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Leg 101–An Overview

James A. Austin Jr.
University of Texas at Austin

Wolfgang Schlager
Vrije Universiteit, Instituut v. Aardwetenschappen

Amanda A. Palmer
Texas A & M University - College Station

Paul A. Comet
Core Labs Singapore

André Droxler
Rice University

See next page for additional authors

Austin, James A. Jr.; Schlager, Wolfgang; Palmer, Amanda A.; Comet, Paul A.; Droxler, André; Eberli, Gregor; Fourcade, Eric; Freeman-Lynde, Raymond; Fulthorpe, Craig S.; Harwood, Gill; Kuhn, Gerhard; Lavoie, Dawn; Leckie, Mark; Melillo, Allan J.; Moore, Arthur; Mullins, Henry T.; Ravenne, Christian; Sager, William W.; Swart, Peter; Verbeek, Joost W.; Watkins, David K.; and Williams, Colin, "Leg 101--An Overview" (1988). *Papers in the Earth and Atmospheric Sciences*. 233.
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Authors

James A. Austin Jr., Wolfgang Schlager, Amanda A. Palmer, Paul A. Comet, André Droxler, Gregor Eberli, Eric Fourcade, Raymond Freeman-Lynde, Craig S. Fulthorpe, Gill Harwood, Gerhard Kuhn, Dawn Lavoie, Mark Leckie, Allan J. Melillo, Arthur Moore, Henry T. Mullins, Christian Ravenne, William W. Sager, Peter Swart, Joost W. Verbeek, David K. Watkins, and Colin Williams

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29. LEG 101—AN OVERVIEW[1]

Leg 101 Scientific Party[2]

ABSTRACT

During Leg 101, the inaugural leg of the Ocean Drilling Program, the *JOIDES Resolution* drilled 19 holes at 11 sites in the Bahamas. Grids of high-resolution seismic profiles provided information crucial for both site selection and regional stratigraphic interpretations. The first major scientific objective was to understand the long-term evolution of the bank-and-basin pattern that currently characterizes the Bahamas archipelago. Drilling and seismic surveys have indicated considerable platform expansion and retreat rather than stationary upward growth. Upbuilding in the Late Jurassic–Early Cretaceous was followed by drowning and retreat in the mid-Cretaceous and by renewed expansion in the Cenozoic. At Site 627 on the southern Blake Plateau, the stratigraphic succession consists of shallow-water platform carbonates/evaporites (late Albian), marly limestones of a mixed terrigenous/carbonate shelf (latest Albian–middle Cenomanian), carbonate ooze of an oceanic plateau (Campanian–Miocene), and finally the turbidite apron of an advancing platform (Neogene). The top of the upper Albian shallow-water platform is characterized seismically by an acoustic unconformity, an amplitude contrast, and a velocity transition (from 2.8 to 4.2 km/s). Jump correlation of a similar acoustic horizon underlying the Straits of Florida (Site 626) with the Great Isaac 1 well on Great Bahama Bank approximately 60 km away suggests that deep-water carbonates in the Straits are also underlain by a mid-Cretaceous shallow-water platform.

Delineating the evolution of platform flanks was the second major scientific objective of Leg 101. Modern facies belts were traced back through the Neogene record in two slope transects. A gentle (2°–3°) slope (north of Little Bahama Bank) is characterized by fine-grained sediments and erosional gullies. Coarse material bypasses the slope in turbidity currents and is deposited on debris aprons. With an increase of slope angle to 10°–12° (southeastern Exuma Sound), the zone of maximum accumulation shifts from the slope to the debris apron, probably because of increased turbidity-current activity. Slumps, debris flows, and turbidites are unusually abundant in the lower and middle Miocene sections and are probably caused by tectonic activity (the "Abaco event") superimposed on long-term slope evolution. Detailed stratigraphy of the two slope transects supports "highstand shedding," the concept that maximum input of platform sediment to the deep sea occurs during highstands rather than lowstands of sea level. Pleistocene glacial periods as well as postulated eustatic lowstands in the Messinian and Pliocene correspond to hiatuses or intervals of slow sedimentation on platform flanks, and perhaps to karst horizons on the platform tops.

Diagenesis of periplatform ooze is rapid. Both high-magnesium calcite and aragonite decrease with depth, and dolomite precipitates. However, lithification is discontinuous and incomplete to burial depths in excess of 200 mbsf and ages of 10–15 Ma.

INTRODUCTION

The decision to make carbonate platforms the focus of the inaugural scientific leg of the Ocean Drilling Program reflects a growing awareness of their importance as recorders of ocean history and reservoirs of oil, gas, and metallic ores (e.g., Tator and Hatfield, 1975; Enos, 1977; Cook and Enos, 1977; Murris, 1980; COSOD, 1982; Tyler et al., 1985; and many others). For decades the Bahamas have served as a modern example and standard for interpreting platforms in the geologic record. Geologic studies focused initially on the shallow-water bank tops but since the 1970s have expanded to periplatform environments (i.e., platform flanks and intervening basins; e.g., Kier and Pilkey, 1971; Lynts et al., 1973; Schlager and James, 1978; Mullins and Neumann, 1979; Schlager and Chermak, 1979).

Leg 101 was designed primarily to add a historic dimension to these investigations of modern periplatform environments. Two topics were given top priority for scientific drilling: (1) ori-

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[2] James A. Austin, Jr. (Co-Chief Scientist), Institute for Geophysics, University of Texas at Austin, Austin, TX 78751; Wolfgang Schlager (Co-Chief Scientist), Rosenstiel School of Marine and Atmospheric Science, Miami, FL 33149 (current address: Vrije Universiteit, Instituut v. Aardwetenschappen, Postbus 7161, 1007 MC Amsterdam, Netherlands); Amanda A. Palmer (ODP Staff Scientist), Ocean Drilling Program, Texas A&M University, College Station, TX 77843; Paul A. Comet, The University, Newcastle-Upon-Tyne, Newcastle, United Kingdom (current address: Core Labs Singapore, 24A-Lim Teck Boo Rd., Singapore 1953); André Droxler, Rosenstiel School of Marine and Atmospheric Science, Miami, FL 33149 (current address: Department of Geology and Geophysics, Rice University, Houston, TX 77251); Gregor Eberli, Geologisches Institut, ETH-Zentrum, Zürich, Switzerland; Eric Fourcade, Laboratoire de Stratigraphie, Université Pierre et Marie Curie, 4 Place Jussieu 75252, Paris Cedex 05, France; Raymond Freeman-Lynde, Department of Geology, University of Georgia, Athens, GA 30602; Craig S. Fulthorpe, Department of Geological Sciences, Northwestern University, Evanston, IL 60201; Gill Harwood, Department of Geology, The University, Newcastle-Upon-Tyne, NE1 7RU United Kingdom; Gerhard Kuhn, Geologisches Institut Göttingen, Federal Republic of Germany (current address: Alfred Wegener Institut für Polarforschung, Columbus Center, D-2850 Bremerhaven, Federal Republic of Germany); Dawn Lavoie, NORDA Code 363, Seafloor Geosciences Division, NSTL, MS 39529; Mark Leckie, Woods Hole Oceanographic Institution, Woods Hole, MA 02543 (current address: Department of Geology and Geography, University of Massachusetts, Amherst, MA 01003); Allan J. Melillo, Department of Geological Sciences, Rutgers University, New Brunswick, NJ 08903 (current address: Chevron U.S.A., New Orleans, LA 70112); Arthur Moore, Marathon Oil Company, P.O. Box 269, Littleton, CO 80160; Henry T. Mullins, Department of Geology, Syracuse University, Syracuse, NY 13244; Christian Ravenne, Institut Français du Pétrole, B.P. 311, 92506 Rueil Malmaison Cedex, France; William W. Sager, Department of Oceanography, Texas A&M University, College Station, TX 77843; Peter Swart, Fisher Island Station, University of Miami, Miami, FL 33139 (current address: Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, Miami, FL 33149); Joost W. Verbeek, Dutch Geological Survey, P.O. Box 157, 2000 A.D. Haarlem, Netherlands; David K. Watkins, Department of Geology, University of Nebraska, Lincoln, NE 68588; Colin Williams, Borehole Research Group, Lamont-Doherty Geological Observatory, Palisades, NY 10964.

gin of bank-and-trough physiography of the archipelago and (2) stratigraphic record of platform flanks, including their response to changing sea level and other environmental controls. In retrospect, the first, or "deep," objective was only partly accomplished, as actual sampling of a mid-Cretaceous shallow-water platform complex was successful only at Site 627 on the southern Blake Plateau. However, the second, or "shallow," objective was completely achieved by the two successful slope transects north of Little Bahama Bank and in southeastern Exuma Sound (Table 1).

Drilling was expected to evaluate two different hypotheses concerning origin of bank-and-trough topography (Fig. 1). According to the first hypothesis, such topography has its roots in structural relief generated during Mesozoic rifting of North America and Africa (Talwani et al., 1960; Mullins and Lynts, 1977). Subsequent carbonate sedimentation has only slightly modified the original horst-and-graben configuration. The contrasting hypothesis postulates that original basement topography has been subdued by carbonate deposition during the Late Jurassic and Early Cretaceous, with eventual creation of a continuous carbonate platform, or "megaplatform," stretching from the modern Florida Escarpment in the west to the Bahama Escarpment in the east (Fig. 1). On regional multichannel seismic reflection (MCS) profiles (Fig. 1), the top of the buried megaplatform has been interpreted as a prominent acoustic unconformity associated with a pronounced downward increase in compressional-wave velocity (to more than 4 km/s; Sheridan et al., 1981; Van Buren and Mullins, 1983; Ladd and Sheridan, 1987; Sheridan et al., 1988). During the mid-Cretaceous, the megaplatform partially drowned and disintegrated, initiating the modern pattern of banks and troughs. According to this theory, continuing faulting and erosion of the platform flanks and upbuilding of the banks have also influenced the evolution of the Bahamas, but their relative significance has been viewed differently by various authors (Paulus, 1972; Meyerhoff and Hatten, 1974; Sheridan et al., 1981; Schlager and Ginsburg, 1981).

Table 1. Comparison of slope transects of Leg 101.

Characteristics	N of Little Bahama Bank (Little Bahama Bank transect)	Exuma Sound (Exuma transect)
Slope height	800 m	1600 m
Declivity	2°–3°	10°–12°
Setting (Mullins and Neumann, 1979)	Ocean-facing, windward	Protected reentrant, windward
Reflector geometry	Basinward converging	Basinward diverging?
Depositional regime (Schlager and Ginsburg, 1981)	"Accretionary"	"Bypass"

Original Leg 101 plans called for sampling the buried megaplatform top interpreted on MCS profiles in at least two of the following locations: the Straits of Florida (Site 626), Exuma Sound (Site 632), and Northeast Providence Channel (Sites 634–

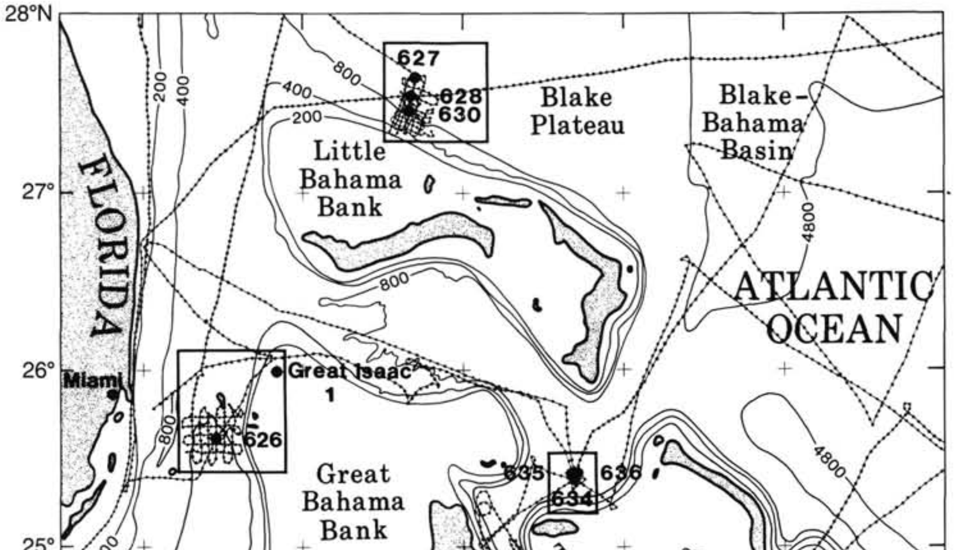

Figure 1. Index map showing geophysical site-survey coverage and location of Leg 101 drilling sites in the Bahamas. The *Fred H. Moore* conducted surveys north of Little Bahama Bank (LBB), in the Straits of Florida (FS), and in Exuma Sound (ES). Additional MCS coverage in the region is also shown, as is the location of the Great Isaac 1 borehole. Bathymetric contours are in meters.

636). However, successful penetration to and through the top of a buried shallow-water carbonate-platform complex occurred only at Site 627 north of Little Bahama Bank on the southern Blake Plateau (Fig. 1).

Bahamian platform flanks were drilled in order to bridge a gap between studies of ancient and modern carbonate slopes. Direct comparisons of such slope environments have been difficult because case studies of ancient examples rely predominantly on vertical (i.e., outcrop) successions, whereas geologic studies of recent slopes often address the entire depositional setting with only a few meters of vertical control (i.e., using piston coring and high-resolution echo-sounding techniques). By recovering complete stratigraphic sequences underneath two different carbonate slopes in the Bahamas, Leg 101 combined the two approaches.

This slope drilling was guided by the following objectives. One goal was to recover a longer record of the facies belts known from the Holocene record to characterize platform-to-basin transitions (Mullins and Neumann, 1979; Schlager and Chermak, 1979; Mullins et al., 1984). A second was to examine further the response of modern Bahamian slopes to two known controls: (1) windward vs. leeward exposure, and (2) depositional setting: open-ocean vs. protected reentrant (Mullins and Neumann, 1979; Cook and Mullins, 1983). A third was to understand the known change in depositional regime from accretion to erosion as the flanks of a carbonate platform steepen and build up (Schlager and Ginsburg, 1981; Schlager and Camber, 1986). Finally, Leg 101 was intended to reveal more about "highstand shedding," the observation that carbonate platforms shed more sediment during highstands of sea level than during lowstands (Kier and Pilkey, 1971; Lynts et al., 1973; Schlager and Ginsburg, 1981; Mullins, 1983; Boardman and Neumann, 1984; Droxler and Schlager, 1985). "Highstand shedding" appeared to be out of phase with siliciclastic systems known to transfer most of their sediment to the deep sea during sea-level lowstands (e.g., Vail et al., 1977).

To keep the number of slope sites manageable, the objectives outlined above were addressed in parallel rather than in series. Leg 101 drilled one three-hole transect (Sites 627, 628, and 630) on an ocean-facing, relatively gentle (i.e., 2°-3°), relatively low (800-m elevation) slope north of Little Bahama Bank, and another (Sites 631, 632, and 633) on a steeper (i.e., 10°-12°), higher (1600-m elevation), reentrant slope in the southeastern part of Exuma Sound (Fig. 1). Apart from depositional setting, height, and declivity, the two slopes differed also in their component reflector geometries (Table 1; see also Austin, Schlager, et al., 1986; Austin et al., this volume). Both transects continuously sampled the Neogene geologic history of these slope environments, including the major facies belts previously described and multiple highstand/lowstand depositional cycles.

Site selection for all Leg 101 scientific objectives was based on geophysical site surveys by the research vessel *Fred H. Moore* in 1984 (Fig. 1; Austin et al., this volume). Approximately 2200 km of 24-trace, 12-fold seismic reflection profiles were collected, along with sonobuoys, bathymetry (underway 3.5 kHz), and magnetics. Three-dimensional seismic coverage proved crucial for both initial site selection and at-sea modifications of drilling plans (Austin, Schlager, et al., 1986; Austin et al., this volume).

DRILLING RESULTS

The Deep Objective: Origin of the Platform-Basin Pattern

Straits of Florida: Site 626

The designated first site of Leg 101 was also the most technically difficult because Site 626 was located almost directly beneath the axis of the modern Gulf Stream (Figs. 1 and 2). Site 626 was intended to provide a complete late Early Cretaceous(?)–Holocene stratigraphic succession beneath the straits, which would in turn document the depositional/erosional history of the Gulf Stream as a complement to similar work conducted both in the southeastern Gulf of Mexico (Buffler, Schlager, et al., 1984; Angstadt et al., 1985) and on the Blake Plateau (Pinet and Popenoe, 1985a, 1985b). This site also represented an attempt to sample the buried megaplatform top inferred from MCS profiles collected in the straits (Sheridan et al., 1981). A rectilinear grid of site-survey profiles (Fig. 2) confirmed that the pronounced velocity discontinuity/impedance contrast believed to be the top of the buried shallow-water carbonate section occurred at approximately 1200 meters below seafloor (mbsf) in the straits southeast of Miami (Figs. 1-3; Austin et al., this volume). Because of the depth of this target horizon, Site 626 was intended as a reentry hole. However, attempts to place a reentry cone in the straits during the shakedown cruise of the *JOIDES Resolution* were unsuccessful because of excessive current strength (Leg 100 Scientific Party, 1985).

Four different single-bit attempts to reach the target horizon were made in the straits (Fig. 2, inset). In all instances, unconsolidated deep-water carbonate sands hindered drilling operations (Austin, Schlager, et al., 1986). The deepest penetration was Hole 626D, which was abandoned in the uppermost Oligocene section at 447 mbsf (Figs. 3 and 4).

Despite failure to reach the interpreted megaplatform top and overall core recovery of only 3%, Site 626 provides some interesting results. First, the presence of winnowed, unconsolidated sands throughout the cored interval suggests that the Gulf Stream has been a pervasive sedimentological agent for at least the last 28 m.y. (Watkins et al., this volume). Second, the recovery of a sequence of middle Miocene debris flows coeval with the intraclastic chalks of the Great Abaco Member of the Blake Ridge Formation sampled in the Blake-Bahama Basin to the north during DSDP Legs 44 (Benson, Sheridan, et al., 1978) and 76 (Sheridan, Gradstein, et al., 1983; Bliefnick et al., 1983) suggests a widespread triggering mechanism (Fulthorpe and Melillo, this volume), hereafter termed the "Abaco event." Third, Site 626 documents that the seismic stratigraphy in the straits calibrated by Sheridan et al. (1981) using jump correlation to the Great Isaac 1 borehole approximately 60 km to the northeast (Fig. 2) is too old by as much as 20 Ma (Austin, Schlager, et al., 1986; Austin et al., this volume). Fourth, comparison of stratigraphic successions, porosity, and subsidence curves at Site 626 and Great Isaac 1 suggests tens of kilometers of northwestward progradation of Great Bahama Bank since the late Miocene (Figs. 1, 2, and 5; Leg 101 Scientific Party, 1985a, 1985b; Schlager et al., this volume; Williams et al., this volume). Mullins et al. (1980) also report northwestward progradation of contourite deposits in the straits north of Site 626 in response to a postulated intensification of Gulf Stream flow in the Miocene. Finally, the upper Lower Cretaceous(?) platform top inferred at Site 626 and observed in the Great Isaac 1 well (and marked by sympathetic velocity contrasts in both locations) is nearly horizontal, suggesting that the margin of Great Bahama Bank in this area is controlled primarily by westward progradation of the platform, not by faulting (Fig. 5). The idea of lateral migration of bank margins agrees well with recent seismic interpretations of adjacent parts of Great Bahama Bank (Eberli and Ginsburg, 1987; Schlager et al., this volume).

Southern Blake Plateau north of Little Bahama Bank: Site 627

Like the seismic stratigraphy of the Straits of Florida, the seismic stratigraphy of the southern Blake Plateau included a high-amplitude reflector accompanying a pronounced downward velocity shift to values in excess of 4.5 km/s (Sheridan et al.,

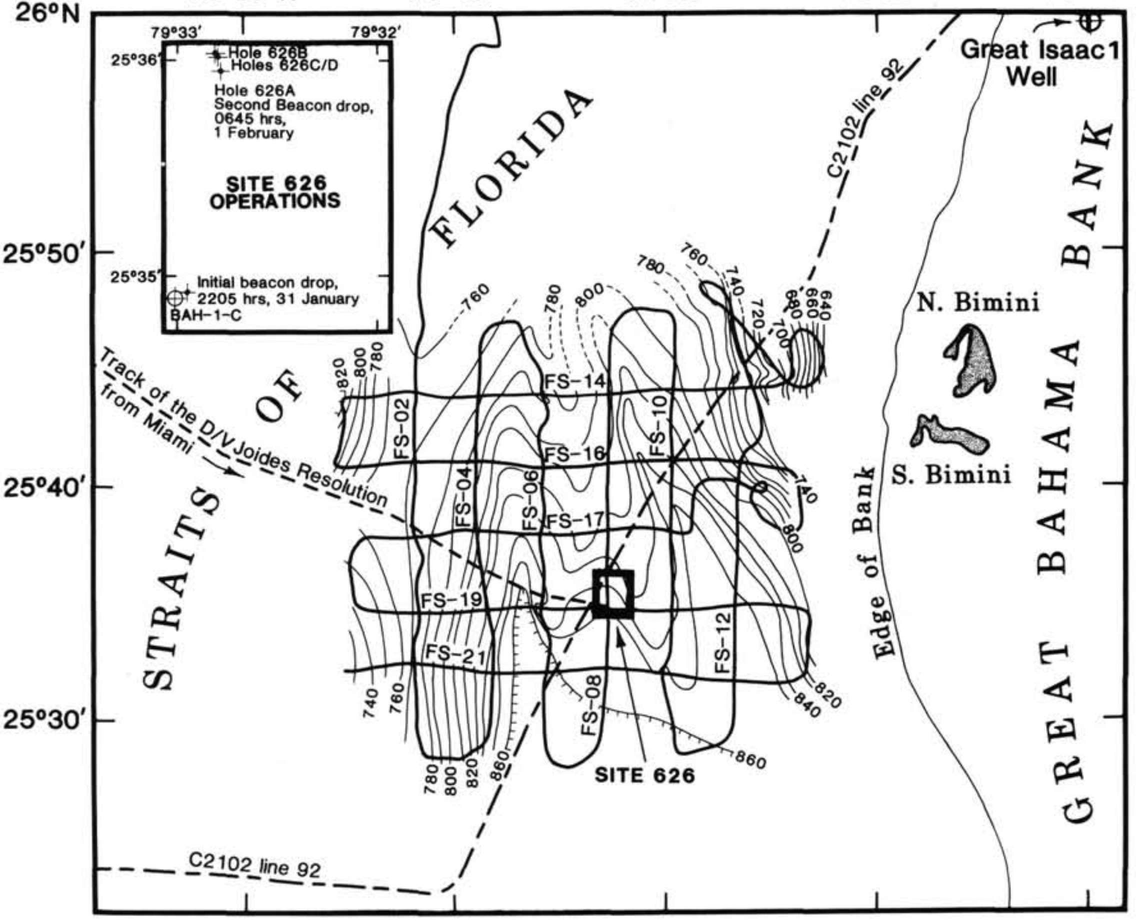

Figure 2. Map of the site-survey grid in the Straits of Florida (see Fig. 1 for general location) superimposed on a bathymetric compilation (in corrected meters, contour interval, 20 m) using 3.5-kHz profiles collected during the survey. Solid lines represent 24-trace, 12-fold seismic reflection profiles collected primarily using a 400-in.^{3} water gun (Table 1). Inset box (upper left) details Site 626 operations (see also Austin, Schlager, et al., 1986). Great Isaac 1 well is located about 60 km to the northeast. Dashed line is part of a regional MCS profile discussed by Sheridan et al. (1981) and Ladd and Sheridan (1987).

1966). Heezen and Sheridan (1966), Sheridan et al. (1969), Sheridan and Enos (1979), Mullins et al. (1982), and Van Buren and Mullins (1983) all interpreted this high-velocity material to be part of a platform-interior carbonate facies. The site-survey grid north of Little Bahama Bank reaffirmed the existence and lateral continuity of the inferred top of the shallow-water carbonate section at depths of generally less than 600 m (Figs. 1, 6, and 7; Austin, Schlager, et al., 1986; Austin et al., this volume). Therefore, in the wake of the failure to reach a similar target at Site 626 in the straits, the decision was made to attempt to sample the interpreted buried platform top in a region where it was both shallower and out of the winnowing influences of the Gulf Stream.

Two holes were drilled at Site 627 using HPC/XCB techniques (Austin, Schlager, et al., 1986). Hole 627B succeeded in sampling the top of a buried platform as predicted: a sequence of dolostone, limestone, and gypsum of late Albian age (Figs. 4 and 8). The first dolostones exhibiting unequivocal evidence of shallow-water platform deposition occurred at 477.7–487.1 mbsf (1513.5–1523.1 m sub-sea level), in almost exact agreement with a local sonobuoy refraction solution for the depth of the platform top (Fig. 7; Austin et al., this volume). Abundant interbedded gypsum, suggestive of a very restricted platform interior, was not encountered until 514.2–519.2 mbsf (1550.2–1555.2 m sub-sea level), in reasonable agreement with the velocity transition to 4.2 km/s material predicted by MCS results at closest-point-of-approach to the drill site (531 mbsf; Figs. 6 and 7; Freeman-Lynde, this volume; Austin et al., this volume). Further penetration into this platform complex was halted and drilling terminated when wet-gas shows were encountered (Austin, Schlager, et al., 1986).

Results from Site 627 put narrow constraints on timing of platform drowning (i.e., the transition from a shallow-water carbonate platform to an open-marine environment) on the southern Blake Plateau. The dolomites yielded an assemblage of shallow-water benthic foraminifers and dinoflagellates of late Albian age, whereas the overlying sequence of deepening-upward marly limestones and chalk (Fig. 8) are of latest Albian to middle Cenomanian age (Austin, Schlager, et al., 1986; Fourcade and Butterlin, this volume; Masure, this volume). Therefore, drowning must have occurred at this location between the latest Albian and the earliest Cenomanian.

In addition to calibrating age and depth of the top of the shallow-water carbonate section, samples from Hole 627B illustrated subsequent transformation of this site, first to a mixed carbonate/terrigenous shelf during the latest Albian or earliest Cenomanian, then to a marginal oceanic plateau characterized by frequent hiatuses between the Campanian and Oligocene, and finally into the prograding turbidite apron of Little Bahama Bank in the Neogene (Figs. 7 and 8). Basic trends in sedi-

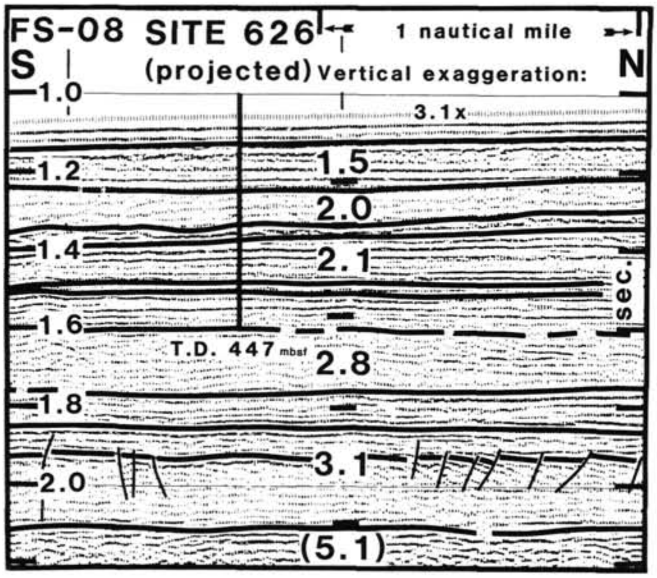

Figure 3. Part of interpreted site-survey profile FS-08 in the vicinity of Site 626 (see Fig. 2 for location). Larger numbers vertically arranged in the center of the profile represent interval velocities in km/s derived from sonobuoy and MCS results (see Austin et al., this volume). Vertical bar represents the total depth (TD) of penetration of Hole 626D in meters. Hole 626D was actually located approximately 0.5 km off the trend of the profile (see Fig. 2 and Austin, Schlager, et al., 1986). Velocity contrast from 3.1 to 5.1 km/s represents the intended drilling target, the inferred top of a mid-Cretaceous(?) shallow-water carbonate platform.

mentation rates at Site 627 resemble those at Site 391 in the Blake-Bahama Basin to the north (Benson, Sheridan, et al., 1978; Fig. 1), suggesting regional rather than local depositional controls. An exception to that correlation is a middle-upper Campanian sequence of carbonate ooze and chalk in Hole 627B not encountered at Site 391. Upper lower-lower middle Miocene debris flows were again encountered at Site 627, substantiating their apparently widespread occurrence from the Straits of Florida to the Blake-Bahama Basin.

Two ties between hiatuses encountered in Hole 627B and seismic sequence boundaries/acoustic unconformities identified on site-survey reflection profiles north of Little Bahama Bank could be made (Figs. 7 and 8; Austin et al., this volume). The F/G sequence boundary marks the top of the intercalated carbonate-gypsum succession, whereas the E/F boundary correlates with a hiatus extending from the uppermost middle Cenomanian to the lowermost Coniacian. Higher in the section, such correlations are more ambiguous (Austin et al., this volume), perhaps because this region was sediment-starved throughout most of the Late Cretaceous and Neogene (Fig. 8; Melillo, this volume; Watkins and Verbeek, this volume; Watkins et al., this volume).

Northeast Providence Channel: Sites 634, 635, and 636

Leg 101 operations in Northeast Providence Channel were originally envisioned only as an alternative, if successful penetration to and through the interpreted "megaplatform" top could not be achieved in at least two of the originally specified locations elsewhere. Unfortunately, this eventuality turned out to be the case, as deep drilling operations were unsuccessful in Exuma Sound (see Site 632 description below) as well as in the Straits of Florida. Site selection in Northeast Providence Channel was based solely on existing regional MCS control (Figs. 1 and 9; Sheridan et al., 1981), which suggested that a deep-penetration attempt on the channel's flank might recover a complete deep-water section above inferred upper Lower Cretaceous shallow-water carbonates, thereby ensuring precise age and stratigraphic control of platform drowning (Fig. 10).

Site 634 was effectively a reoccupation of Deep Sea Drilling Project (DSDP) Site 98, which bottomed in upper Santonian-lower Campanian bioclastic turbidites containing perireef debris (Paulus, 1972). Its primary goal was to reach and sample a velocity discontinuity (2.87 km/s above and 4.89 km/s below) at a depth of approximately 770 mbsf (Fig. 10), which had been interpreted by Sheridan et al. (1981) as the same shallow-water platform top successfully sampled at Site 627.

Only one hole was drilled at Site 634 using standard rotary-drilling techniques. Unfortunately, poor hole conditions in skeletal grainstones, rudstones, and debris flows with minor intercalated chalk of latest Santonian-earliest Campanian age prevented penetration beyond 480 mbsf (Fig. 4; Austin, Schlager, et al., 1986). These lithologies were also encountered at the base of DSDP Site 98. Their presence suggests Campanian development of a talus apron derived from a nearby shallow-water carbonate platform of Cenomanian-Campanian age (Paulus, 1972; Austin, Schlager, et al., 1986; Butterlin and Fourcade, this volume; McClain et al., this volume).

A suite of Schlumberger logs (Compensated Neutron, Gamma Ray, and Gamma Spectroscopy) run in the drill string provides some detailed information on both porosities and lithologies in the thick Campanian section, which was poorly sampled (Fig. 4). Cores and logs combined yield revised ages for two acoustic horizons regionally correlated by Sheridan et al. (1981) (Fig. 10). Their upper Eocene/upper Oligocene sequence boundary correlates in depth either with the Paleocene/Eocene boundary or with the top of the Campanian section at Site 634, and their lower Eocene/upper Eocene boundary falls within the Campanian calciturbidites (Austin, Schlager, et al., 1986).

Attention then shifted to the thalweg of Northeast Providence Channel, where the target reflector presumed to be the top of the mid-Cretaceous platform was less than 200 mbsf (Figs. 9 and 10). Site 635 was located on the lower part of the northern flank of Northeast Providence Channel (Fig. 9). Hole 635B reached 118 mbsf before a stuck core barrel forced final termination of drilling (Austin, Schlager, et al., 1986). From 61 to 118 mbsf, Hole 635B penetrated a sequence of slightly argillaceous chalk and limestone of late Albian age (Fig. 4). These carbonates were deposited in a bathyal environment characterized by intercalations of muddy debris flows and small slumps with minor faulting (Fig. 11). The environment is most shallow (neritic?) at the bottom of the hole (Watkins and Verbeek, this volume). However, lack of clasts derived from a shallow-water platform suggests that this area was located farther from any such platform than the depositional environment suggested by the Campanian calciturbidite section sampled at Sites 98/634. As Sites 634 and 635 are less than 5 km apart, this result points to changes in configuration of platform margins during the Cretaceous.

Of particular interest were dark laminated zones within Site 635 limestones that were characterized by high total-organic-carbon contents, some in excess of 6% (Katz, this volume). These rocks are coeval with organic-rich "black shales" of the Hatteras Formation encountered by drilling in the adjacent deep western North Atlantic basin (Hollister, Ewing, et al., 1972; Benson, Sheridan, et al., 1978; Tucholke, Vogt, et al., 1979), but they are much shallower in paleodepth. This occurrence suggests widespread oxygen deficiency throughout the water column in the Atlantic during the mid-Cretaceous.

A final attempt to penetrate the interpreted shallow-water platform top beneath the thalweg of Northeast Providence Channel was made at Site 636 (Figs. 9 and 10). Time ran out before significant penetration could be achieved. Two cores recovered only fragments of Neogene canyon fill.

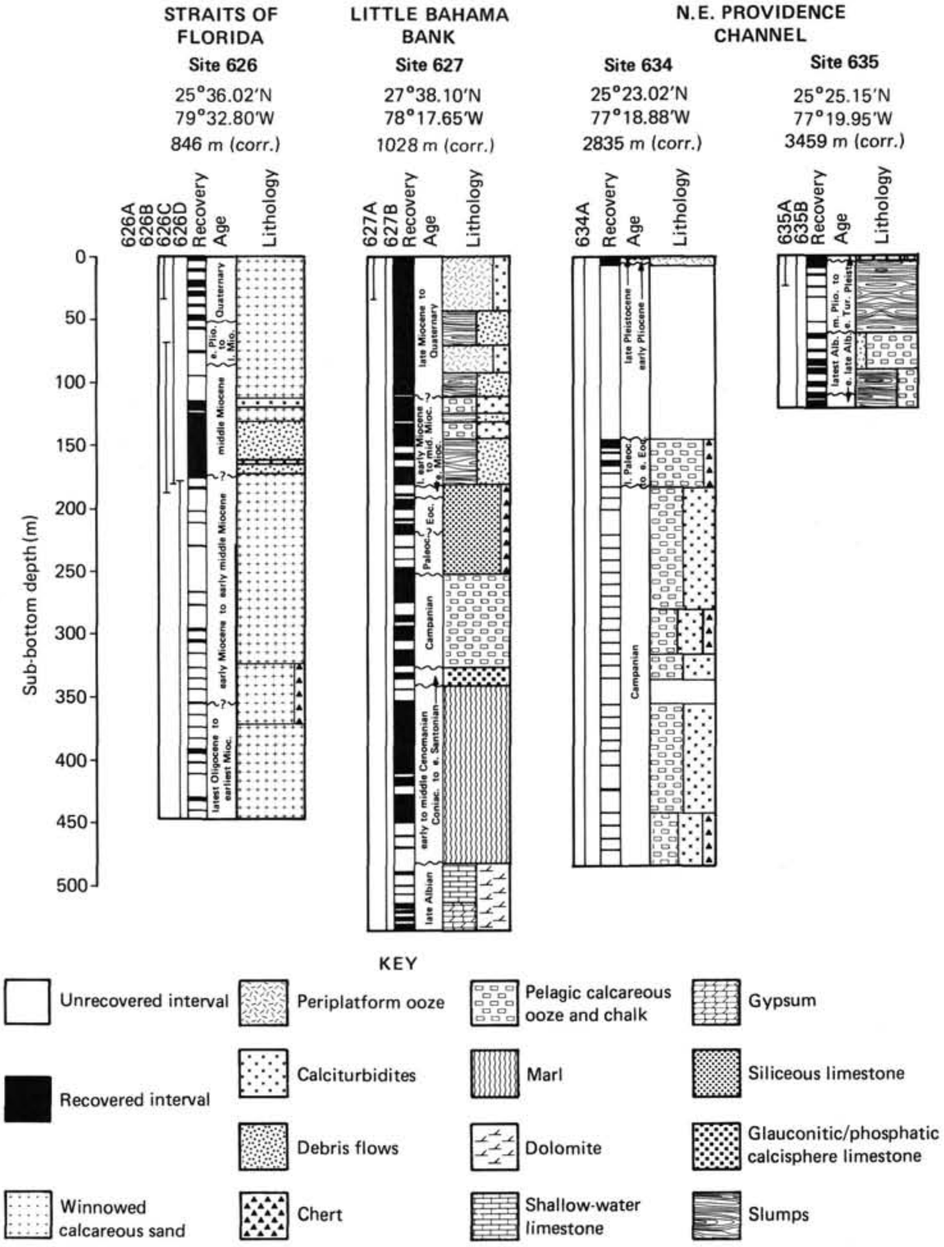

Figure 4. Summaries of lithologies recovered in attempts to sample the top of the inferred "megaplatform": Sites 626, 627, 634, and 635. Only Site 627 achieved that objective. Locations and water depths commonly represent averages (see also Austin, Schlager, et al., 1986).

The Shallow Objective: Evolution of Modern Carbonate Slopes

Transect of a Low, Gentle Slope: Little Bahama Bank (Sites 627, 628, and 630)

Although the primary goal of Site 627 was to sample the mid-Cretaceous shallow-water carbonate platform buried beneath the southern Blake Plateau, this site also served as the seaward end of the three-hole transect designed to understand the stratigraphic record of a gentle (2°–3°) carbonate slope of modest height, considered an "accretionary" slope by Schlager and Ginsburg (1981). Site 627 successfully sampled more than 90% of the lower Miocene-Holocene section, which records the prograding flank of Little Bahama Bank (Austin, Schlager, et al., 1986; Figs. 8 and 12). Above some lower to middle Miocene debris flows of the Abaco event, the Neogene section was composed of a combination of periplatform ooze and turbidites with associated slumps and debris flows, as predicted. Numerous hiatuses in this section attest to sediment removal by both slumping and bottom currents (Austin et al., this volume; Harwood and Towers, this volume).

Site 628 was approximately 6 nmi bankward from Site 627 in the modern debris apron of the platform flank (Figs. 6 and 7). One HPC/XCB hole recovered a sequence of upper Paleocene-lower Eocene to Holocene periplatform ooze with intercalated debris flows, slumps, and turbidites (Austin, Schlager, et al., 1986; Fig. 12). Based on the recent sediment cover, Mullins et al. (1984) suggested that this region should be characterized by mud-supported debris flows and more abundant, thick, coarse-grained turbidites. Sampling at Site 628 generally supported this view. The thickness and grain size of sediment gravity flows in-

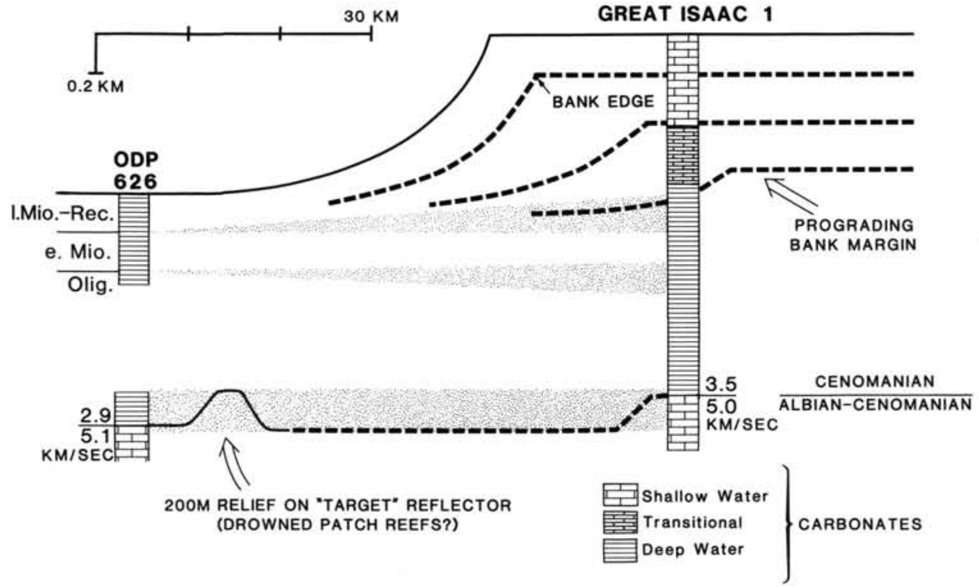

Figure 5. Comparison of stratigraphy sampled at Site 626 and at the Great Isaac 1 borehole (after Austin, Schlager, et al., 1986; see also Schlager et al., this volume; Austin et al., this volume). Velocity contrast believed to be the top of a shallow-water platform beneath the Straits of Florida correlates approximately in depth with a velocity contrast of similar magnitude associated with the top of an Albian-Cenomanian shallow-water carbonate section in the Great Isaac 1. Local depth fluctuation of the "target" horizon in the Straits of Florida may be the result of either karstification or persistent patch-reef development atop the drowned "megaplatform." While the uppermost Oligocene-Holocene sediments at Site 626 are all deep-water deposits, the succession of carbonate facies in the Great Isaac 1 well suggests that a shallow-water platform occupying what is now the northwestern corner of Great Bahama Bank drowned in the mid-Cretaceous, to be succeeded by a deep-water section until the late Miocene, when shallow-water conditions were reestablished. This succession suggests pronounced (at least tens of kilometers) lateral migration of bank margins through time (see also Austin, Schlager, et al., 1986; Eberli and Ginsburg, 1987; Schlager et al., this volume).

creased upward from the middle Miocene, coinciding with a general upward increase in the incidence of slumps and calciturbidites throughout the drilled interval (Kuhn and Meischner, this volume). Sedimentation rates in the upper Miocene–upper Pliocene section exceeded 30 m/m.y. (Watkins et al., this volume). This sequence is interpreted as a transition from a marginal oceanic plateau in the Paleogene to a prograding platform flank in the Neogene. However, middle Miocene debris flows do not fit this trend. They are coeval with those encountered at Sites 626 and 627 and at DSDP Sites 391/534 to the northeast, providing further support for a widespread Abaco event.

The site-survey line connecting Sites 627 and 628 indicates the presence of both normal faults and imbricate thrusts (Fig. 7; Austin et al., this volume; Harwood and Towers, this volume). The presence of both folds and slumps within the cored interval at Site 628 supports this interpretation. The thrusts affecting this part of the platform flank are toe thrusts of major slumps higher on the slope (Van Buren and Mullins, 1983; Harwood and Towers, this volume). Seismic stratigraphy suggests that most of these slumps are also of Miocene age (Harwood and Towers, this volume) and that they may be in part another expression of the Abaco event.

Whereas seismic sequences could be traced laterally from Sites 627 and 628 despite the observed faulting (Fig. 7), intervals of deposition and erosion in the two sections do not match, nor do they correlate well with sea level curves of Vail et al. (1977) and Haq et al. (1987) (Fig. 13). In particular, a thick interval of Oligocene–lowermost Miocene carbonate ooze at Site 628 has no equivalent at Site 627 (Moran and Watkins, this volume). Such local, intermittent sedimentation patterns may be related to episodic scouring of the Gulf Stream/Antilles Current system during a long period of general sediment starvation in the southwestern North Atlantic.

Site 630 constituted the upslope end of the Little Bahama Bank transect (Figs. 1 and 6). (Note: Site 629 is not discussed in this summary because it was an unsuccessful attempt to spud-in.) The primary objective of Site 630 was to sample a complete sequence of periplatform ooze in order to monitor perennial off-bank transport in an interfluve between gullies (Fig. 6; see also Austin, Schlager, et al., 1986). Hole 630A achieved 88% recovery of a sequence of late Miocene and younger sediments, which was divided into two units (Fig. 12). The lower unit, composed of periplatform ooze and turbidites, was interpreted as being analogous to the debris apron at the foot of the modern platform slope. The upper unit, a nearly turbidite-free ooze, reflected the environment that still persists at this location: a slope characterized by numerous gullies that receives only fine-grained sediment exported by the nearby platform, while the coarse material bypasses the slope to be deposited on the debris apron as graded beds. The observed succession of debris apron overlain by upper slope ooze was consistent with the northward progradation of the platform flank deduced from Sites 627 and 628 (Austin, Schlager, et al., 1986).

Seismic stratigraphy was more ambiguous at Site 630 than at Sites 627 and 628, primarily because of the gullied nature of the upper slope and the proximity of major slump scars on the mid-slope (Austin et al., this volume; Harwood and Towers, this volume). However, two acoustic unconformities could be tied to borehole stratigraphy: one to a Pleistocene hiatus near the seafloor and the other to a turbidite event and/or a diagenetic

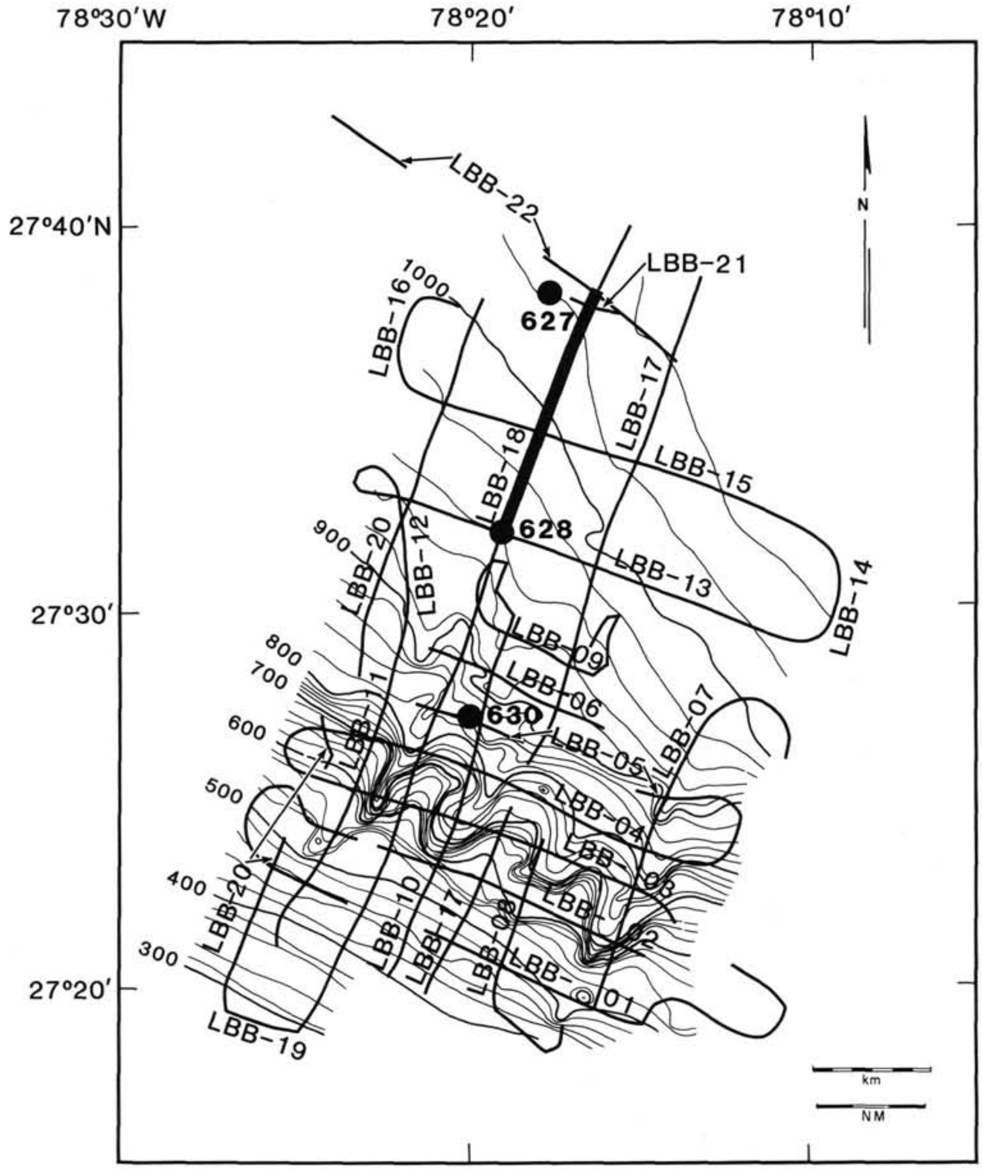

Figure 6. Geophysical-survey grid for Sites 627, 628, and 630 on the slope north of Little Bahama Bank superimposed on a bathymetric compilation (contour interval, 20 m) prepared from existing data and 3.5-kHz profiles collected by the *Moore* during the site survey (see also Fig. 1). All MCS profiles are 24-trace, 12-fold, collected primarily with a 400-in.^{3} water gun (see also Austin et al., this volume). Breaks in the lines represent data gaps created by either sound-source malfunctions or processing problems. Location of LBB-18 (Fig. 7) is shown by the bold line.

boundary (i.e., increase in lithification) at approximately 200 mbsf (Austin, Schlager, et al., 1986; Eberli, this volume; Lavoie, this volume).

At all Little Bahama Bank sites, understanding the diagenesis of periplatform sediments was also an important objective. Because of its high content of aragonite and high-magnesium calcite, periplatform ooze was expected to follow pathways of diagenesis different from those of low-magnesium calcite ooze. As expected, high-magnesium calcite decreased rapidly in the top 10 m (i.e., during the late Quaternary), and was present only in traces deeper in the section (Austin, Schlager, et al., 1986; Swart and Guzikowski, this volume). Aragonite declined more steadily, disappearing in the upper Miocene at approximately 150 mbsf (Austin, Schlager, et al., 1986). Lithification occurred intermittently at Sites 627, 628, and 630. Thin layers of chalk first appeared in the top 5 m, yet only 50% or less of the deepest periplatform sediments (200–250 mbsf, lower Miocene) were lithified to chalk (Austin, Schlager, et al., 1986; Dix and Mullins, this volume). A pronounced increase in calcium from the seafloor to 400 mbsf (Fig. 14) may have been caused by upward migration of brines from Cretaceous evaporites of the buried megaplatform (Swart and Guzikowski, this volume).

Transect of a High, Steep Slope: Exuma Sound (Sites 631, 632, and 633)

The second slope drilled during Leg 101 was steeper (10°–12°) and higher (1.6 km) than the one north of Little Bahama Bank (Table 1). In this setting, bypassing by turbidity currents was expected to be more complete, and sedimentation rates accordingly lower (Schlager and Ginsburg, 1981). In addition, Exuma Sound drilling was supposed to provide a direct comparison of a closed-basin vs. an open-ocean depositional setting.

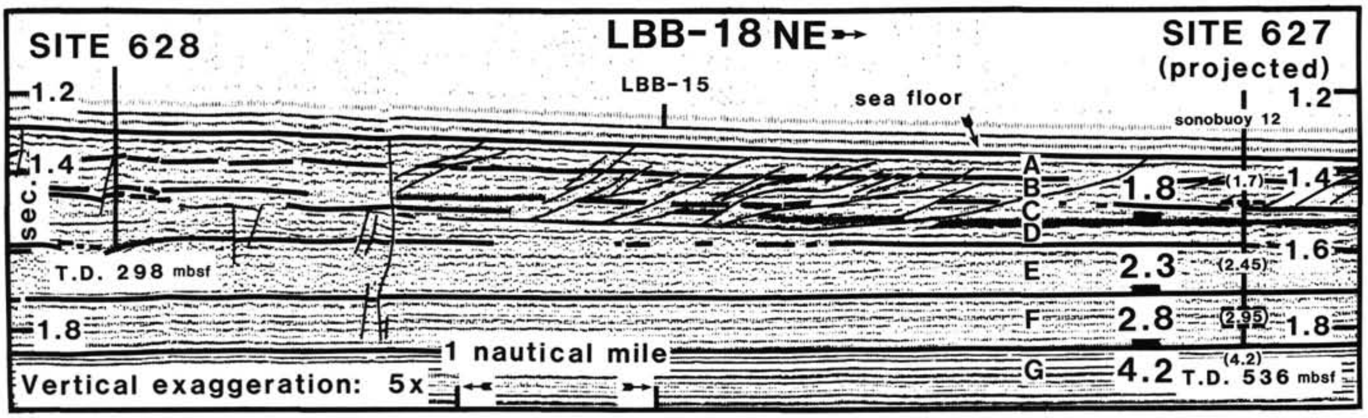

Figure 7. Part of site-survey profile LBB-18 between Sites 627 and 628. Site 627 was actually located approximately 1 nmi off this profile (see also Fig. 6 and Austin, Schlager, et al., 1986). Letters refer to individual seismic sequences (Austin, Schlager, et al., 1986). Large numbers approximately 0.5 nmi southwest of the projected position of Site 627 are interval velocities derived from LBB-18 semblance velocity analysis at that point. Smaller numbers in parentheses are an averaged set of interval velocities from sonobuoy 12, whose location coincides with the projected position of Site 627 on LBB-18 (see Austin et al., this volume). Note the general similarity of the two velocity models, but that the transition to 4.2 km/s material occurs at a shallower depth in the sonobuoy solution. Possible explanations of the discrepancy are discussed in Austin, Schlager, et al. (1986). Also note interpreted thrust faults between the two sites and a normal fault believed to be the Walkers Cay normal fault (Van Buren and Mullins, 1981) just northeast of Site 628. This fault may still be active, as it appears to offset the seafloor. (The actual position of the seafloor is indicated.) Earlier acoustic energy is a characteristic precursor of the water-gun sound source used to acquire this profile.

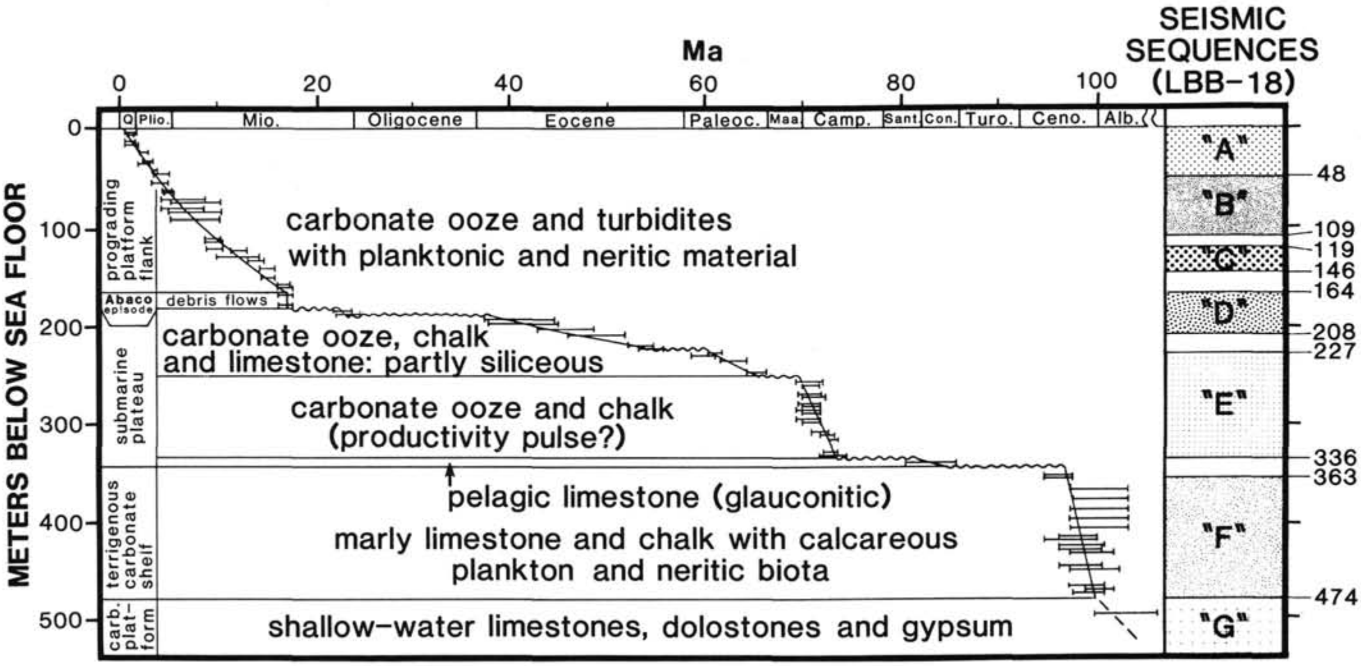

Figure 8. Geologic history of Site 627 (see also Austin, Schlager, et al., 1986). Accumulation-rate curve includes biostratigraphic age control (horizontal bars) and hiatuses (horizontal wavy lines). Seismic stratigraphy at the site is along the right-hand margin (refer also to Fig. 7), and the genetic interpretation of the sampled sediments on the left-hand margin. The F/G sequence boundary correlates in depth with the top of the upper Albian shallow-water carbonate platform.

Site 631, like Site 630, was located on the upper slope (Fig. 15). One HPC/XCB hole was drilled to a depth of 244 mbsf, recovering 65% of an Oligocene(?)-Miocene and younger section composed of periplatform ooze and chalk (Fig. 12; Austin, Schlager, et al., 1986). Accumulation rates of uppermost Miocene to mid-Pliocene oozes were on the order of 90 m/m.y., substantially exceeding the maximum rates observed at Site 630 (Watkins, et al., this volume). The upper 100 m contained greenish, organic-rich layers exuding a strong H_2S odor, suggesting active bacterial sulfate reduction in the presence of organic matter (Austin, Schlager, et al., 1986; Swart and Guzikowski, this volume).

Because of slope steepness and rough bottom topography in the vicinity of Site 631, a coherent seismic stratigraphic framework could not be developed. However, hummocky clinoforms adjacent to parallel continuous reflections suggest a levee/interfluve sequence, and a shingled seismic facies pattern on ES-07, the site-survey dip-line crossing the drill site (Fig. 15; see

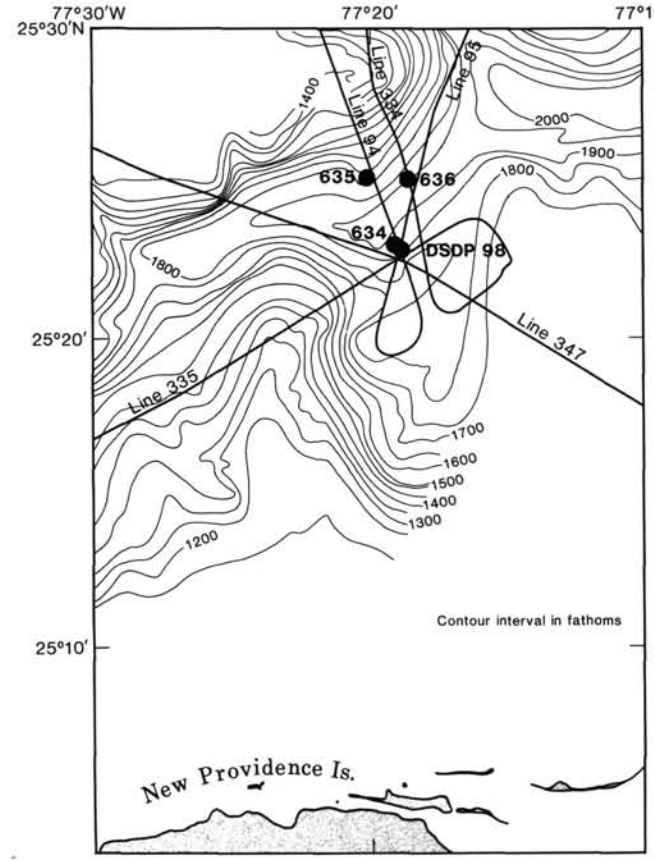

Figure 9. Relation of Leg 101 Sites 634, 635, and 636 in Northeast Providence Channel to DSDP Site 98 (see also Fig. 1). Regional multichannel seismic reflection coverage is from Sheridan et al. (1981). Bathymetry is from Andrews et al. (1970). The portion of line 94 connecting the ODP sites is shown in Figure 10.

Austin, Schlager, et al., 1986), suggests progradation of the slope. Nonetheless, no clear evidence of slumping and/or debris flows exists in Site 631 cores. Perhaps continuous downslope creep is responsible for the observed seismic pattern, which would also explain both the lack of hiatuses in Hole 631A and the observed gradients in physical properties (Austin, Schlager, et al., 1986; Watkins and Verbeek, this volume; Melillo, this volume; Watkins et al., this volume; Eberli, this volume).

Site 632 had two objectives. The first was to serve as the basinward end of the Exuma Sound slope transect in order to document the record of presumably rapidly deposited ooze and turbidites within an enclosed reentrant (Fig. 15). The second was to continue calibration of seismic stratigraphic frameworks previously developed for this part of the Bahamas (e.g., Sheridan et al., 1981; Austin, 1983; Schlager et al., 1984). Two holes were drilled at Site 632 (Austin, Schlager, et al., 1986). Both sampled an upper Miocene to Holocene sequence of periplatform ooze, chalk, and platform-derived turbidites representative of a basin-floor facies (Fig. 12), in contrast to the turbidite-free muds recovered on the bypass slope at Site 631.

Sedimentation rates in upper Miocene periplatform chalk and intercalated turbidites were higher than at Site 631 and fluctuated considerably (Austin, Schlager, et al., 1986). Rapid (120 m/m.y.) deposition and numerous turbidites were encountered in the upper Miocene, upper lower Pliocene, and the uppermost Pliocene–Quaternary, punctuated by either hiatuses or intervals with slow sedimentation rates and few turbidites in the lowermost Pliocene and upper Pliocene (Fig. 16; Watkins, this volume; Kuhn and Meischner, this volume; Reymer et al., this volume).

Site 632 provided important calibration for the seismic stratigraphy of Exuma Sound. Most significant was correlation of the top of a sequence of uppermost Miocene turbidites and periplatform limestones with horizon "O," a regionally identified sequence boundary (Fig. 17; Sheridan et al., 1981; Ladd and Sheridan, 1987) coeval with another calibrated at Site 626 in the Straits of Florida (Austin, Schlager, et al., 1986). Seismic sequences above and below this marker showed distinct channeling on orthogonal site-survey lines (ES-05 and ES-07, Fig. 15; Austin, Schlager, et al., 1986), suggesting that Neogene turbidites entered the northwest-southeast-trending axial valley of Exuma Sound from several directions.

Site 633 completed the Exuma Sound transect. Analogous to Site 628 north of Little Bahama Bank, its primary objective was to examine the toe-of-slope environment (Fig. 15). One HPC/XCB hole recovered 49% of an upper Miocene–Holocene sequence of periplatform ooze, chalk, and limestone with thin turbidites to a depth of 227 mbsf (Fig. 12). An accumulation rate of at least 58 m/m.y. characterized the uppermost Miocene–lower Pliocene section, with rates perhaps as high as 115 m/m.y. (Melillo, this volume; Watkins and Verbeek, this volune; Watkins et al., this volume). However, turbidites were unusually few, thin, and fine grained. The reason may be that Site 633 was located on a late Miocene(?) topographic high, which might have originated in response either to progradation of a spur of the slope or to slumping.

The slumping hypothesis gains support from the seismic stratigraphy at Site 633, which suggests at least four episodes of mass-wasting, as indicated by the superposition of hummocky clinoforms (Fig. 17). Additional supporting evidence comes from the aragonite content in Hole 633A, which is nearly constant in the interval 52–142 mbsf, unlike its steady decrease with depth at Site 632 (see Droxler et al., this volume). Anomalies in the downhole trends for porosity, density, and water content are also consistent with homogenization related to gravitational mass-wasting (Austin, Schlager, et al., 1986; Eberli et al., this volume). However, the lithologic and paleontologic uniformity of the section below 55 mbsf contrasts with high-resolution stratigraphy derived from the upper 55 m, where aragonite content, oxygen isotopes, nannoplankton assemblages, and paleomagnetic signatures document cyclic variations in export and preservation of platform-derived mud in the Pliocene-Pleistocene (Droxler et al., this volume; Reymer et al., this volume; Sager, this volume).

Geochemical results from Exuma Sound drilling reflect those from north of Little Bahama Bank in that high-magnesium calcite seems to disappear with depth faster than aragonite, and diagenetic alteration is particularly rapid in the upper 10 m of section (Swart and Guzikowski, this volume; Dix and Mullins, this volume). However, both sedimentation rates and contents of high-magnesium calcite are higher in sediments from Exuma Sound, and metastable minerals persist at greater depths in Sites 631, 632, and 633 (Austin, Schlager, et al., 1986). Resultant thick overgrowths on planktonic foraminifers make dating difficult at Site 631 (Melillo, this volume). Burial lithification is also faster in Exuma Sound. Together with the slow stabilization of metastable minerals, this leads to the unusual occurrence of well-cemented Miocene chalk containing 20% aragonite at depths of less than 300 mbsf (Austin, Schlager, et al., 1986). Pore waters at Sites 631, 632, and 633 do not exhibit downhole increases of calcium characteristic of slope sites north of Little Bahama Bank (Fig. 14), suggesting that buried Cretaceous evaporites that may be supplying excess calcium at Sites 627, 628, and 630 either do not exist or are buried more deeply beneath southeastern Exuma Sound (Swart and Guzikowski, this volume).

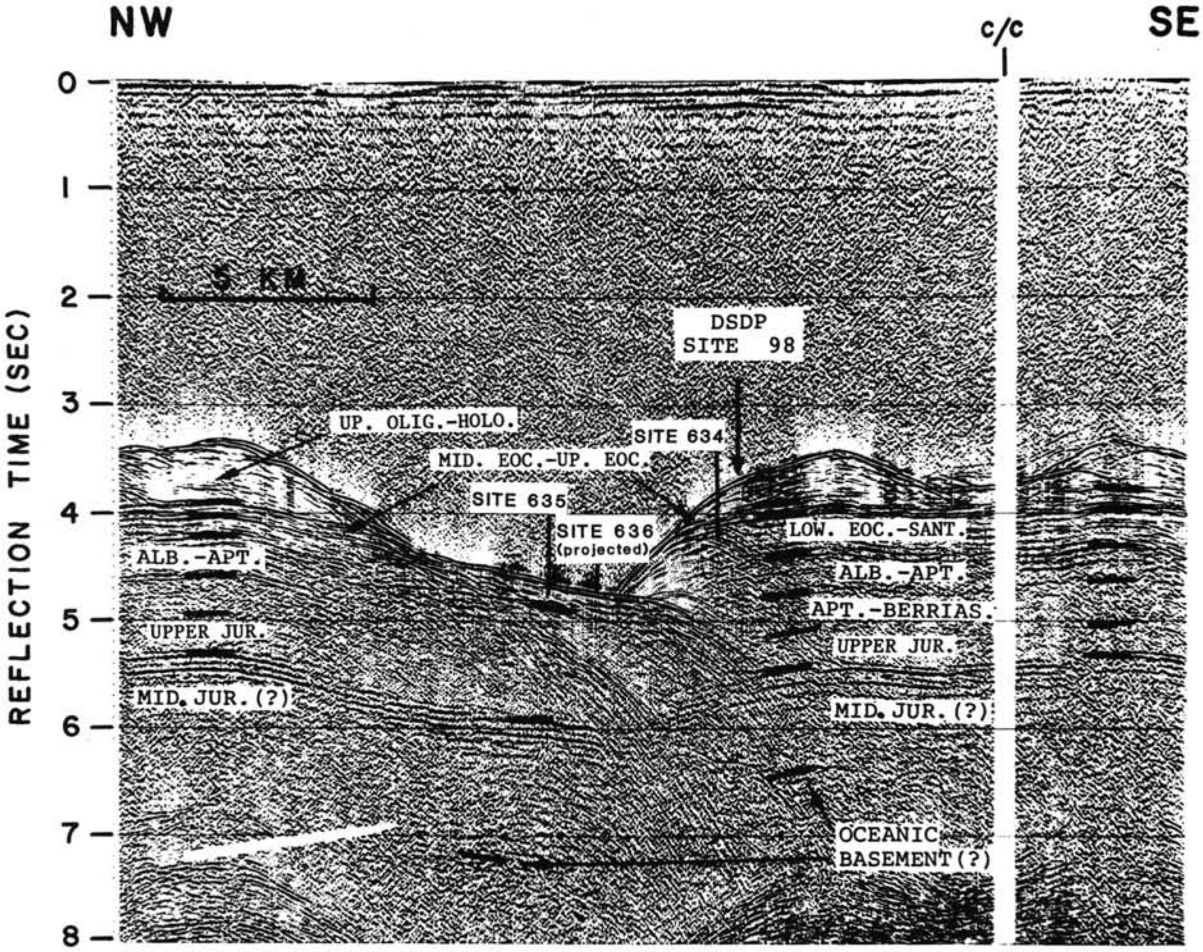

Figure 10. Part of multichannel seismic reflection line 94, with an interpretation taken from Sheridan et al. (1981). This is a 24-trace, 24-fold profile shot with large air guns, unlike the higher resolution water-gun profiles shot during the Leg 101 site surveys. Locations of Sites 634, 635, 636, and DSDP Site 98 are indicated. The spatial relationship of Site 636 to this profile is indicated on Figure 9. The "target" horizon, the inferred top of a mid-Cretaceous(?) shallow-water carbonate platform, is the high-amplitude acoustic surface separating interpreted Albian-Aptian and lower Eocene-Santonian sequences on this profile. Shallower sequence boundaries were recalibrated as a result of drilling at Site 634 (see also Austin, Schlager, et al., 1986). C/C = course change.

DISCUSSION

Platform Drowning

Site 627 proved unequivocally that a shallow-water carbonate platform complex occupied what is now the southern part of the Blake Plateau and was drowned in the late Albian. DSDP Sites 390 and 392 approximately 300 km northeast of Site 627 had already shown that a similar bank complex existed there, but only until Barremian time (Benson, Sheridan, et al., 1978). Therefore, diachronous, stepwise drowning of the Blake Plateau is implied.

This concept of stepwise drowning of a preexisting megaplatform receives further indirect support from Leg 101 results in Northeast Providence Channel. At Site 635, upper Albian limestone is bathyal, with some neritic influence only at the bottom of the hole. If the acoustic horizon and associated velocity contrast left unsampled just beneath these limestones is indeed the top of a shallow-water platform, then that platform drowned no later than the middle Albian. At Site 627, on the other hand, the oldest "post-drowning" sediments are uppermost Albian-lowermost Cenomanian, whereas the age of the underlying platform is late Albian (Austin, Schlager, et al., 1986; Watkins et al., this volume). This indicates a small but distinct age difference between the drowning events at Sites 627 and 635. Another possibility is that Site 635 is located in a deep reentrant of an Early Cretaceous shallow-water platform. Other such reentrants have been documented in the Bahamas (Schlager et al., 1984; Ball et al., 1985; Eberli and Ginsburg, 1987).

Another fact in favor of stepwise drowning (and perhaps post-drowning platform segmentation) is that platform tops drilled at Site 627 and inferred at Sites 626 and 635 now also differ in their elevation. In the central Straits of Florida, the inferred platform top is approximately 2 km below present sea level, with a mapped local relief of approximately 0.2 km (Fig. 5; Austin et al., this volume). North of Little Bahama Bank, the top of the platform is only 1.5 km below present sea level, with little apparent local relief (Figs. 1 and 7; Austin et al., this volume; Harwood and Towers, this volume). In Northeast Providence Channel, the inferred top is roughly 3.7 km below sea level, and its local relief is unknown (Austin, Schlager, et al., 1986). The difference of 0.5 km between Sites 626 and 627 translates to a southwesterly dip of an inferred platform top of 0.1°, whereas the difference of 2.2 km between Sites 627 and 635 means a dip of 0.4° to the south-southeast. These dips are higher than could be expected for a depositional surface of a reef-rimmed platform, but they fit regional patterns of differential subsidence of the North American passive margin (Watts and Steckler, 1981; Klitgord et al., 1984). The southerly component of this tilt could

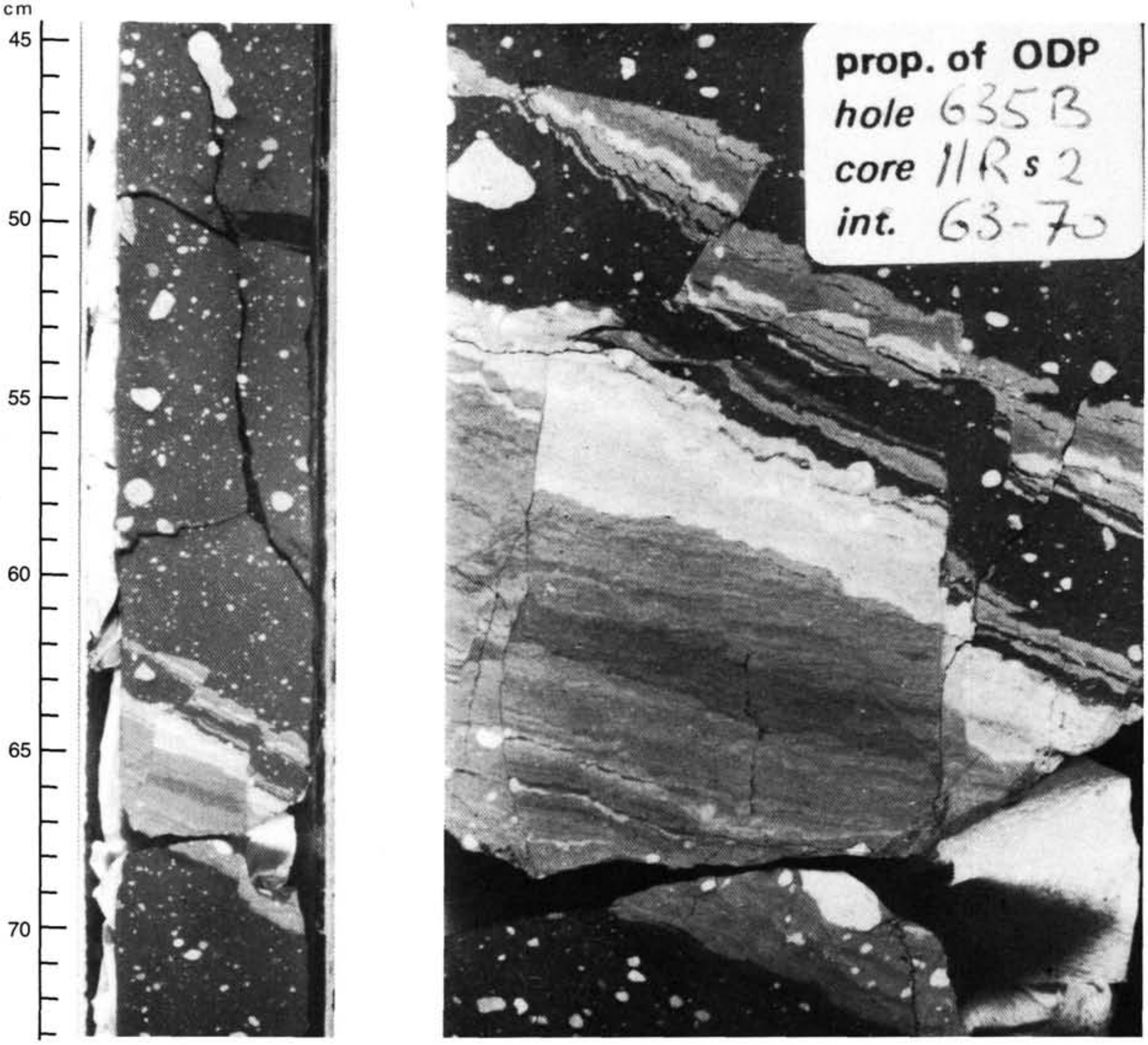

Figure 11. A. Section 2 of Core 101-635B-11R showing a sequence of white chalk clasts in a darker, micritic matrix. The micritic material is disrupted by an interval of faulted slump folds. This section is interpreted as a debris flow/slump that occurred in a dewatering carbonate slope environment during the late Albian (Austin, Schlager, et al., 1986). B. Close-up of part of the same section, showing faulted slump folds with what appear to be primary depositional dips.

also have been caused by the collision of the Bahamas carbonate province with the Greater Antilles island arc in the Late Cretaceous–Paleogene (Malfait and Dinkelman, 1972). This convergence is thought to be responsible for southerly dips of deep reflections observed north of Cuba (Angstadt et al., 1985) and Hispaniola (Goreau, 1981; Austin, 1983; Austin et al., this volume). Similarity of subsidence curves calculated from the Great Isaac 1 well and Site 626 also supports a continuous, albeit tilted, carbonate platform surface (Williams et al., this volume).

Nonetheless, faulting and other tectonic deformation definitely contribute to the bank-basin topographic pattern. For example, faults are visible on seismic profiles collected over Great Bahama Bank (Eberli and Ginsburg, 1987). Another example is the Walkers Cay normal fault originally identified by Van Buren and Mullins (1981) north of Little Bahama Bank, which is visible on site-survey profile LBB-18 (Fig. 7). Although such normal faulting does not appear to cut the platform top (F/G sequence boundary), it could be responsible for upward migration of hydrocarbons encountered at Sites 627 and 632 in Exuma Sound. Vertical relief between mid-Cretaceous platform tops known at Site 627 and inferred at Site 635 could also be related to northwest-southeast-trending Atlantic fracture zones, extensions of which have been mapped across the northwestern Bahamas using both aeromagnetics and basement depth estimates beneath the Florida Peninsula derived from available well control (Sheridan et al., 1981; Klitgord et al., 1984). These fracture zones are thought to control placement and development of both Northeast and Northwest Providence channels and Great Abaco Canyon east of the Blake Plateau (Sheridan et al., 1969; Sheridan et al., 1981; Mullins et al., 1982). Fracture zones may also be responsible for the faulting that appears to have produced Abaco Knoll, just northeast of Sites 634, 635, and 636 (Corso et al., 1985). Collision of the Bahamas and the Greater Antilles in the Late Cretaceous–Paleogene produced faults in the southeastern Gulf of Mexico and in the southern Straits of Florida (Angstadt et al., 1985), and it may also have contributed to tectonic deformation in other parts of the Bahamas (Austin, 1983; Mullins and Sheridan, 1983).

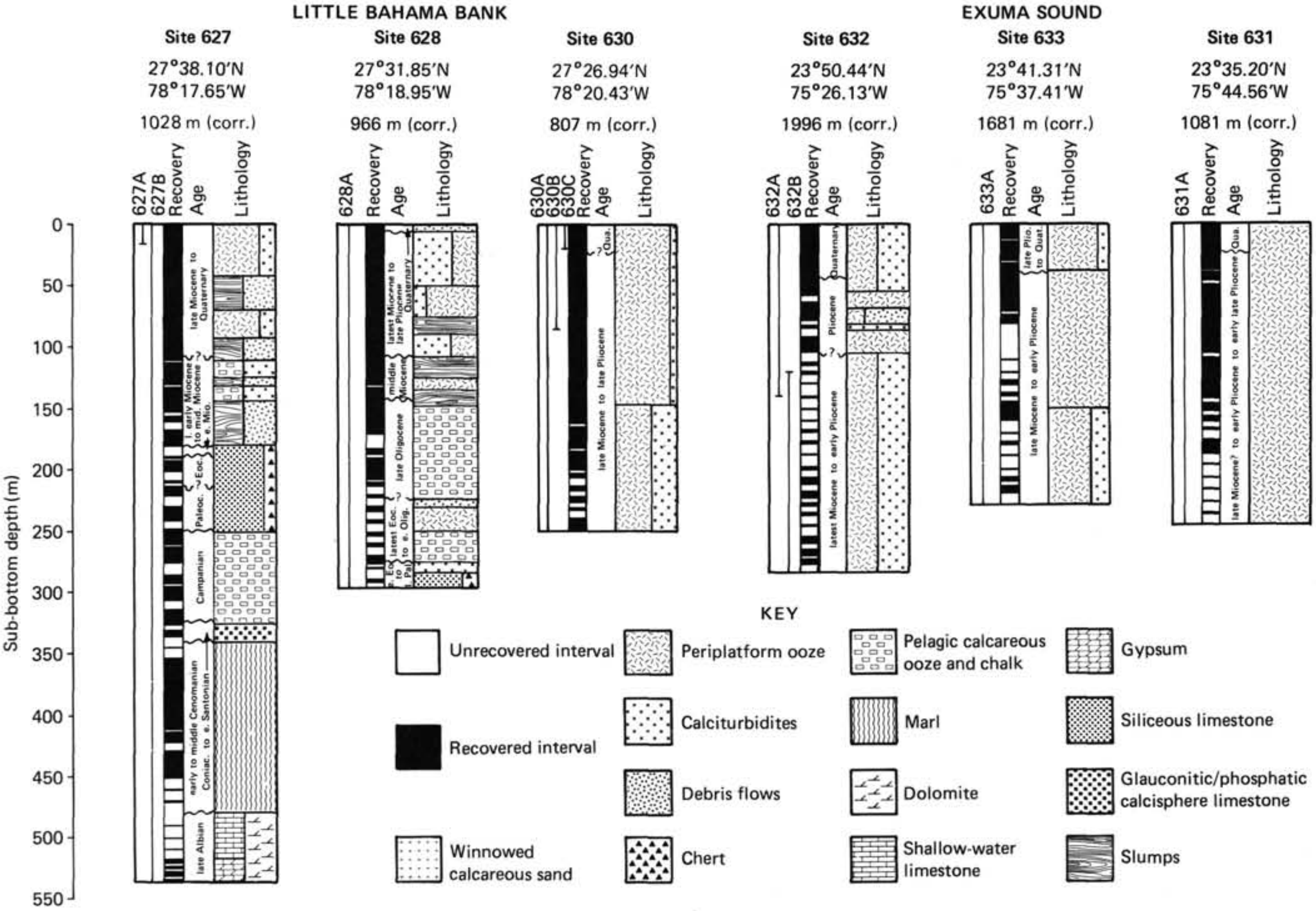

Figure 12. Summary of lithologies recovered during the two carbonate-slope transects north of Little Bahama Bank (Sites 627, 628, and 630) and in the southeastern part of Exuma Sound (Sites 631, 632, and 633).

Slope Evolution

Highstand Shedding

Advanced drilling technology designed specifically to recover soft and semilithified sediments allowed recovery of nearly complete sections documenting the Neogene evolution of two different types of carbonate slopes (Table 1). Results support the concept of "highstand shedding" (Droxler and Schlager, 1985) whereby maximum carbonate-bank productivity and consequent off-bank transport of carbonate debris occur during highstands of sea level (Fig. 16). Highstand shedding from platforms is out of phase with siliciclastic systems that deliver most sediment to the deep sea during lowstands of sea level (e.g., Vail et al., 1977; Poag, 1985; Haq et al., 1987). Specific examples of highstand shedding encountered during Leg 101 include (1) slow, turbidite-free sedimentation at Site 632 during the Messinian lowstand (TM3.2/TM3.3 boundary, Haq et al., 1987; see Figs. 13 and 16); (2) a tendency in all slope sites toward slow or interrupted sedimentation in the late Pliocene, coincident with the lowstand accompanying development of Arctic glaciation (Figs. 13 and 16; Melillo, this volume; Watkins and Verbeek, this volume); and (3) slow, low-turbidite sedimentation during late Pleistocene glacial periods (Droxler et al., this volume; Reymer et al., this volume). This response of carbonate banks to sea-level fluctuations has also been generally predicted by piston-coring investigations in the Bahamas (Kier and Pilkey, 1971; Mullins, 1983; Droxler et al., 1983; Boardman and Neumann, 1984; Droxler, 1984; Boardman et al., 1986). Highstand shedding is also indicated by correlation of sedimentation rates in Exuma Sound and available stratigraphy of the Bahama Banks themselves (Beach, 1982; Williams, 1985; Fig. 16), although dating of karst horizons (i.e., bank-exposure surfaces) on the platforms is less precise than Leg 101 biostratigraphic determinations from the slopes.

Slope transects of Leg 101 also show that "eustatic" signals from periodic flooding and exposure of the banks are overprinted by other, more local processes (Melillo, this volume). For example, Miocene debris flows encountered in the Straits of Florida, north of Little Bahama Bank, and in the abyssal Blake-Bahama Basin suggest a regional rather than a global triggering mechanism, the so-called Abaco event. In addition, numerous but not completely correlatable hiatuses in well-sampled Tertiary sections at Sites 627 and 628 only 6 nmi apart (Fig. 13) suggest depositional complexity introduced by meandering Gulf Stream/Antilles currents.

Sediment Record

Leg 101 represents an attempt to close a gap between studies on recent carbonate slopes and those on their ancient counterparts. Windward-leeward orientations, setting in open ocean vs. restricted embayment, and other factors such as slope angle and height were already understood to influence recent sedimentation on Bahamian slopes (Mullins and Neumann, 1979; Schlager and Ginsburg, 1981; and others). However, whereas outcrop/piston-coring studies normally concentrated on slope cross sections (i.e., the surficial change through time), Leg 101 drill-

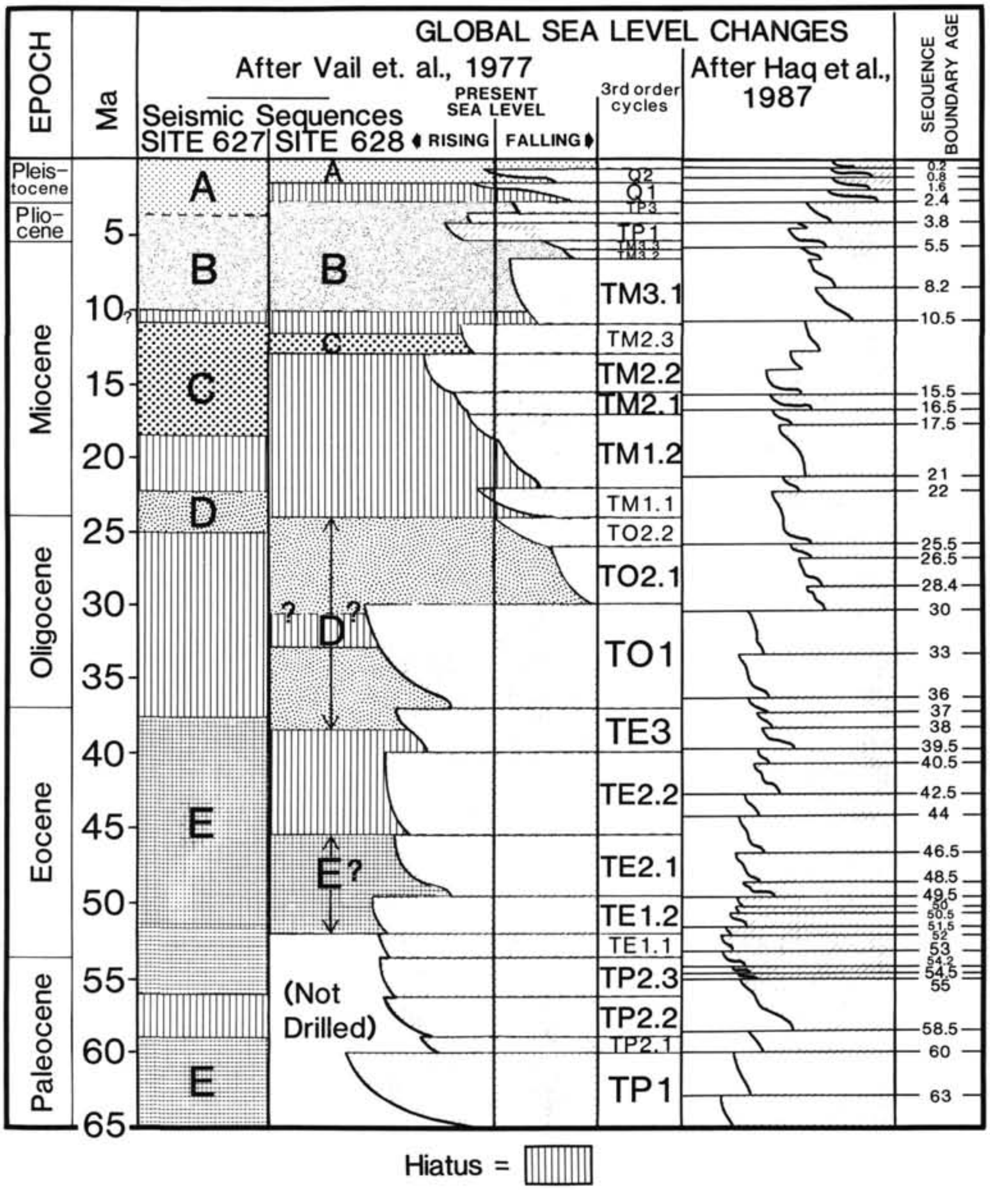

Figure 13. Comparison of geologic results and seismic stratigraphy at Sites 627 and 628 (only 6 nmi apart, see Fig. 7) north of Little Bahama Bank relative to the Vail et al. (1977) and Haq et al. (1987) global sea-level curves. Patterns highlighting the seismic sequences are the same as those in Figure 8. The successions at the two sites differ markedly, particularly in the Oligocene, suggesting that local topography and/or tectonism, perhaps in conjunction with regional sediment starvation, play important roles in modulating response of this carbonate slope to postulated eustatic sea-level fluctuations (see also Austin, Schlager, et al., 1986).

ing allowed construction of complete Neogene geologic histories of slope development.

Results from Leg 101 suggest some modifications of previous ideas concerning carbonate platform flank development. Both in Exuma Sound and north of Little Bahama Bank, the slope proper is a zone of mud accumulation. Coarser debris bypasses the slope in turbidity currents and is deposited as graded beds on the debris apron and basin floor. As expected, the steeper southeastern slope of Exuma Sound is more efficient than the gentle northern slope of Little Bahama Bank in funneling sediment into deep water. Therefore, basin sedimentation is faster and the content of bank-derived material in turbidites is higher in Exuma Sound (Fig. 18; Kuhn and Meischner, this volume). However, there is a significant difference between the two slopes in sediment partitioning. In Exuma Sound, sedimentation rates are higher in the basin than on the slope (Fig. 18). In contrast, north of Little Bahama Bank sedimentation rates are highest on the slope and decrease toward the Blake Plateau (Fig. 18). Increasing slope angle appears to shift the depocenter from slope to basin, as suggested by Schlager and Camber (1986). However, sedimentation rates in Exuma Sound are much higher than expected, and there are no signs of intermittent erosion and sediment starvation that would herald the transition from "accretionary" to "erosional" slope regimes. All slopes up to 12° explored during Leg 101 are still accreting rapidly.

Geochemistry

Results from Leg 101 confirm that high-magnesium calcite is less stable in Bahamian slope environments than aragonite (Swart and Guzikowski, this volume). Dolomite forms at an early stage, perhaps at the expense of high-magnesium calcite (Dix and Mullins, this volume). Primary dolomite formation may create over-

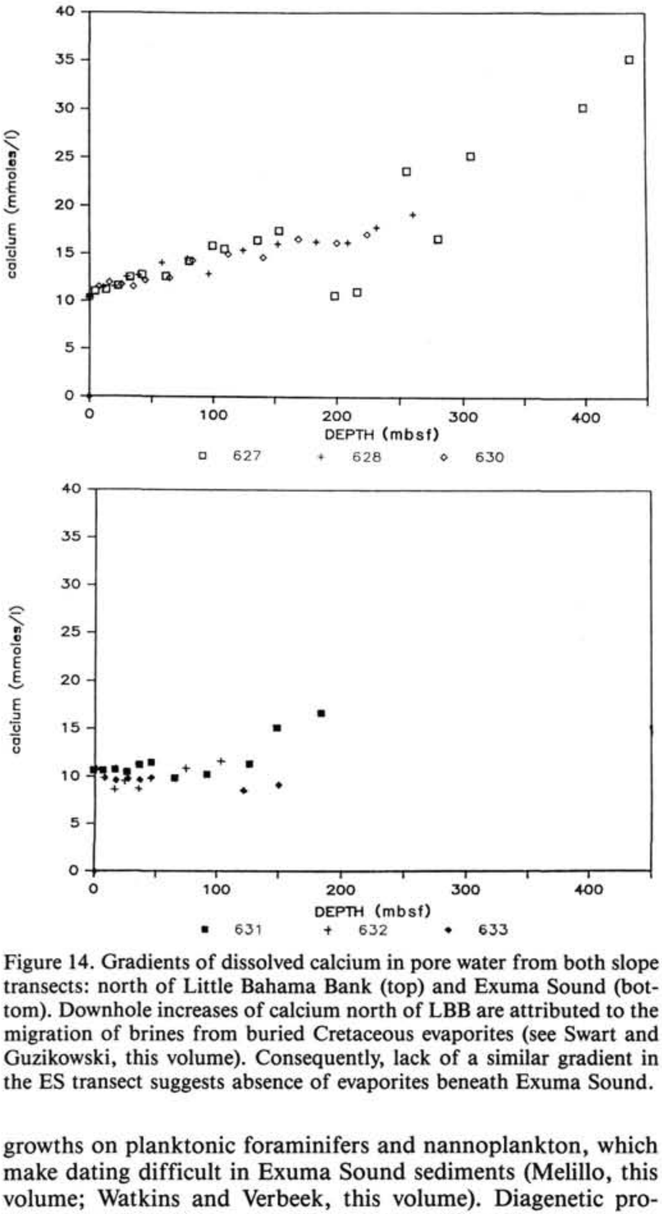

Figure 14. Gradients of dissolved calcium in pore water from both slope transects: north of Little Bahama Bank (top) and Exuma Sound (bottom). Downhole increases of calcium north of LBB are attributed to the migration of brines from buried Cretaceous evaporites (see Swart and Guzikowski, this volume). Consequently, lack of a similar gradient in the ES transect suggests absence of evaporites beneath Exuma Sound.

growths on planktonic foraminifers and nannoplankton, which make dating difficult in Exuma Sound sediments (Melillo, this volume; Watkins and Verbeek, this volume). Diagenetic processes appear to be most rapid near the seafloor (Austin, Schlager, et al., 1986; Dix and Mullins, this volume). However, it is unclear whether changes in diagenetic patterns at approximately 10 mbsf are geochemically significant or an artifact of hiatuses occurring at this depth (Watkins and Verbeek, this volume). Furthermore, debate continues concerning the speed at which periplatform ooze alters diagenetically, particularly in comparison to typical pelagic carbonate ooze (Swart and Guzikowski, this volume; Dix and Mullins, this volume).

Abaco Event

Throughout the entire Leg 101 drilling area, the early and middle Miocene were times of intensive sediment gravity transport. At Site 626, this was the only time in the last 28 m.y. when the Gulf Stream was unable to winnow fine-grained sediment to produce sandy contourites (Austin, Schlager, et al., 1986; Fulthorpe and Melillo, this volume). At Sites 627 and 628, this interval is again unique, because its unusually coarse turbidites and debris flows do not fit the overall upward-coarsening trend characteristic of the Neogene section north of Little Bahama Bank. These Miocene debris flows also contain a large amount of reworked neritic material (Fourcade and Butterlin, this volume; Palmer, this volume). Furthermore, Harwood and Towers (this volume) demonstrate that the large slumps on the Little Bahama Bank slope are of middle Miocene age. All these sediments are coeval with intraclastic chalks of the Abaco Member of the Blake Ridge Formation just to the north in the Blake-Bahama Basin (Benson, Sheridan, et al., 1978; Bliefnick et al., 1983). They may also have been deposited at the same time as the collapse of part of the West Florida Escarpment (Mullins et al., 1986). However, elsewhere, for example in the South Atlantic (Barker, Carlson, et al., 1983; Hsü, LaBrecque, et al., 1984), this pulse of gravitational mass-wasting appears to be lacking. Taken together, these observations suggest a widespread but regional triggering mechanism, perhaps earthquakes induced by continuing convergence between the Bahamas and the northern Caribbean (Fulthorpe and Melillo, this volume).

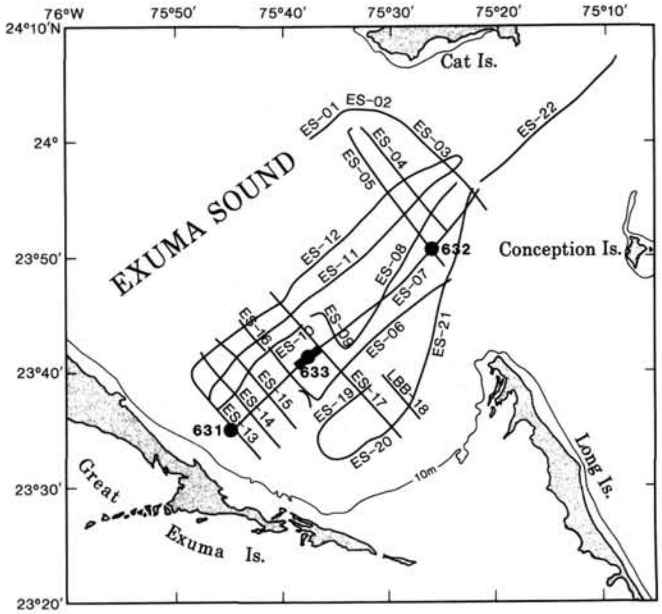

Figure 15. Site-survey grid in southeastern Exuma Sound. Navigation was accomplished by integrating LORAN C, Transit satellite, and radar bearings off nearby islands. Locations of Sites 631, 632, and 633 are shown (see Austin, Schlager, et al., 1986). The portion of ES-07 shown in Figure 17 is indicated by the bold line. All profiles are 24-trace, 12-fold, collected with a 400-in.^{3} water gun (see also Austin et al., this volume).

SUMMARY AND CONCLUSIONS

Leg 101 had both deep and shallow drilling objectives. In an attempt to understand the reasons for the bank-and-basin morphology of the Bahamas, the "deep" objective, Leg 101 proved that a prominent acoustic unconformity identified beneath the southern Blake Plateau correlates with the top of a drowned, shallow-water carbonate platform complex of mid-Cretaceous age. Jump correlation of these results to both the Great Isaac 1 well and Site 626 suggests that such a platform underlies all of the northwestern Bahamas. Platform drowning occurred in steps during the mid-Cretaceous. During the Late Cretaceous and Tertiary, north- and west-facing platform flanks prograded tens of kilometers. However, faulting and/or regional tilting remain possible mechanisms controlling the long-term platform-basin pattern.

In terms of carbonate-slope evolution, the "shallow" objective, Leg 101 drilling provided support for the concept of highstand shedding, a depositional response to sea-level fluctuations

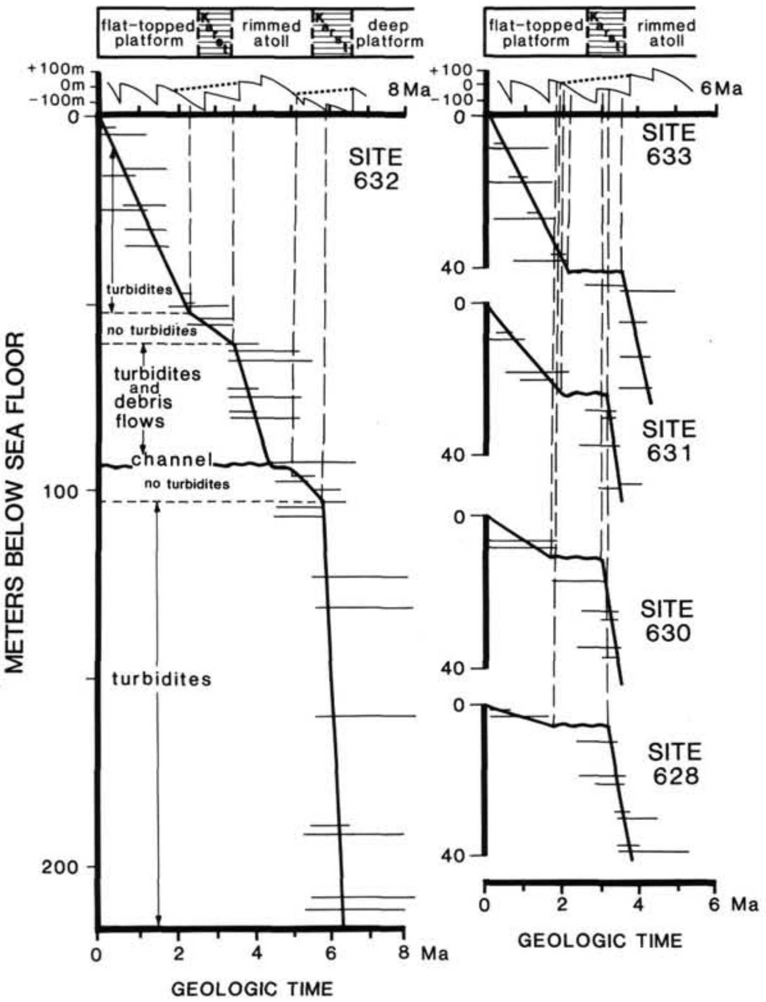

Figure 16. Comparison of accumulation-rate curves for all slope sites north of Little Bahama Bank and in southeastern Exuma Sound with calibrated stratigraphic successions on the banks themselves (after Williams, 1985) and Vail et al.'s (1977) global sea-level curve. Biostratigraphic control is indicated by short, horizontal-line segments (see also Austin, Schlager, et al., 1986). Depositional hiatuses (horizontal wavy lines)/low sedimentation rates (near-horizontal parts of the accumulation-rate curves) on the slopes appear to correspond to both lowstands and times of bank exposure (and associated development of karst surfaces). In contrast, higher depositional rates (near-vertical parts of the accumulation-rate curves) on the slopes correlate with global highstands and periods of bank inundation. These results are interpreted as support for the concept of "highstand shedding" in carbonate depositional systems, a response which is nearly the opposite of that observed in siliciclastic regimes (see text). Dashed line connecting parts of the Vail et al. (1977) sea-level curve corresponds to the estimated subsidence rate for the Bahamas at present, 11-12 m/m.y., which can also be used to estimate the approximate duration of bank exposure assuming the amplitudes of sea-level excursions proposed.

opposite to that of siliciclastic systems. Bahamian slopes were generally covered by muddy sediments, whereas graded sand and rubble characterized turbidite aprons at toes-of-slope and on basin floors. Slope bypassing by turbidity currents and slumps was more efficient on steeper slopes, but all slopes drilled during Leg 101 are accreting rapidly. Therefore, the transition to truly erosional depositional environments on carbonate platform flanks must occur at declivities over 12°.

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This is University of Texas Institute for Geophysics Contribution 728.

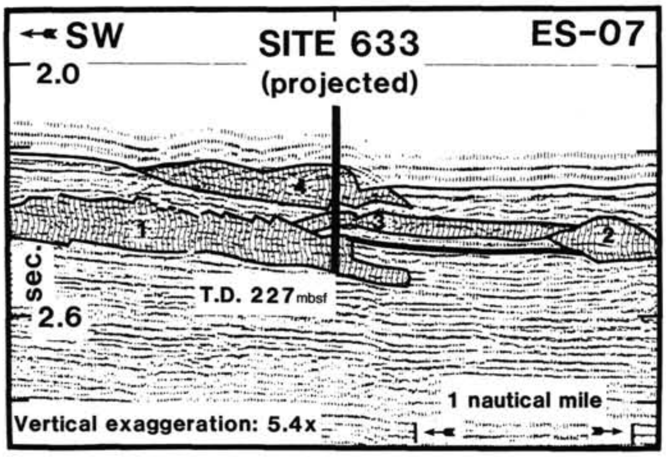

Figure 17. Portion of site-survey profile ES-07 that crosses Site 633, just basinward of the toe-of-slope in Exuma Sound (see Fig. 15 for location). Site 633 was located at the tie between ES-07 and line 361, an MCS profile oriented parallel to the long axis of Exuma Sound collected using large air-gun sources (Ladd and Sheridan, 1987; see also Figs. 1 and 17 and Austin et al., this volume). Note the four discrete slump/slide masses (each highlighted by a different number), which may be building the slope basinward. A regional seismic stratigraphic marker (heavy solid line) identified by Ladd and Sheridan (1987) as horizon "O" marks the top of a sequence of uppermost Miocene turbidites and periplatform limestones at Site 632 (see also Austin, Schlager, et al., 1986; Austin et al., this volume).

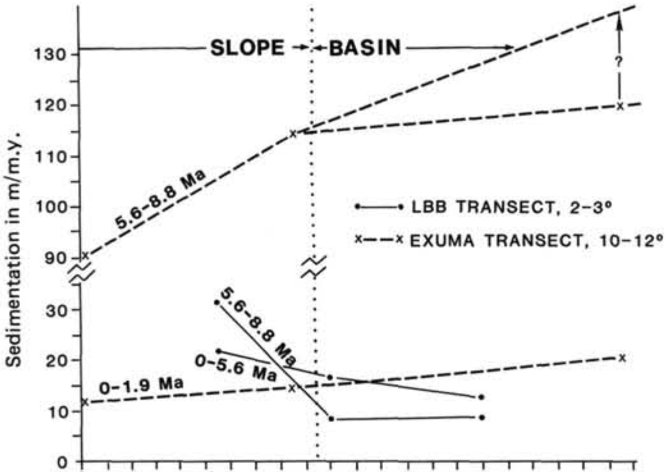

Figure 18. Accumulation rates of various Neogene time intervals of the Little Bahama Bank and Exuma Sound slope transects. Note that on the gentle (i.e., LBB) slope, sedimentation rates are highest on the slope and decrease basinward. On the steep Exuma slope, rates in the basin are higher than on the slope, which is interpreted as evidence for more efficient basinward transport by turbidity currents.

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