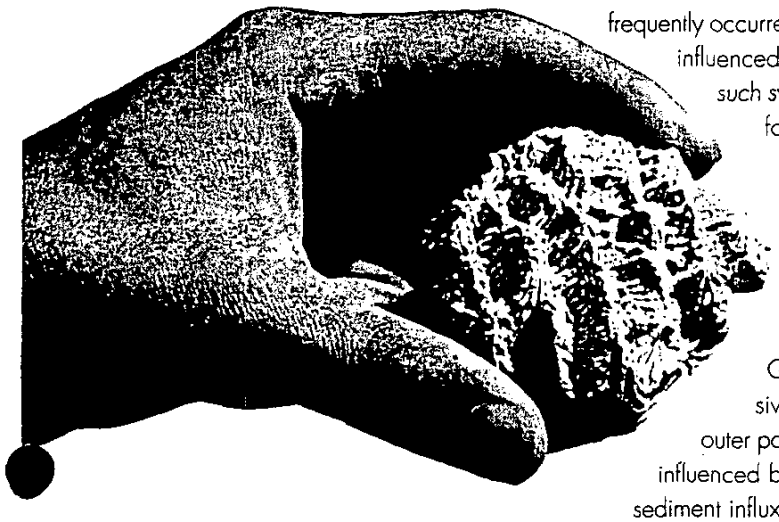
Leg 133

ODP Leg 133
Northeast Australian
Margin:

A CHRONICLE OF CARBONATE PLATFORM DEVELOPMENT

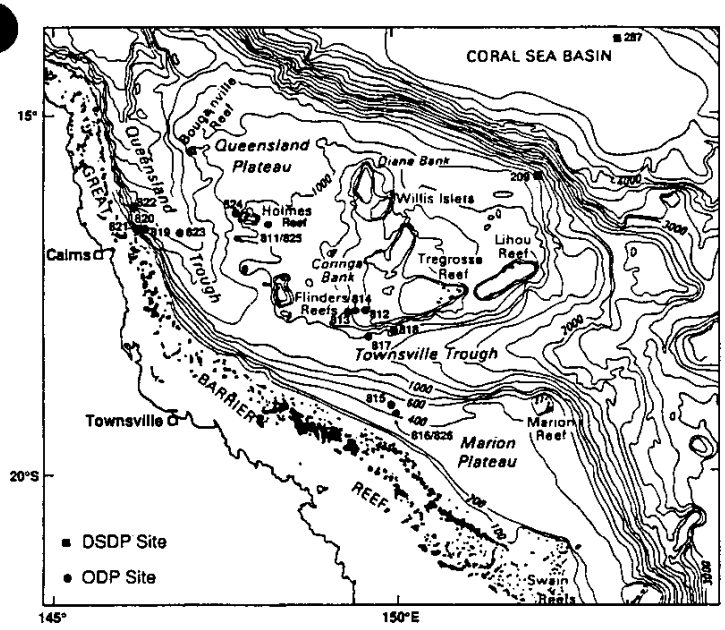
Dolomitized middle Miocene coral mold of faviid Platygyra was recovered at ODP Leg 133, Site 812, from 246 meters below the sea floor. The crushing action at the bottom of a rotary drill hole into hard dolostone makes recovery of this delicate specimen all the more special, a treasure from the deep sea.

John Tennison, Ocean Drilling Program, College Station, Texas



Throughout this century, carbonate-platform evolution has puzzled geologists in both academia and industry. Since the 1950s, modern shallow-water environments in subtropical to tropical regions that are actively producing carbonate sediments, the building material for carbonate platforms, have been choice research areas for carbonate sedimentologists. These carbonate factories serve as modern analogs for ancient carbonate environments, but knowledge of the processes controlling evolution of carbonate platforms, from their initiation through growth and demise, remains rudimentary. Understanding these processes is crucial for our interpretation of the rock record in ancient carbonate platforms.

Our knowledge of modern carbonate platforms is derived mostly from studies of the Bahama banks, an isolated platform, and the Persian Gulf, a foreland basin. However, in ancient examples, carbonate platforms have most frequently occurred directly adjoining passive continental margins and are thus influenced by periods of terrigenous influx. An ideal modern analog for such systems is found on the northeast Australian margin, best known for the Great Barrier Reef but also including two other major marginal platforms, which collectively make up the world's largest carbonate-platform system. The Great Barrier Reef is actually a very young carbonate complex encased and surrounded by terrigenous sediments. The Queensland Plateau is a large isolated carbonate platform that has been separated from continental influence since the Miocene by the Queensland Trough, whereas the Marion Plateau is an extensive extinct Neogene carbonate platform that developed on the outer part of the continental shelf. The evolution of these platforms was influenced by the interaction of a variety of factors, including terrigenous sediment influx, sea-level fluctuation, tectonic subsidence, and climatic and paleoceanographic changes in time and space.



Scientists taking part in ODP Leg 133 drilled at 16 sites along the northeast Australian margin.

To determine the importance of these different factors in a variety of settings, a comprehensive drilling proposal was submitted to the Ocean Drilling Program by the Australian Bureau of Mineral Resources. Sixteen sites along two transects were selected to be drilled on ODP Leg 133 to compare and contrast the evolution of the different carbonate systems. The first transect extends eastward from the outer shelf and slope of the Great Barrier Reef (sites 819-822) into the Queensland Trough (site 823) and onto the Queensland Plateau (sites 811/825 and 824). The second transect extends northward from the edge of the Marion Plateau (sites 815, 816, and 826) across the Townsville Trough to the Queensland Plateau slope (sites 817 and 818) and onto the margin of the Queensland Plateau (sites 812-814). The general sedimentary geometry is well defined in an extensive network of high-resolution seismic profiles that were acquired in preparation for Leg 133. Several seismic sequences were evident on the pre-site seismic surveys, but the ages, depositional environments, and lithologies were unknown. Our aim was to integrate results obtained from core material recovered on Leg 133 with the seismic data. These results include determination of sedimentary facies, biostratigraphy, paleomagnetism, geochemistry, and physical properties, in addition to an extensive downhole-logging program.

This scientific endeavor brought together a whole range of specialists and was ideally suited for the Ocean Drilling Program. ODP is funded by the United States National Science Foundation, Canada/Australia Consortium, the European Science Foundation Consortium, France, Japan, West Germany and the United Kingdom. About half the scientists on each cruise are from the United States, and half are from the other partner nations.

Leg 133 departed Guam on Aug. 9, 1990, for the Coral Sea. The scientists on board JOIDES Resolution included experts on various aspects of carbonate environments and diagenesis, together with a team of seismic, magneto-, chemo- and biostratigraphers and logging specialists. Many of us had no prior experience with deep-ocean drilling, having concentrated our research efforts on outcrops or in shallow-water environments. The wide range of expertise proved invaluable for completing the

The DIANAUT Program Revisits ODP Sites in the Atlantic

The DIANAUT program was designed to investigate mechanisms of heat transfer and associated hydrogeological processes in the oceanic crust as a function of age and distance from the ridge axis. This was to be accomplished by measuring *in situ* the various parameters that relate directly to local hydrologic characteristics. Geophysical logging activities were selected to measure the temperature profile and geothermal gradient, to analyze the chemical composition of borehole fluids, to quantify fluid circulation, to identify wellbore fractures, and to characterize the nature of basement alteration.

The unique scientific program DIANAUT stems from the concept of obtaining a series of complementary geophysical logs in conjunction with the wireline re-entry capability provided by the French logging shuttle, NADIA, and introduced during Feasibility trials (FARE campaign) in 1988. One main advantage of re-entry by this system is the elimination of problems associated with ship heave. Access to a completely stable logging platform permits precise control of depth and logging speed, and enables the deployment of sensitive instruments such as the thermal flow-meter and the temperature probe.

The French research ship NADIR left the Azores Nov. 5, 1990. Three Deep Sea Drilling Project sites in the north Atlantic were selected for this study, ranging in age from 3.5 million to 154 million years. The first of these was DSDP/ODP hole 333A, which was drilled near the Mid-Atlantic Ridge just north of the Oceanographer Fracture Zone. The age of basement is late Pliocene/early Pleistocene. The hole was cased to 61 meters below sea floor (mbsf) into stiff nannofossil ooze, reached basement at 219 mbsf and bottomed out at 529 mbsf, leaving behind part of the lowermost bumper sub. The hole was drilled in 1974, and if still open, would permit the first re-entry logging in this well. This is important not only because core recovery was poor during drill-

monumental tasks during eight full weeks of drilling at 16 sites, with little travel time between sites. In addition to setting new records for total penetration (more than 10,000 meters) and core recovery (more than 5,500 meters), we set records for downhole measurements with the most holes (12) and meters (5,125 meters) logged and the most core samples squeezed for interstitial waters (545) during a single drilling leg. This concentrated program was accomplished with wholehearted effort of the entire technical and drilling staff aboard Resolution.

Although our shipboard results remain preliminary at this stage, Leg 133 drilling has already produced valuable and sometimes surprising new information about the evolution of carbonate-platform environments. Unlike siliciclastic systems, the carbonate system is self generating — that is, the producers of carbonate sediments are living organisms. Environmental changes, such as water temperature, nutrient flux, or depth of light penetration, determine the composition of the bioassemblage and their rates of productivity and thus influence platform development. Combining litho-, chemo-, magneto- and biostratigraphic analyses to estimate the timing of events, we interpret a Cenozoic record of environmental change that can be used tentatively to differentiate between influences of sea-level fluctuation, tectonic subsidence, terrigenous flux, paleoclimate, and paleoceanography in the evolution of the northeast Australian margin.

"Although our shipboard results remain preliminary at this stage, Leg 133 drilling has already produced valuable and sometimes surprising new information about the evolution of carbonate-platform environments."

The reconstruction begins with the initiation of carbonate sedimentation on the Queensland Plateau in the early middle Eocene, when the seas transgressed across the metasedimentary continental basement. Temperate faunas inhabited the local seas during the latest Oligocene, but by the latest early Miocene, tropical faunas dominated on the Queensland and Marion plateaus. The transition from temperate to tropical waters reflects the northward movement of the Australian plate combined with the initiation of the southward flow of tropical waters from the equatorial Pacific. During the early middle Miocene, the tropical waters supported robust reef growth that gradually declined during the late middle Miocene, possibly in conjunction with paleoenvironmental changes induced by the steady drop in eustatic sea level during this period.

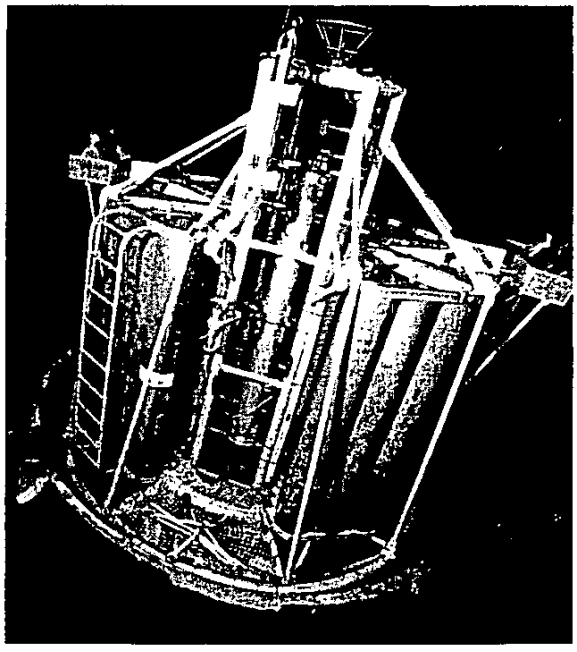
Carbonate production on the shallow-water banks diminished dramatically in the late Miocene in response to global climatic deterioration, accelerated by a seasonal influx of colder waters into the tropical environment, and continued eustatic sea-level falls. The banks apparently were unable to respond to climatic amelioration in the earliest Pliocene. A pulse of more rapid subsidence on the Queensland Plateau, in combination with rising eustatic sea level, may have essentially drowned the banks. Conditions stabilized in the late early Pliocene when the carbonate banks were rejuvenated, remaining more or less productive until the present. However, the renewed bank production was on a much reduced scale compared with the flourishing reefs and banks of the early to middle Miocene and has barely been able to keep up with continued subsidence. But, the reefs on the Marion Plateau have never recovered from suffocation by increased terriginous influx. Initiation of reef growth on the Great Barrier Reef is even younger, beginning at about one million years ago.

Diagenesis has been a major topic of re-

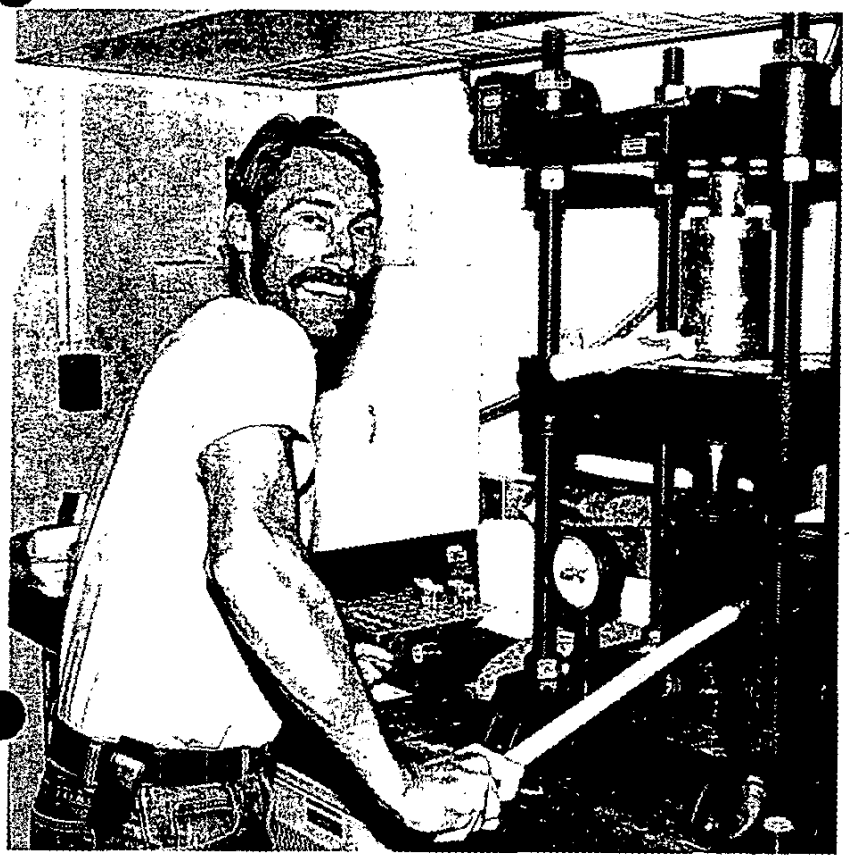
ing, but also because it would extend retroactively the number of DSDP/ODP holes logged.

The second site selected for DIANAUT was DSDP/ODP hole 395A, which has undergone several re-entry operations by JOIDES during Leg 78B and Leg 109. The hole was cased to a depth of 111 mbsf, sediment thickness extended for 88 meters, and total depth was 664 mbsf. The hole remains accessible for logging to a depth of about 600 mbsf. Results of previous downhole measurements done during Legs 78B and 109 (for example, temperature profile and fluid sampling) indicate a downward flow of water that penetrates basement to a depth of about 320 mbsf.

The final DIANAUT site was DSDP/ODP hole 534A located in the Blake Bahama Basin. This hole was cased to a depth of 531 mbsf and reached oceanic crust of middle Callovian age at a depth of 1,665 mbsf. The hole was logged to some extent during Leg 76 and has recently been re-entered from

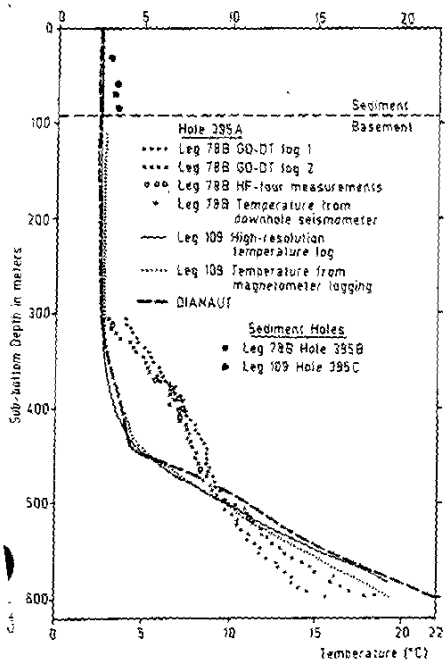


The re-entry system NADIA sets on the drilling cone at hole 534A.
NAUTILE crew, IFREMER



With the new emphasis on geochemical processes in deep-sea environments, Leg 133's scientific agenda included an intensive water-sampling program. Squeezing just one of the 545 samples analyzed during Leg 133 required physical endurance and muscle power.
ODP

search in carbonate systems. In particular, the massive dolomitization of carbonate platforms and margins, common in the geologic past, has received much attention as the mechanisms promoting diagenesis remain elusive, if not confounding. Drilling on the Queensland Plateau recovered intervals containing extensively dolomitized carbonates. Associated pore-water geochemistry and temperature profiles indicate the presence of distinctive fluid-flow patterns within the platform that were likely to have influenced or controlled dolomitization. Considerable dolomite formation was also recognized in the mixed carbonate and siliciclastic Pleistocene sediments on the Great Barrier Reef margin, a process associated with dissolution of metastable high-magnesium calcite. Shore-based studies of the dolomite and interstitial fluids should provide insights



The DIANAUT Program's main focus is to investigate temperature profiles, and this graph shows the temperature profile of hole 395A.
Kopietz and others, 1990

ship, with temperature data suggesting a possible upward movement of fluids into the open ocean.

PRELIMINARY RESULTS

All of the logging operations reported below were performed from the sea floor, with attendant data acquisition in the submersible NAUTILE. The NADIA re-entry system was set down successfully in the drill cone at water depths of 1,666 meters (Hole 333A), 4,383 meters (Hole 395A), and 4,971 meters (Hole 534A).

SITE 333A: The first successful wireline re-entry into this DSDP/ODP hole from the sea floor was accomplished Nov. 9 when a temperature profile was recorded. Unfortunately, an obstruction was encountered at a depth of 219 mbsf, close to the sediment-basalt interface, and the temperature probe could not proceed any deeper. No other tools were run in this hole due to inclement weather conditions preventing the launch of the NADIA system and

into the processes controlling dolomite formation in ancient carbonate platforms. Leg 133 drilling has provided critical data that may contribute new clues to crack that seemingly ageless riddle, the "dolomite problem."

Leg 133 ended Oct. 11, 1990, when JOIDES Resolution docked in Townsville, Australia. Our results from drilling and shipboard studies remain preliminary, and attempts to relate the causes and consequences of the interpreted environmental changes recognized in the sediment record await further results from future shore-based studies. New information toward resolving enigmatic problems surrounding carbonate-platform development will undoubtedly evolve from these studies.

Regarding the future of ocean-drilling operations, an important contribution of Leg 133 has been to show that environmentally safe drilling on passive continental margins can be accomplished successfully with careful planning, and modern high-resolution seismic imaging of the proposed drill sites.

ODP LEG 133 SCIENTIFIC PARTY

Co-chief scientists:
Peter J. Davies, Bureau of Mineral Resources, Geology & Geophysics, Australia; and
Judith A. McKenzie, Geological Institute, ETH-Zentrum, Switzerland.
Staff scientist:
Amanda Palmer-Julson, Texas A&M University.
Also:
Christian G. Betzler, Institute & Museum for Geology and Paleontology at Tubingen, West Germany;
Thomas C. Brachert, Institute for Paleontology at Erlangen, West Germany;
Min-Pen Chen, National Taiwan University, Republic of China;
Jean-Pierre Crumiére Claude Bernard University, France; George R. Dix, University of British Columbia, Canada;
André Droxler, Rice University; David A. Feary, Bureau of Mineral Resources, Geology & Geophysics, Australia;
Stefan Gartner, Texas A&M University;
Craig R. Glenn, University of Hawaii;
Alexandra Isern, University of Rhode Island;
Richard D. Jarrard, Lamont-Doherty Geological Observatory;
Peter D. Jackson, British Geological Survey, United Kingdom;
Miriam Katz, Lamont-Doherty Geological Observatory;
Kenji Konishi, Kanazawa University, Japan;
Dick Kroon, University of Edinburgh, United Kingdom;
John Ladd, ODP, National Science Foundation;
Donald F. McNeill, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami;
José Manuel Martín, University of Granada, Spain;
Lucien F. Montaggioni, University of Provence, France;
Daniel Müller, Geological Institute, ETH-Zentrum, Switzerland;
Sheraz Khan Omarzai, University of California, Santa Cruz;
Christopher J. Pigram, Bureau of Mineral Resources, Geology & Geophysics, Australia;
Peter K. Swart, Rosenstiel School of Marine and Atmospheric Sciences;
Philip A. Symonds, Bureau of Mineral Resources, Geology & Geophysics, Australia;
Keith F. Watts, University of Alaska, Fairbanks
Wuchang Wei, Florida State University.

The measured temperatures reveal a strong discontinuity at 72 mbsf and a geothermal gradient slightly less than the one previously calculated during Leg 37 across the depth interval 0-156 mbsf. The low values of temperature and heat flow are similar to those obtained 16 years earlier and provide evidence for circulation of fluids in Layer 2 (basalts).

SITE 395A: Five geophysical logs were obtained in hole 395A. The series of successful re-entry measurements consisted of, in order of deployment, temperature profile, fluid sampling, borehole televiewer log, magnetometer profile, and thermal flowmeter measurements.

The accumulated data from these geophysical logs indicate that a strong downflow persists and penetrates into the upper part of the crust. This phenomenon was observed and reported during Legs 78B and 109. However, our direct measurements of fluid flow obtained from thermal flowmeter tests in casing indicate that vertical flow is actually much greater than previously estimated. The temperature record depicts a warming of the bottom of the hole and a gradual return to thermal equilibrium.

SITE 534A: Geophysical logs could be obtained to a maximum depth of 693 mbsf, at which point an obstruction in the borehole, likely the result of collapsing sediments, prevented further penetration. A temperature log, fluid sampling, and flowmeter measurements were obtained in this well. The temperature record shows higher temperatures and temperature gradients than those observed at the two prior DIANAUT sites, and flowmeter measurements indicate a weak upflow of borehole fluid in casing. Preliminary shipboard results of borehole fluid chemistry provide additional support for the upward migration of sedimentary pore fluids.

The DIANAUT program evolved as the first scientific application of wireline re-entry based on refinements in design and capabilities to the original FARE campaign. Its successful implementation confirms the usefulness of wireline re-entry by means of the NADIA/NAUTILE system for continued borehole experimentation.

THE DIANAUT SHIPBOARD PARTY

Chief scientist:
Robert Gable (BRGM, Orleans, France).

DIANAUT staff scientist:
Jean-Claude Foucher (BRGM, Orleans);
Joris Gieskes (SIO, San Diego);
Alfred Hess (USGS, Denver);
Andrew Magenhheim (SIO, San Diego);
Roger Morin (USGS, Denver);
Bertrand Sichler (IFREMER, Brest, France).

DIANAUT staff technical support NADIA:
Jacques Legrand, Jacques Dupont, Andre Echardour, Henri Floc'h, and Luc Floury (all from IFREMER, Brest, France)