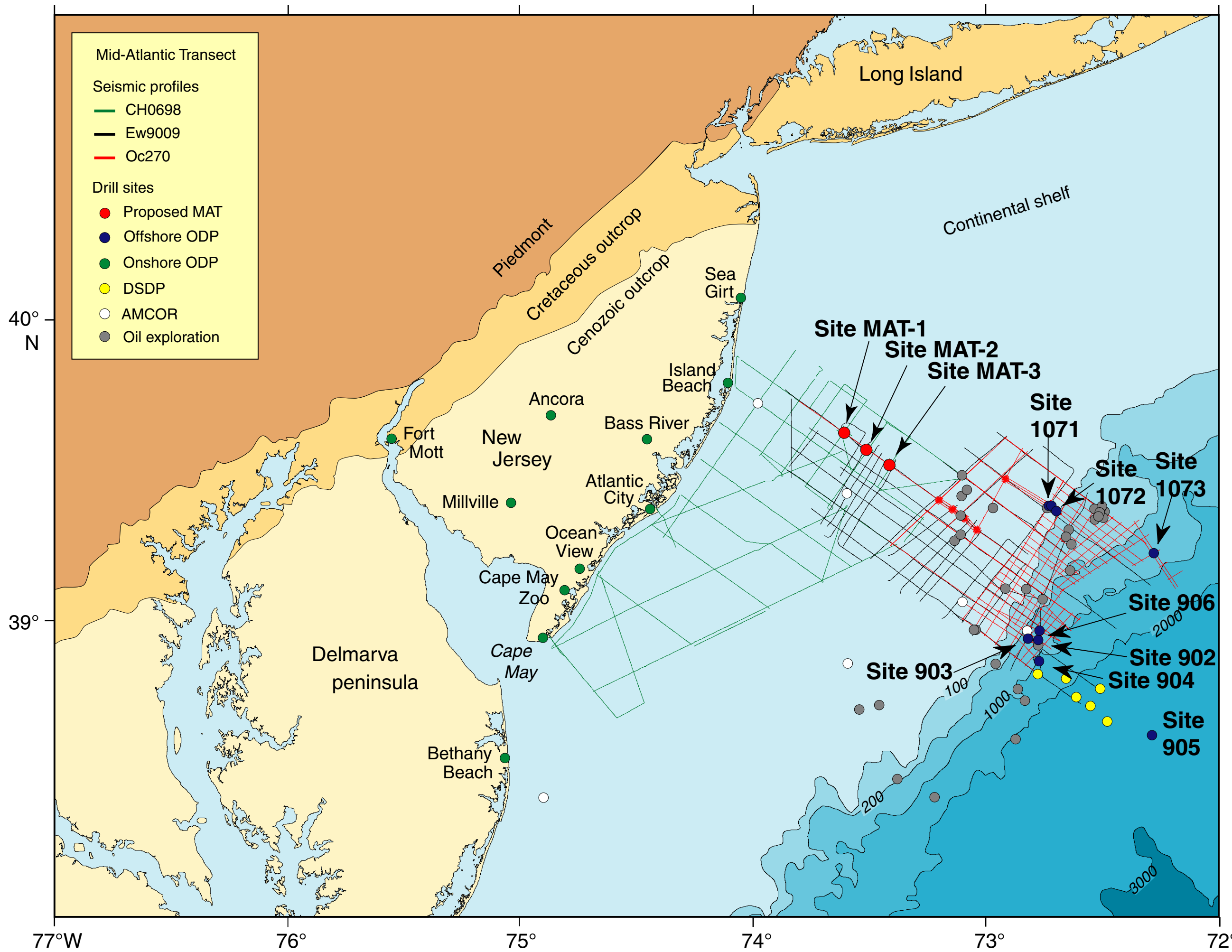


Figure F3. Ew9009 Line 1003 through proposed Sites MAT-1, MAT-2, and MAT-3 (yellow subseafloor columns; see Fig. F2 for location). Generalized locations of ODP boreholes onshore and offshore (gray columns) and previously proposed but undrilled MAT Sites MAT-4A to MAT-7A (white columns) are also shown. Several key surfaces (colored lines; K/T boundary = ~65 Ma, o1 = ~33.5 Ma, m5 = ~16.5 Ma, m4 = ~14 Ma, m3 = ~13.5 Ma, and m1 = ~11.5 Ma) have been traced from the inner shelf to the slope. Clinoform shape of sediments bracketed by these unconformities is thought to be the result of large sea level fluctuations (Vail and Mitchum, 1977).

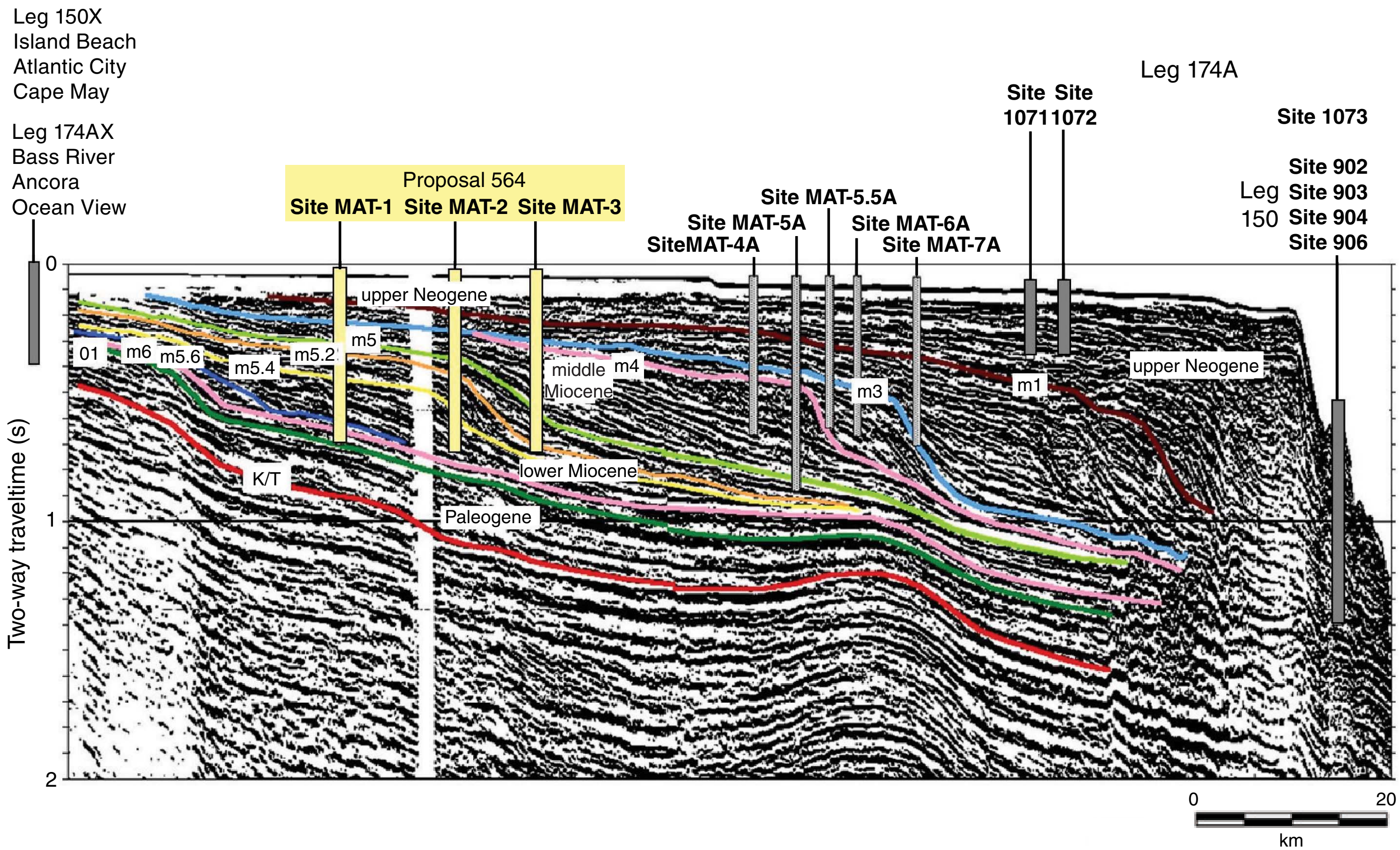


Figure F4. Comparison of Oligocene–Miocene slope sequences, onshore sequences, oxygen isotopes, Bahamian reflections (Eberli, Swart, Malone, et al., 1997), and the inferred eustatic record of Haq et al. (1987) for New Jersey shelf-slope and onshore sequences (after Miller et al., 1998).

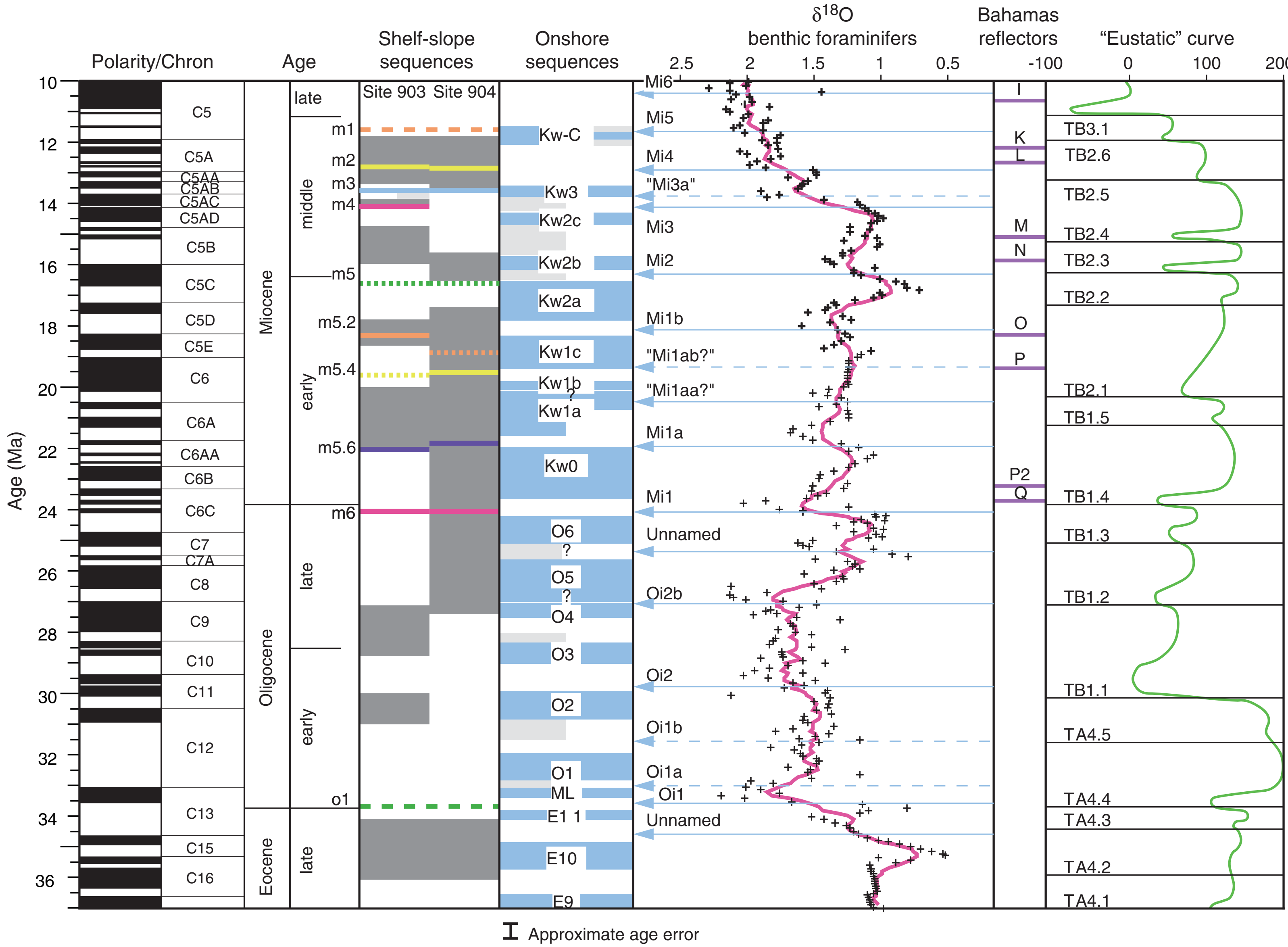


Figure F5. Idealized locations of a three-hole transect to determine time and magnitude of the base-level fall associated with sequence boundary "SB2." Transect will sample the youngest sediments below SB2 (Site MAT-1), the oldest sediments above SB2 (Site MAT-2), and more distal sediments above SB2 to ensure dateable material and provide additional backstripping information (Site MAT-3). Bio- and lithofacies will evaluate predicted models of clinoform evolution. Because of the stacked arrangement of sequences offshore New Jersey, several clinoforms can be sampled at one location. HST = highstand systems tract, TST = transgressive systems tract, LST = lowstand systems tract.

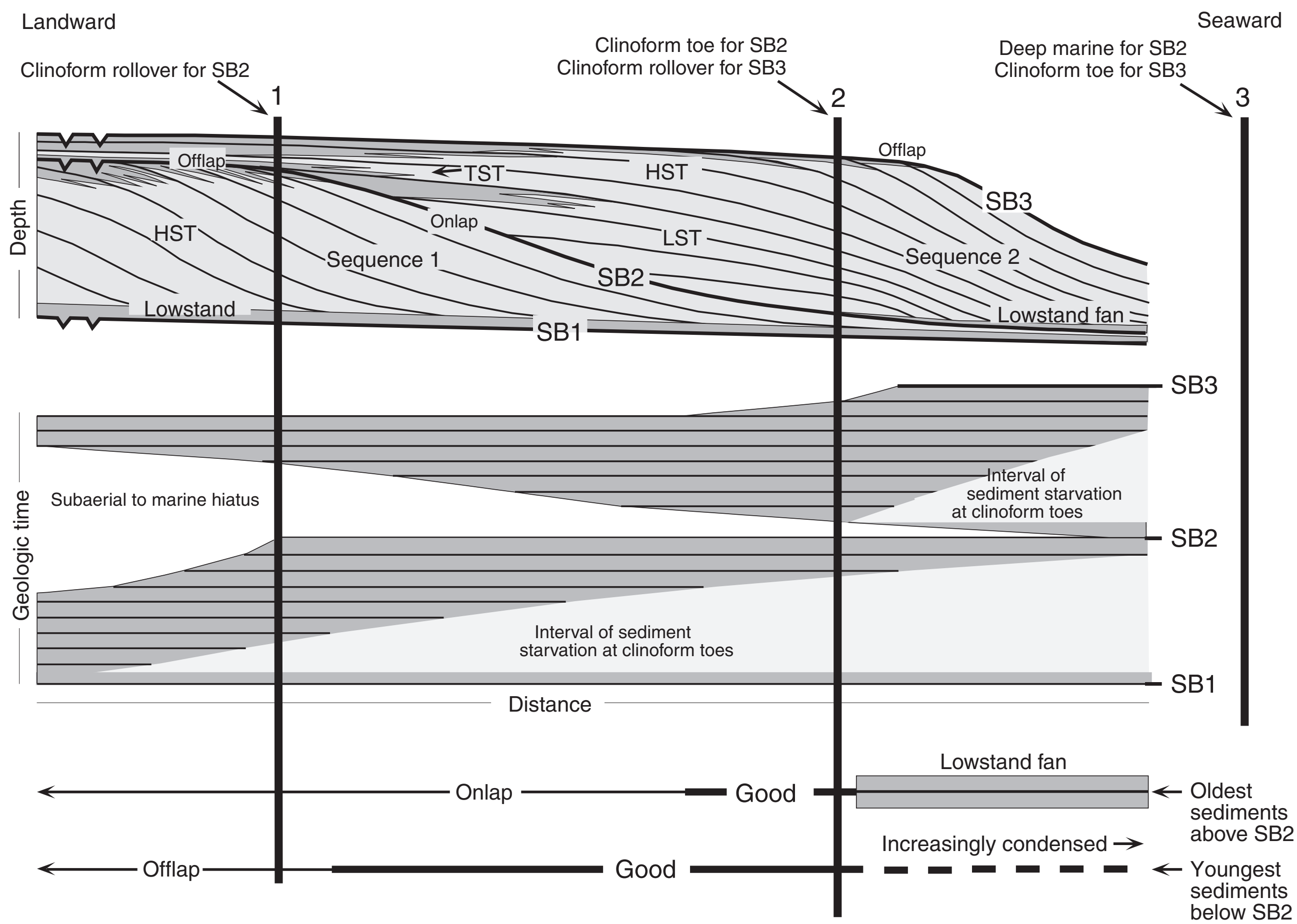


Figure F6. Oc270 dip Line 529 passes through primary Sites MAT-1A, MAT-2D, and MAT-3A and reveals several middle to lower Miocene clinoforms (color) and sequence boundaries (white labels). Drilling will evaluate these predictions, determine the relationship of clinoform evolution to facies distribution, and establish links between depositional geometry, sediment character, and changes in eustatic sea level. CDP = common depth point.

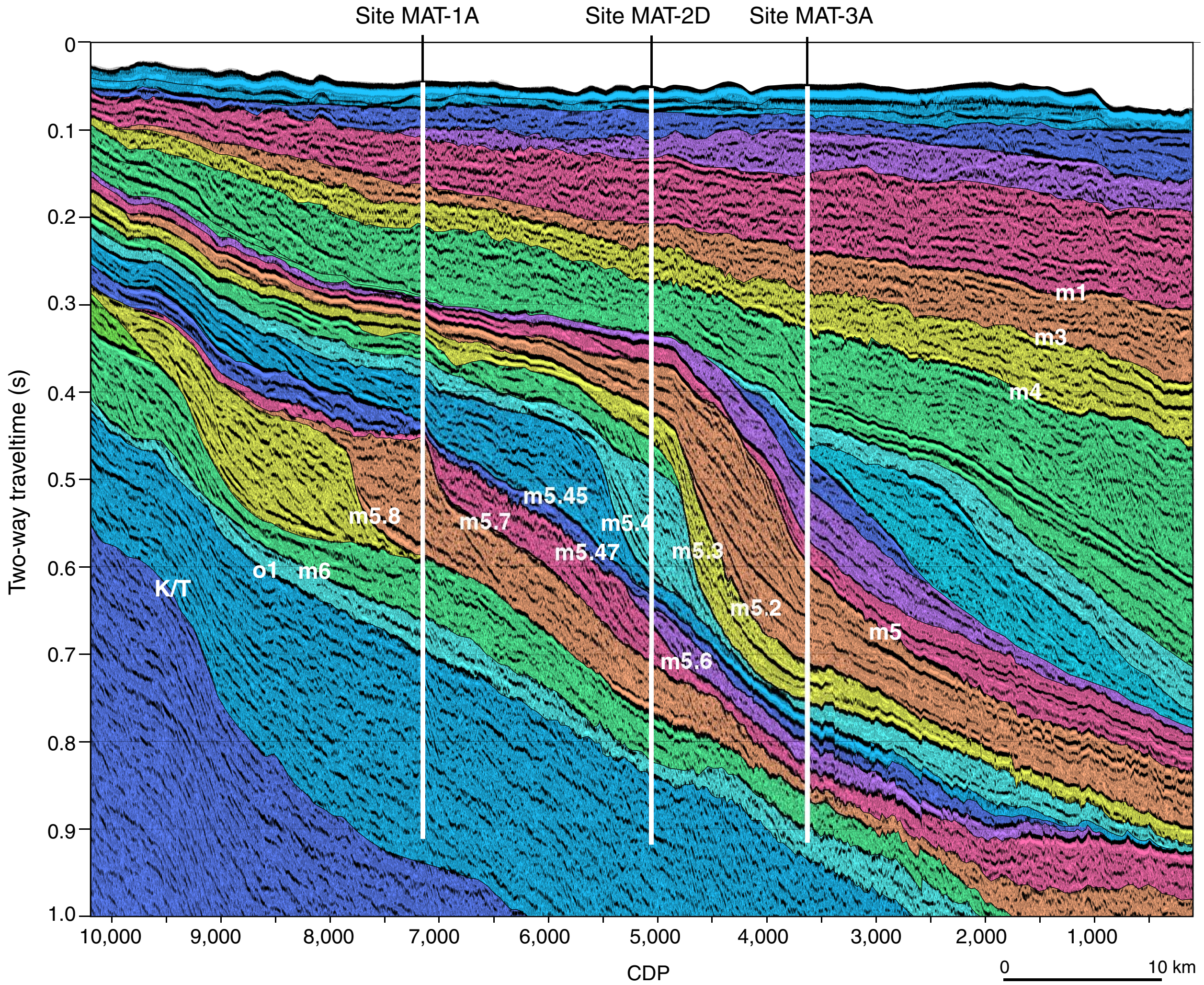
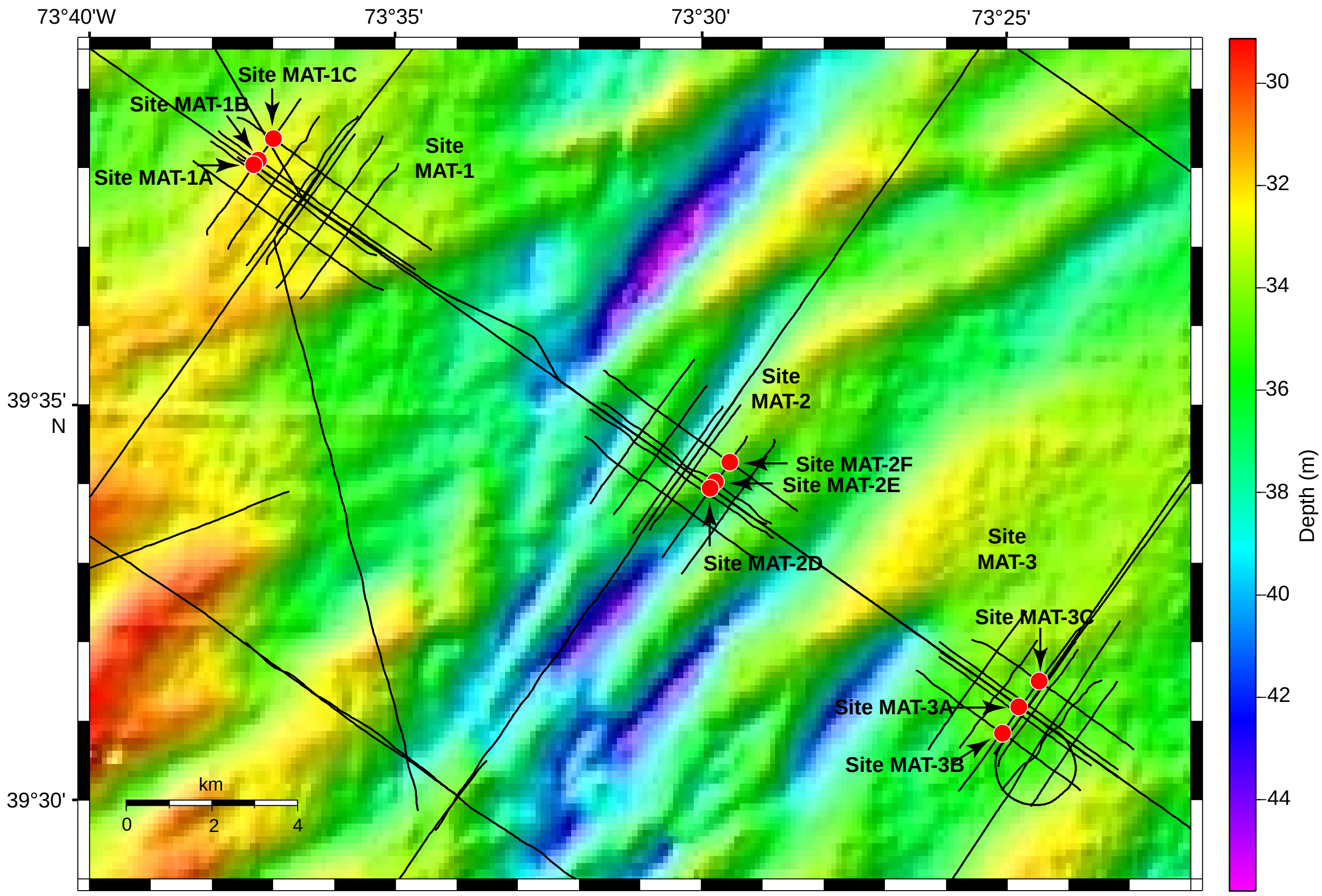


Figure F7. Bathymetry and tracks of MCS profiles in the vicinity of proposed Sites MAT-1 to MAT-3. Primary sites MAT-1A, MAT-2D, and MAT-3A lie on Oc270 dip Line 529 (Fig. F6), as well as on the center line of each detailed seismic grid from cruise CH0698. Alternate sites are at crossings of CH0698 profiles in each grid.



Site summaries

Proposed Site MAT-1

Priority:	Operational priority 1, scientific priority 2.
Position:	Site MAT-1A = 73°37′17.926″W, 39°38′02.728″N Site MAT-1B = 73°37′14.880″W, 39°38′06.238″N Site MAT-1C = 73°36′59.828″W, 39°38′21.908″N
Water depth (m):	32
Target drilling depth (mbsf):	750; middle–upper Oligocene
Approved maximum penetration (mbsf):	750
Survey coverage:	Seismic: • High-resolution seismic reflection CH0698 107, 102 for Site MAT-1A; 109, 102 for Site MAT-1B; 113, 102 for Site MAT-1C (collected R/V *Cape Hatteras* CH0698, 1998 cruise). • Deep penetration seismic reflection R/V *Maurice Ewing* Ew9009 1003. • Seismic grid CH0698 (collected *Cape Hatteras* CH0698, 1998 cruise). • Swath bathymetry available but not on databank (collected during CCGS *Fredrick G Creed* April 1996 and R/V *Onrust* September 1998 cruises). Imagery: • No photography or video available. Sampling: • Grain size analysis from *Onrust* September 1998 cruise. • Rock sampling or dredging: not applicable. Other: • Bathymetry from Oc270 July 1995, *Fredrick G Creed* April 1996, *Cape Hatteras* CH0698, and *Onrust* September 1998 cruises available.
Objective (see text for details):	Determine age of surfaces correlated with sequence boundaries m1, m4, m5, m5.2, m5.4, m5.6, m5.8, m6, and o1. Determine facies of surfaces correlated with sequence boundaries. Determine paleobathymetry of surfaces correlated with sequence boundaries. Evaluate facies and age of Paleogene sediments.
Drilling, coring, and downhole measurement program:	Push/rotary core to TD, cased as needed. High-priority logging suite: total through-pipe gamma ray, induction resistivity, sonic measurements, magnetic susceptibility, open-hole spectral and total gamma ray, mechanical caliper, vertical seismic profiling, in situ borehole temperature. Low-priority logging suite: hydrogeological properties, acoustic imaging (including acoustic caliper).
Anticipated lithology:	Sediments: medium to coarse sand, possible pebbles and shell fragments, sandy mudstone, mudstone, marly chalk, limestone. Basement: not reached.

Site summaries (cont.)

Proposed Site MAT-2

Priority:	Operational priority 2, scientific priority 1.
Position:	Site MAT-2D = 73°29′50.158″W, 39°33′56.592″N Site MAT-2E = 73°29′45.780″W, 39°34′01.499″N Site MAT-2F = 73°29′32.341″W, 39°34′16.320″N
Water depth (m):	Sites MAT-2D and MAT-2E = 35 Site MAT-2 F = 34
Target drilling depth (mbsf):	750; middle–upper Oligocene
Approved maximum penetration (mbsf):	750
Survey coverage:	Seismic: • High-resolution seismic reflection CH0698 207, 218 for Site MAT-2D; 209, 218 for Site MAT-2E; 213, 218 for Site MAT-2F (collected R/V *Cape Hatteras* CH0698, 1998 cruise). • Deep penetration seismic reflection R/V *Maurice Ewing* Ew9009 1003. • Seismic grid CH0698 (collected *Cape Hatteras* CH0698, 1998 cruise). • Swath bathymetry available but not on databank (collected during CCGS *Fredrick G Creed* April 1996 and R/V *Onrust* September 1998 cruises). Imagery: • No photography or video available. Sampling: • Grain size analysis from *Onrust* September 1998 cruise. • Rock sampling or dredging: not applicable. Other: • Bathymetry from Oc270 July 1995, *Fredrick G Creed* April 1996, *Cape Hatteras* CH0698, and *Onrust* September 1998 cruises available.
Objective (see text for details):	Determine age of surfaces correlated with sequence boundaries m1, m4, m5, m5.2, m5.4, m5.6, m5.8, m6, and o1. Determine facies of surfaces correlated with sequence boundaries. Determine paleobathymetry of surfaces correlated with sequence boundaries. Evaluate facies and age of Paleogene sediments.
Drilling, coring, and downhole measurement program:	Push/rotary core to TD, cased as needed. High-priority logging suite: total through-pipe gamma ray, induction resistivity, sonic measurements, magnetic susceptibility, open-hole spectral and total gamma ray, mechanical caliper, vertical seismic profiling, in situ borehole temperature. Low-priority logging suite: hydrogeological properties, acoustic imaging (including acoustic caliper). If VSP proves successful at Site MAT-1 and unsuccessful at the first hole of Site MAT-2, a second dedicated hole for VSP may be drilled at Site MAT-2.
Anticipated lithology:	Sediments: medium to coarse sand, possible pebbles and shell fragments, sandy mudstone, mudstone, marly chalk, limestone. Basement: not reached.

Site summaries (cont.)

Proposed Site MAT-3

Priority:	Operational priority 3, scientific priority 3.
Position:	Site MAT-3A = 73°24′47.657″W, 39°31′10.319″N Site MAT-3B = 73°25′05.318″W, 39°30′50.738″N Site MAT-3C = 73°19′39.890″W, 39°31′30.133″N
Water depth (m):	34
Target drilling depth (mbsf):	750; middle–upper Oligocene
Approved maximum penetration (mbsf):	750
Survey coverage:	Seismic: • High-resolution seismic reflection CH0698 307, 310 for Site MAT-3A; 301, 310 for Site MAT-3B; 313, 310 for Site MAT-3C (collected R/V *Cape Hatteras* CH0698, 1998 cruise). • Deep penetration seismic reflection R/V *Maurice Ewing* Ew9009 1003. • Seismic grid CH0698 (collected *Cape Hatteras* CH0698, 1998 cruise). • Swath bathymetry available but not on databank (collected during CCGS *Fredrick G Creed* April 1996 and R/V *Onrust* September 1998 cruises). Imagery: • No photography or video available. Sampling: • Grain size analysis from *Onrust* September 1998 cruise. • Rock sampling or dredging: not applicable. Other: • Bathymetry from Oc270 July 1995, *Fredrick G Creed* April 1996, *Cape Hatteras* CH0698, and *Onrust* September 1998 cruises available.
Objective (see text for details):	Determine age of surfaces correlated with sequence boundaries m1, m4, m5, m5.2, m5.4, m5.6, m5.8, and m6. Determine facies of surfaces correlated with sequence boundaries. Determine paleobathymetry of surfaces correlated with sequence boundaries.
Drilling, coring, and downhole measurement program:	Push/rotary core to TD, cased as needed. High-priority logging suite: total through-pipe gamma ray, induction resistivity, sonic measurements, magnetic susceptibility, open-hole spectral and total gamma ray, mechanical caliper, vertical seismic profiling, in situ borehole temperature. Low-priority logging suite: hydrogeological properties, acoustic imaging (including acoustic caliper). VSP survey will be attempted if VSP is unsuccessful at Sites MAT-1 and MAT-2.
Anticipated lithology:	Sediments: medium to coarse sand, possible pebbles and shell fragments, sandy mudstone, mudstone. Basement: not reached.

Appendix

New Jersey Shallow Shelf ESO sampling and measurement plan

This plan was presented at the January 2006 Integrated Ocean Drilling Program (IODP) Science Technology Panel meeting in Kochi and was approved by the panel. The plan is subject to amendment according to the scientific needs and interests of the expedition scientists or operational constraints. The most pressing operational constraint during the offshore phase is likely to be space, both for analysis and for accommodation. The priority given to the respective offshore measurements are as follows:

1. Curation,
2. Downhole logging,
3. Multisensor core logging (MSCL),
4. Inorganic geochemistry,
5. Microbiology,
6. Sedimentology, and
7. In situ borehole temperature measurements.

Offshore sampling and analysis

Please see **www.marum.de/en/Offshore_core_curation_and_measurements.html** in addition to the text below.

Core curation

There will be a mobile core curation laboratory container on board the drilling platform, supervised by the Chief Curator. Curatorial personnel will also cover the opposite shift. The curators will have delegated responsibility in the absence of the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO) Curation Manager and IODP Curator Dr. Ursula Röhl. A sufficient number of core storage containers will be on the drilling platform. There will be no splitting of the cores at sea, as it will be more efficient to carry out most of the following scientific analysis during the Onshore Science Party in Bremen.

Offshore core flow

For details of the offshore core flow, see Figure **AF1.**

Lithologic description

Core catcher samples will be collected, split, and labeled and the working half handed over to the scientists in charge of sedimentologic description. If no core catcher is collected, a sample from the lower end of the section will be taken for analysis.

Inorganic geochemistry

Pore water samples (e.g., squeezers and rhizone moisture samplers) (Seefeld et al., 2005) will be taken on a routine basis (every three cores if recovery is good). Pore water should be extracted immediately from a core sample, and ephemeral properties (e.g., salinity, pH, alkalinity, and ammonia) will be analyzed immediately. Sample splits for onshore analysis (e.g., cations, sulfide, and ^{13}C) will be prepared and preserved offshore. Depending on the parameter, the interstitial water sample might be specially treated in order to conserve it for later analyses.

Microbiology

The precise sampling strategy is defined by the requests of the science party microbiologists, as IODP microbiology policies in relation to routine sampling for microbiology are currently under discussion. Samples will be taken immediately in the field under the most sterile possible conditions. Results will be interpreted with care as contamination may occur during drilling and any microbial material found may not be in situ. Fluorescent microspheres will be added to the drilling mud to assist evaluation of contamination of samples for microbiology studies. Proper sample archiving (deep freezing) will be conducted.

Offshore petrophysics measurements

Downhole logging

The following is a generic list of minimum and additional logging tools that are intended to be run at each of the three proposed sites. The tools are listed by the formation properties which they measure, and not by “operator”-based trademark names.

High-priority suite:

- Total through-pipe gamma ray.
- Induction resistivity.
- Sonic measurements.
- Magnetic susceptibility.

- Open-hole spectral and total gamma ray.
- Mechanical caliper.
- Vertical Seismic Profile (VSP) logging.
- In situ borehole temperature.

Lower-priority suite:

- Hydrogeological properties.
- Acoustic imaging (including acoustic caliper).

Core logging

Cores will be logged on the drilling platform in a modified 20 ft container, housing a single MSCL track comprising one magnetic susceptibility loop, density, velocity, and resistivity sensors measuring gamma ray attenuation, magnetic susceptibility, electrical resistivity, and *P*-wave velocity. The single core-logger system will include a spares kit.

Onshore sampling and analysis

Onshore core flow

For details of the offshore core flow, see Figure **AF2.**

Location

The Onshore Science Party will be undertaken at the IODP Bremen Core Repository and Laboratory at the University of Bremen, with access to the laboratories at the MARUM-Center for Marine Environmental Sciences and the Department of Geosciences.

Planned analysis and available facilities

The following facilities will be available for the Expedition Scientists at the Bremen IODP Core Repository (**www.marum.de/en/Onshore_Science_Party_OSP.html**). Note that it is not considered prudent to transport all these facilities to the drilling platform:

- Core splitting: an archive half will be set aside as per IODP policy.
- Core description: ESO will provide a system that is IODP standard. For data entry, ESO will employ an Offshore Drilling Information System (DIS) system that is entirely compatible with others being used in IODP.

- Core photography: core shots (table layout) on a routine basis, close-ups on request.
- Core sampling: for Onshore Science Party samples (paleomagnetism, physical properties, X-ray diffraction (XRD), inorganic geochemistry, and carbonate [TC]/total organic carbon [TOC]).
- Smear slide preparation: as requested, preparation, description, and interpretation.
- Micropaleontology: microscope laboratory (access to laboratory for routine sample preparation, including a hood if acid needs to be applied).
- Inorganic geochemistry: whole-rock and pore fluid chemistry, inductively coupled plasma–optical emission spectrometry (ICP-OES; Perkin-Elmer Optima3000), energy dispersion polarization X-ray fluorescence (EDP-XRF; Spectro-Xepos), and TC/TOC (Leco).
- Bulk mineralogy and X-ray diffraction (XRD) analysis (Philips XpertPro).
- Petrophysical measurements:
    - Selected repeat whole-core measurements for quality assurance/quality control (QA/QC) if required.
    - Natural gamma ray logging on whole cores.
    - Thermal conductivity measurements.
    - Split-core MSCL: *P*-wave, gamma ray attenuation [GRA] density, and magnetic susceptibility (if required).
    - Physical properties of discrete samples (moisture/sample density): determination of index properties (wet bulk density, grain density, porosity, void ratio). Following IODP procedure, core samples will be oven-dried, the dried sample volume quantified using a Quantachrome penta-pycnometer, and masses using a high-precision balance.
    - Velocity measurements.
    - Color reflectance measurements (Minolta spectrophotometer).
    - Digital imaging (line-scan camera on MSCL track).
    - X-Ray computed tomography (CT) scanning before Onshore Science Party (a limited number of two- and three-dimensional whole-core scans using a General Electric Prospeed SX can be done at MARUM upon request and on selected core sections only).
- Paleomagnetic measurements:

    - Natural remnant magnetism (NRM) with stepwise demagnetization (2G long-core cryogenic magnetometer) on U-channels (pass through) or samples (robot system which feeds up to 100 adapted sample cubes)
- Core sampling: a detailed sampling plan will be devised at the completion of the offshore phase and after the scientists have submitted their revised sample requests.
- Corewall viewing and integration: a system will be available for the viewing/comparison of line-scan core images and log data.
- Seismic workstation: viewing software (to be decided) to overlay wireline log and VSP measurements onto seismic images at each drill site.

Figure AF1. Offshore core flow. (1) If no core catcher is collected, a 20 cm^3 plug sample will be taken from the base of the lower end of a section every 6 m for shipboard sedimentologic description and sampled for preliminary shore-based studies. (2) Depending on the length of the core catcher, and only if there is inadequate material in the working half and a sample is deemed necessary by the Co-Chief, additional material from the archive half of the core catcher can be used for sampling for shipboard lithological description and preliminary shore-based studies. (3) Samples will be taken from core catchers for shore-based studies: preliminary mineralogy, $^{87}Sr/^{86}Sr$ dating of shell fragments, and dinocyst stratigraphy. These results will be supplied to the Science Party in advance of the Onshore Science Party in Bremen. MSCL = multisensor core logger.

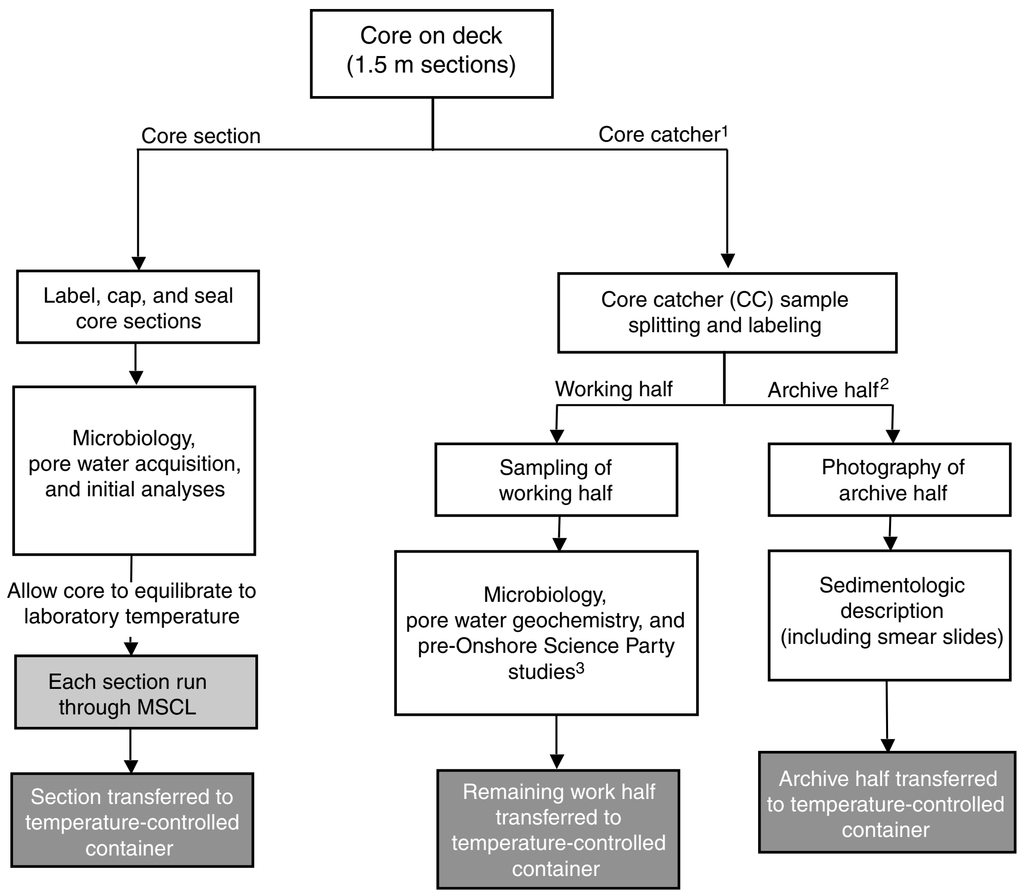
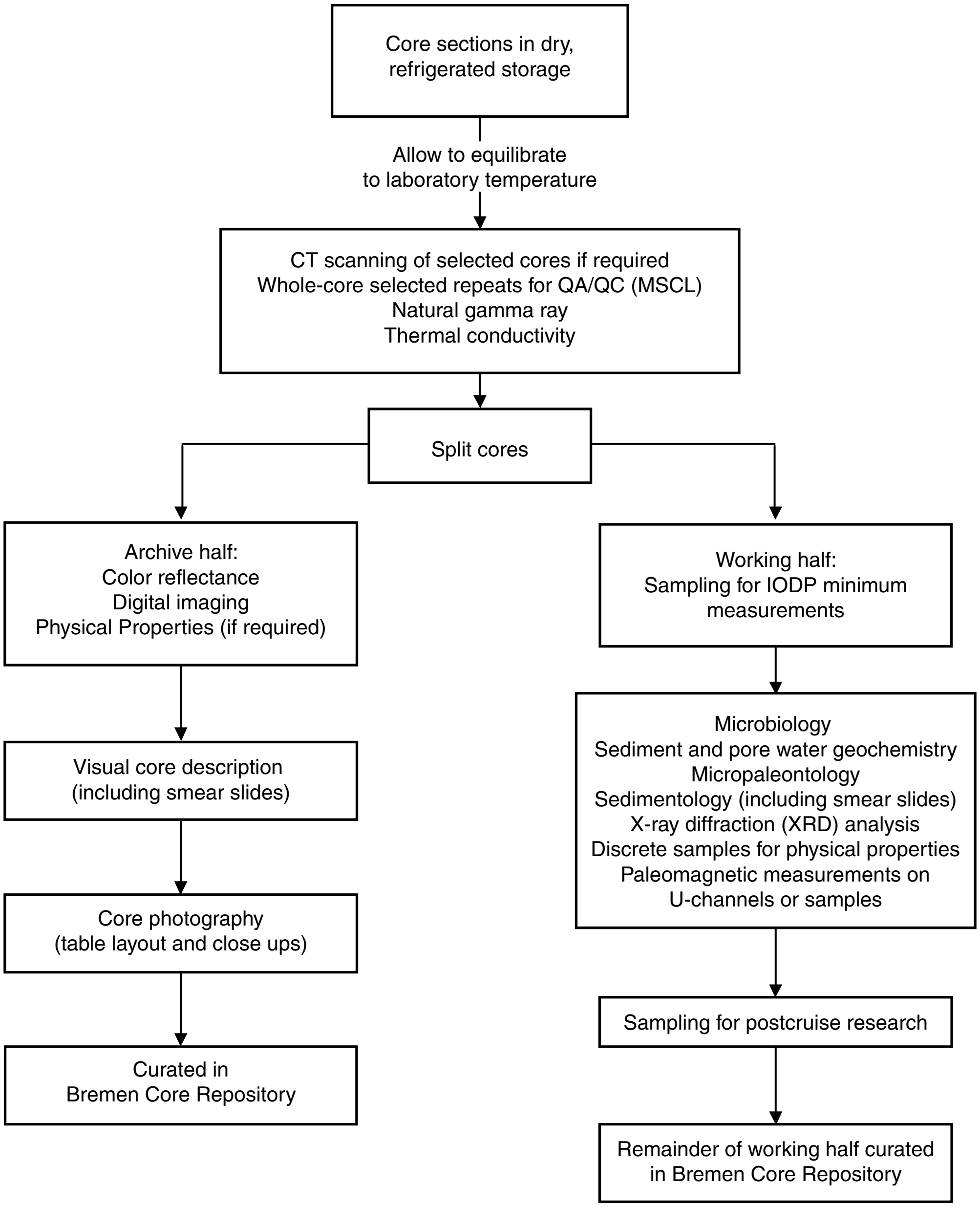


Figure AF2. Onshore core flow. CT = computed tomography, QA/QC = quality assurance/quality control, MSCL = multisensor core logger.



Expedition scientists and scientific participants

The current list of participants for Expedition 313 can be found at **www.eso.ecord.org/expeditions/313/313.htm.**