Leg 203 Preliminary Report

Dynamics of Earth and Ocean Systems

30 May–7 July 2002

Shipboard Scientific Party

Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

August 2002

PUBLISHER'S NOTES

This report was prepared from shipboard files by scientists who participated in the cruise. The report was assembled under time constraints and does not contain all works and findings that will appear in the *Initial Reports* of the ODP *Proceedings*. Reference to the whole or to part of this report should be made as follows:

Shipboard Scientific Party, 2002. Leg 203 Preliminary Report. *ODP Prelim. Rpt.,* 103 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/prelim/203_prel/203PREL.PDF>. [Cited YYYY-MM-DD]

Distribution: Electronic copies of this series may be obtained from the Ocean Drilling Program's World Wide Web site at http://www-odp.tamu.edu/publications.

This publication was prepared by the Ocean Drilling Program, Texas A&M University, as an account of work performed under the international Ocean Drilling Program, which is managed by Joint Oceanographic Institutions, Inc., under contract with the National Science Foundation. Funding for the program is provided by the following agencies:

- Australia/Canada/Chinese Taipei/Korea Consortium for Ocean Drilling
- Deutsche Forschungsgemeinschaft (Federal Republic of Germany)
- Institut National des Sciences de l'Univers–Centre National de la Recherche Scientifique (INSU-CNRS; France)
- Ocean Research Institute of the University of Tokyo (Japan)
- National Science Foundation (United States)
- Natural Environment Research Council (United Kingdom)
- European Science Foundation Consortium for Ocean Drilling (Belgium, Denmark, Finland, Iceland, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland)
- Marine High-Technology Bureau of the State Science and Technology Commission of the People's Republic of China

DISCLAIMER

The following scientists and personnel were aboard the *JOIDES Resolution* for Leg 203 of the Ocean Drilling Program:

SHIPBOARD SCIENTIFIC PARTY

John Orcutt
Co-Chief Scientist
Scripps Institution of Oceanography
University of California, San Diego
8765 Biological Grade, EAMS Code 6317
IGPP Room 2213
La Jolla CA 92037
USA
Work: (858) 534-2887
Fax: (858) 822-3372
jorcutt@igpp.ucsd.edu

Adam Schultz
Co-Chief Scientist
Department of Earth Sciences
Cardiff University
PO Box 914
Cardiff CF10 3YE
United Kingdom
Work: (44) 29 2087 4325
Fax: (44) 29 2087 4326
adam@ocean.cf.ac.uk

Thomas A. Davies
Staff Scientist
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Work: (979) 862-2283
Fax: (979) 845-0876
davies@odpemail.tamu.edu

Costanza Bonadiman
Petrologist
Department of Earth Sciences
Università degli Studi di Ferrara
Corso Ercole I d'Este, 32
44100 Ferrara
Italy
Work: (39) 0532 293740
Fax: (39) 0532 210161
bdc@dns.unife.it

Arno Buysch
Logging Staff Scientist
Applied Geophysics
Aachen University of Technology (RWTH-Aachen)
Lochnerstrasse 4-20
52056 Aachen
Germany
Work: (49) 241 809 4825
Fax: (49) 241 809 2132
a.buysch@geophysik.rwth-aachen.de

Richard L. Carlson
Physical Properties Specialist
Department of Geology and Geophysics
Texas A&M University
College Station TX 77843-3115
USA
Work: (979) 845-1398
Fax: (979) 845-6162
carlson@geo.tamu.edu

Julie Carlut
Paleomagnetist
Laboratoire de Geologie
École Normale Supérieure
24 rue Lhomond
75231 Paris
France
Work: (33)
Fax: (33) 01-44-32-20-00
jcarlut@geologie.ens.fr

Teruaki Ishii
Petrologist
Ocean Research Institute
University of Tokyo
1-15-1 Minamidai
Nakano-ku
Tokyo 164-8639
Japan
Work: (81) 3-5351-6447
Fax: (81) 3-5351-6445
ishii@ori.u-tokyo.ac.jp

Ralph Moberly
Sedimentologist
Department of Geology and Geophysics/SOEST
University of Hawaii at Manoa
1680 East-West Road
Honolulu HI 96822-2270
USA
Work: (808) 956-8765
Fax: (808) 956-5154
ralph@soest.hawaii.edu

Sidonie Revillon
Petrologist
Southampton Oceanography Centre
School of Ocean and Earth Science
University of Southampton
European Way, Waterfront Campus
Southampton SO14 3ZH
United Kingdom
Work: (44) 23-8059-2067
Fax: (44) 23-8059-3052
sxr@soc.soton.ac.uk

Xixi Zhao
Paleomagnetist
CSIDE
Institute of Geophysics and Planetary Physics
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA
Work: (831) 459-4847
Fax: (831) 459-3074
xzhao@es.ucsc.edu

STUDENT TRAINEES

Kimberly Artita
Department of Geology and Geophysics/SOEST
University of Hawaii at Manoa
1680 East-West Road
Honolulu HI 96822-2270
USA
Work: (808) 397-5840
kimby@soest.hawaii.edu

Kerri L. Heft
School of Earth and Ocean Sciences
University of Victoria
PO Box 3055 STN CSC
Victoria, British Columbia V8W 3P6
Canada
Work: (250) 472-4048
kerrih@uvic.ca

TRANSOCEAN OFFICIALS

Thomas Hardy
Master of the Drilling Vessel
Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station TX 77840-1917
USA

Wayne Malone
Drilling Superintendent
Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station TX 77840-1917
USA

ODP SHIPBOARD PERSONNEL AND TECHNICAL REPRESENTATIVES

Christopher Bennight
Marine Laboratory Specialist (Chemistry)

Lisa Brandt
Marine Laboratory Specialist (Chemistry)

Lisa Crowder
Marine Laboratory Specialist (Underway Geophysics)

Roy Davis
Laboratory Officer

Randy Gjesvold
Marine Electronics Specialist

Ted Gustafson
Marine Laboratory Specialist (Downhole Tools/Thin Sections)

Stan Hammon
Marine Laboratory Specialist (Physical Properties)

Scott Herman
Marine Laboratory Specialist (Paleomagnetism)

Michiko Hitchcox
Marine Laboratory Specialist (Yeoperson)

Eric Jackson
Marine Laboratory Specialist (Core Laboratory)

Brian Jonasson
Operations Manager

Michael Meiring
Marine Electronics Specialist

Erik Moortgat
Marine Computer Specialist

Chieh Peng
Assistant Laboratory Officer/Storekeeper

Cyndi Prince
Marine Laboratory Specialist (Photography)

Preston Sutton
Marine Laboratory Specialist (X-Ray)

Kerry Swain
Schlumberger Logging Engineer

Steve Tran
Marine Computer Specialist

Paula Weiss
Marine Laboratory Specialist (Curation)

ABSTRACT

We drilled a cased reentry hole (Hole 1243A) at 5°18.0541′N, 110°4.5798′W in the eastern equatorial Pacific, the location of a future Dynamics of Earth and Ocean Systems (DEOS) multidisciplinary observatory. The drill site was located in 10- to 12-Ma lithosphere at a water depth of 3882 m. The hole was drilled to a total depth of 224 m, which included 121 m of sediment and 103 m of basement penetration. We inserted casing to 212 meters below seafloor (mbsf) and cemented the casing in place, with the top of the cement at a depth of 199 mbsf. Subsequent logging showed that the casing was well bonded to basement in the lower 40 m and that the deviation of the hole never exceeded 1° from vertical. Casing complications obviated coring and scientific logging this hole. Hole 1243A will subsequently be used to install an observatory-quality broadband three-component seismometer (0.001–5 Hz) as well as a high-frequency three-component seismometer (1–20 Hz) to ensure high-fidelity recording over the range of frequencies normally recorded by the terrestrial Global Seismic Network. The seismic system, as well as other instrumentation associated with the observatory, will be connected to a DEOS mooring for both power and high-speed data telemetry to a land station and the Internet.

The equatorial site satisfies two scientific objectives of crustal drilling: (1) it is located in one of the high-priority regions for the Ocean Seismic Network and DEOS, and (2) it is in oceanic crust created by fast seafloor spreading, providing a rare opportunity to examine crustal genesis, evolution, and crust/mantle interaction for a seafloor-spreading end-member responsible for generating the majority of the oceanic lithosphere. To satisfy the secondary objective, we drilled a second uncased hole (5°18.0543′N, 110°4.2544′W) fitted with a reentry funnel 600 m east of Hole 1243A. Rotary coring alone was used in an effort to sample the sediment/basement interface as well as the uppermost fast-spreading lithosphere. Hole 1243B is characterized by 110 m of sediment and a total penetration of 195 m. Core recovery throughout basement averaged 25%, and the lower sediment and basement were logged. This is a multidisciplinary project that primarily represents the interests of the National Science Foundation's component of the international DEOS planning effort and the International Ocean Network.

INTRODUCTION

Dynamics of Earth and Ocean Systems

The ocean and earth sciences are on the threshold of a revolution involving new questions and requiring novel technologies. It is no longer sufficient to consider each constituent of the Earth-ocean-atmosphere system in isolation or to study the individual physical, chemical, and biological components of that system alone. To understand the present state of the planet and to determine with increasing accuracy environmental change in all of its aspects, we must observe the Earth's interior, its hydrosphere and biosphere on spatial scales appropriate to each component's pattern of heterogeneity, and multiple scales of interaction with other components.

There is an increasing requirement for such observations to be made continuously rather than intermittently. Many natural processes within the Earth system take place on characteristic timescales spanning hours to decades, whereas others are punctuated by brief episodic outbursts of activity that rise above a less energetic continuum. Since Darwin's voyage on the *Beagle,* earth and ocean scientists have used ships for expeditions of discovery. Much of our knowledge of the ocean basins comes from such discrete expeditionary visits. By the nature of such work, one can gain an understanding of the different regions of the oceans in the three dimensions of space. This approach does not afford knowledge of temporal variations, aside from episodic visits to stations previously surveyed or relatively brief continuous time-series observations from autonomously recording instrument packages deployed by ships and then subsequently recovered.

This approach has provided society with a broad understanding of the fundamental principles that regulate the physical, chemical, biological, and geological processes in the ocean. However, timely advances in our knowledge of the oceans and the Earth beneath are now limited by the lack of sustained observations over extended periods and over the range of spatial scales now required to address scientific issues of great importance; the complex network of interactions between ocean subsystems must be studied in depth.

The study of change extends across many disciplines, including the dynamics of the lithosphere and mantle, climate, biogeochemical cycles in the upper ocean, and the interrelationships between fluids and life in the crust. A successful observatory network must be, therefore, multidisciplinary in nature, providing physical, meteorological, chemical, biological, and geophysical time-series observations and enabling new understanding of the Earth system. Many processes are characterized by very low signal-to-noise ratios (e.g., seismology, geoelectromagnetic induction, or acoustic thermometry), and only long-term observations can be used to enhance these signals vis-a-vis noise processes. An observatory network requires the establishment of a permanent presence in the oceans; Ocean Drilling Program (ODP) Leg 203 is a critical step in this direction.

The Dynamics of Earth and Ocean Systems (DEOS) planning initiative in the United States (US) and the United Kingdom (UK) in coordination with partners in several member states of the European Union and Japan, represented by the International Association of Seismology and Physics of the Earth's Interior (IASPEI)/International Ocean Network (ION) Consortium, has identified a network of sites for multidisciplinary observatories focused on the atmosphere, ocean, and the Earth beneath it. Whereas for centuries observatories have been commonly used on land for many purposes, long-term continuous observations of natural phenomena in the oceans represent a new frontier for the sciences. A component of DEOS seeks to establish a global network of ocean observatories through the use of moorings (Fig. F1) for power supply and high-bandwidth telemetry. In other locations, generally those closer to land, DEOS calls for the use of direct submarine cable connections to shore. The drilling and establishment of a cased legacy hole (Leg 203, Hole 1243A) at the remote equatorial Pacific ION multidisciplinary observatory site provides an ideal location in the 2004 to 2005 time frame for the initial installation of a moored observatory.

The location of Site 1243 also provided a rare window into the petrology, geochemistry, and paleomagnetic history of fast-spreading 10- to 12-Ma Pacific basement material. During Leg 203, 87 m was cored and logged through basement in Hole 1243B, one of only four Deep Sea Drilling Project (DSDP)/ODP sites in Pacific basement of that age at which >80 m penetration through basement has been achieved. A full suite of shipboard analyses of basement rock cores will be reported in the Leg 203 *Initial Reports* volume.

GEOLOGIC AND OCEANOGRAPHIC SETTING

Site 1243 in the eastern equatorial Pacific (Fig. F2) is in a particularly interesting location for understanding the interplay between ocean chemistry, productivity, climate, and plate tectonics in a fast-spreading environment. The climatic implications were studied in detail with a series of 11 holes drilled during Leg 138. We returned to the immediate vicinity of Site 852 from that leg to develop a legacy hole for the purpose of supporting a long-term multidisciplinary observatory to be used for studies ranging from the seismic structure of the mantle to air-sea interaction in an environment of great scientific interest.

The age of the lithosphere in this region, based on a full spreading rate of 141 mm/yr and an East Pacific Rise subsidence curve (e.g., Parker and Oldenburg, 1973), is in the range of 10–12 Ma (Figs. F2, F3); this age is also consistent with paleoceanographic results from Leg 138. The water depth at Hole1243A (Ocean Seismic Network [OSN]-2) is 3882 m. Based on seismic profiles and drilling during Leg 138, the sediment at Site 852 is 116 m thick and overlies basement, which is quite smooth, with variability in relief probably much less than 100 m. Whereas sediment thicknesses of as much as 400 m could be found to the south, there is no particular advantage in deploying the borehole seismometer beneath the thicker sediment cover. A thicker sediment column will not attenuate seafloor noise, and an increased sediment thickness will only decrease the frequency of reverberations in the sediment column, which could begin to interfere with seismic observations. For example, the two-way traveltime (TWT) for compressional waves in 400 m of sediment is ~0.5 s for a frequency of 2 Hz. This is a particularly interesting band for recording earthquakes at teleseismic distances. On the other hand, the TWT at Site 852 is only 0.15 s for a frequency of 6.7 Hz, a frequency above that normally found in teleseismic compressional wave arrivals.

There is every reason to believe that the crustal section at the site will be quite typical of Pacific oceanic crust. Figure F4 illustrates the installation of the seismic component of an observatory at site OSN-1 south of Oahu; a similar procedure will be followed at proposed sites for the Hawaii-2 Observatory (H2O-1) (2004) and OSN-2 (2005).

The equatorial Pacific is a region of considerable interest in paleoceanography, oceanography, and climate studies, given the high productivity of the region and the sensitivity of the rates of sedimentation to both climate change and changes in circulation patterns associated with tectonic changes. The circulation pattern is associated with prevalent surface winds and the change in the sign of Coriolis force at the equator. The wind patterns are driven by the warm waters in the west and the cooler waters in the east. The rising air in the west and sinking air in the east drive the easterly winds associated with the trade winds. The trade winds give rise to northern Ekman transport to the north of the equator and southward Ekman transport to the south; this divergence leads, in turn, to upwelling and high productivity at the equator. Directly on the equator, the effects of rotation vanish and easterly trade winds push the surface water directly, through friction, to the west. The water transported by the winds piles up in the western Pacific with an offset of ~0.5 m, providing the potential for a semiperiodic El Niño. The Intertropical Convergence Zone (ITCZ) is the result of these effects (Fig. F5).

Today, the ITCZ is always north of the equator in the eastern Pacific. The equatorial current system is dependent upon the seasons with the ITCZ at its most northerly position (~10°N) from August to December. Figure F6A illustrates a superposition of the winds on dynamic sea height from satellite altimetry measurements. Figure F6B shows the residual and demonstrates quite clearly the different current regimes discussed above. Figure F7 is a more complex plot, showing the Ekman transport in Figure F7A, the wind driven geostrophic component in Figure F7B, and, finally, the combination of the two currents superimposed on the temperature anomaly in Figure F7C. In this case, the surface current at the future observatory site in Hole 1243A (OSN-2) is ~1 kt and the Equatorial Undercurrent lies well to the south. The actual current regime will vary at the site through the year and through El Niño cycles, providing an excellent opportunity for a high-power, high-bandwidth mooring to study change.

The high productivity associated with the circulation system acting in conjunction with a component of the absolute plate motion of the Pacific plate in a northerly direction has resulted in a bulge in the sedimentation, which is asymmetric to the north (Fig. F8). Beginning with the Swedish Deep Sea Expedition (e.g., Kolbe, 1955), it has become abundantly clear that the sediments in this area record climatic cycles well into the past. Studies of the early piston cores led to the development of the concept of a lysocline and a calcite compensation depth (e.g., Arrhenius, 1952; Bramlette, 1961; Berger, 1972). The advent of the geomagnetic timescale coupled with additional coring substantially increased the resolution of these studies. The sedimentation patterns in the area coupled with plate tectonics led to the concept of "plate stratigraphy" (Berger, 1973; Winterer, 1973; Berger and Winterer, 1974), which explained the general features of Cenozoic sediments in the equatorial Pacific.

The equatorial Pacific is an ideal site for one of the initial deployments of a permanent seafloor observatory. The weather in the region is generally fine, and the limited swell reduces the level of surface-induced noise at the seafloor. One of the north-south arrays in the Toga-Tao experiment (e.g., Adams et al., 1995), which monitors the development and growth of El Niño, is located at this longitude, so ocean weather conditions are well known.

The international nature of the consortia organizing and implementing plans for multidisciplinary ocean observatories (e.g., DEOS, ION, and others) encourages the view that operational maintenance of the emerging global network of such sites will also be a collaborative effort. Furthermore, in an ideal world in which the US National Oceanic and Atmospheric Administration and the University National Oceanic Laboratory System come to share ship time and programs, the maintenance of the surface mooring needed for the station could become a shared responsibility.

SCIENTIFIC OBJECTIVES

Leg 203 addresses the second of three initiatives outlined in the ODP Long Range Plan—in situ monitoring of geological processes (see p. 49–51; JOIDES Planning Committee, 1996). It also represents an initial step in accomplishing the oceanic crustal component of the third initiative—exploring the deep structure of continental margins and oceanic crust (see p. 52–54; JOIDES Planning Committee, 1996). The drilling is intimately tied to the use of seafloor observatories (see p. 63; JOIDES Planning Committee, 1996) and represents the partnership of ODP with the DEOS multidisciplinary ocean observatory planning effort in the US and the UK and the partnership of ODP with the multinational IASPEI/ION Consortium.

Data obtained from oceanographic expeditions or from the deployment of conventional autonomous recording packages cannot by themselves provide the range or continuity of temporal sampling, or the consistency of spatial sampling, required to address modern observational requirements. There is a pressing need for long-term continuous observations of the present state of the Earth-ocean-atmosphere system as well as the response of the physical, chemical, and biological constituents of that system to natural and anthropogenic change. The DEOS ocean observatory planning initiative was launched to foster a long-term continuous observational presence at the air/sea interface, throughout the water column, at the seafloor, and below. The temporal and spatial scales of such observations must be appropriate to the process under study and range from seconds to decades and from centimeters to millions of meters.

In parallel with DEOS efforts in the US and the UK (planning for which has been supported by the National Science Foundation and Natural Environment Research Council, respectively), the international ION Consortium, representing participants from a number of member states of the European Union, Japan, and the US, has for much of the past decade been implementing plans for a global distribution of deep-Earth seafloor-based seismic observatories and has been planning for establishment of collocated seafloor-based magnetic observatories.

A primary objective of Leg 203 was to establish a deep cased legacy hole in a geographical region identified by a number of studies (e.g., Purdy, 1995) and agreed by ION as essential to the establishment of an unbiased global distribution of broadband digital seismic observatories. The target site was designated OSN-2 after the US-based OSN seismic observatory planning effort was subsequently subsumed into the DEOS planning framework. The site chosen also serves a variety of additional purposes outside of OSN, some of which are detailed below.

The Observatory

Drilling at the proposed OSN-2 site addresses both teleseismic, regional, seismic, and whole-Earth seismic studies. The site is located in a region on the Earth's surface ~2000 km from the nearest continental or island seismic observatory. For uniform coverage of seismic stations on Earth's surface, which is necessary for whole-Earth imaging using modern tomographic inverse methods, a seafloor seismic observatory is required in the eastern equatorial Pacific. This site is one of three high-priority prototype observatories for the OSN (Purdy, 1995).

Global seismic tomography provides three-dimensional images of the lateral heterogeneity in the mantle and is essential in addressing fundamental problems in subdisciplines of geodynamics, such as mantle convection, mineral physics, large-scale geoid anomalies, geochemistry of ridge systems, geomagnetism, and geodesy. Specific problems include the characteristic spectrum of lateral heterogeneity as a function of depth, the anisotropy of the inner core, the structure of the core/mantle boundary, the role of oceanic plates and plumes in deep mantle circulation, and the source rupture processes of Southern Hemisphere earthquakes, which are among the world's largest (Forsyth et al., 1995).

The culturally important earthquakes (those that pose a hazard to structures) in South America are only observed at regional distances on land stations in South and Central America and Global Seismic Network stations on the Galapagos Islands and Easter Island. This restricts the azimuthal information to an arc spanning ~180°. Seafloor stations are required to observe these earthquakes at regional distances to the west and to constrain the earthquake source mechanisms.

It is intended that the infrastructure to be installed at the observatory site will include the facility for real-time data telemetry and for in situ power generation. Because the equatorial observatory data will be available in real time, data will be incorporated into focal mechanism and centroid moment tensor determinations within minutes of Central and South American earthquake events. Other problems that can be addressed with regional data are the structure of the 400-, 525-, and 670-km discontinuities in the northeastern Pacific, the variability of elastic and anelastic structure in the Pacific lithosphere from Pn and Sn, and pure-path oceanic surface wave studies.

In 1998, in the pilot experiment at the OSN-1 site established by ODP (Site 843) in seafloor west of Hawaii, three broadband seismometers were deployed (one on the seafloor, one buried in the sediment, and one in the borehole) to compare the performance of different styles of installation. Figures F9 and F10 summarize for vertical and horizontal component data, respectively, the improvement that we expect to see in ambient seismic noise by placing a sensor in basement rather than on or in the sediment. Above 0.3 Hz, the seafloor, buried, and borehole spectra at the OSN-1 site show the borehole installation to be 10 dB quieter on vertical components and 30 dB quieter on horizontal components (Stephen et al., 1999; Collins et al., 2001). Shear wave resonances within the thin sediments are the physical mechanism responsible for the higher noise levels in or on the sediment.

The site of the future seismic observatory established during Leg 203 will also play a role in completing the global distribution of permanent seafloor magnetic observatories. Long-period data from magnetic observatories are essential for studies of the geodynamo convection of the outer core, rotation of the inner core, the structure of the mantle near the D″ discontinuity and the core-mantle boundary, studies of variations in the length of day, and investigations of the temperature, composition, and state of the upper and midmantle as revealed by the three-dimensional variations in electrical conductivity structure. The spatial sampling requirements for such observations are similar to those of global seismology, with a particularly severe bias introduced by the absence of seafloor stations.

The remote location of the site and the infrastructure to be installed in support of the intended geophysical observatories provides an opportunity for multidisciplinary observations of the air/sea interface, the water column, the seafloor, and below. The cased legacy hole established during Leg 203 may, thereby, serve as the first component of a future multidisciplinary marine laboratory.

Basement Drilling on the Pacific Plate

As noted in the Leg 200 Scientific Prospectus, there are no deep boreholes (>100 m) in the Pacific plate, the largest modern tectonic plate. Table T1 summarizes the boreholes drilled on "normal" crust on the Pacific plate that have >10 m of basement penetration and crustal ages <100 Ma. ODP/DSDP holes in seamounts, plateaus, aseismic ridges, and fracture zones are not included. Holes with crustal ages >100 Ma are not included because they would be affected by the mid-Cretaceous super plume (Pringle et al., 1993). In 30 yr of deep ocean drilling and >1000 ODP/DSDP holes worldwide, there have been only 17 holes with >10 m penetration into the normal igneous Pacific plate, only five holes during ODP and three holes with >100 m penetration. Furthermore, there are no boreholes off axis in "very fast" spreading crust. Thus, Leg 203 provides a reference station in normal 10- to 12-Ma ocean crust that will constrain geochemical and hydrothermal models of crustal evolution.

Although fast-spreading ridges represent only ~20% of the global ridge system, they produce more than one-half of the ocean crust on the surface of the planet, almost all of it along the East Pacific Rise. Most ocean crust currently being recycled back into the mantle at subduction zones was produced at a fast-spreading ridge. If we wish to understand the Wilson cycle in its most typical and geodynamically significant form, we must examine ocean crust produced at fast-spreading ridges. We have also known for longer than 40 yr that crust created by fast seafloor spreading is both simple and uniform, certainly so in terms of seismic structure (Raitt, 1963; Menard, 1964). Successful deep drilling of such crust during Leg 203 is likely to provide fundamental information that can be extrapolated to a significant fraction of the Earth's surface (Dick et al., 1996).

Drilling Strategy

Leg 203 was governed by two primary scientific objectives, in order of priority:

1. To drill, case, and cement a legacy hole with sufficient penetration depth into basement (~100 m) for successful coupling in a low-noise environment of a long-term DEOS/OSN observatory broadband seismic package; and
2. To sample and log the sediment–basement transition in young fast-spreading Pacific crust and the basement to a depth of 100 m or more.

The Leg 203 operational strategy stressed the importance of preserving the integrity of the cased legacy hole (Objective 1) while attempting to achieve the goals of Objective 2. The first objective was accomplished, although problems with inserting 16-in casing into the 18½-in well bore forced us to complete Hole 1243A without coring or scientific logging. The second objective was largely satisfied by the decision to jet in to near the sediment/basement interface and then to core with the rotary core barrel (RCB) nearby Hole 1243B, although we did not achieve crustal penetration to the desired 100 m but managed to penetrate to 85 m in basement before drilling became too difficult to continue.

The close proximity of Site 1243 to Site 852 permits us to take advantage of information previously obtained from geophysical surveys and coring at Site 852. Evidence from the seismic reflection survey suggests that Holes 1243A and 1243B are sufficiently close in character to Site 852 such that data obtained from that site will still be broadly representative of the same formations and conditions. During Leg 138, four holes were cored at Site 852 with the advanced hydraulic piston corer (APC), three of which penetrated through roughly the entire sediment column, which was ~116 m thick. The redundant coring resulted in recovery of a complete sedimentary section.

With the exception of some refinements in paleomagnetic interpretation that newly cored sediments might make possible, the existence of a complete sedimentary section made it unnecessary to conduct further sediment coring during Leg 203. A shipboard proposal to jet in and use APC coring at a proposed hole (Hole 1243C) was approved by the scientific party. However, the decision by ODP to change the end-of-leg port to Victoria, British Columbia, Canada, rather than the originally scheduled port of San Francisco, California, necessitated cutting operations by 4 days. This exacerbated pressure on operating time that was related to difficulties in drilling Hole 1243B and curtailed plans to attempt Hole 1243C.

Logging Plan

In order to integrate properties across the areas sampled by coring (Hole 1243B), we planned a full suite of logs. However, because of the aforementioned problems with casing Hole 1243A, we were unable to run the usual suite of logs in that hole because it was fully cased. We did, however, run both an inclinometer log and a cement bond log.

In Hole 1243B we deployed, as planned, the following:

1. The standard logging triple combination (triple combo) tool string, including tools for measurements of gamma ray activity, density, porosity, resistivity, and temperature;
2. The Formation MicroScanner (FMS)-sonic tool string, including tools for measurement of elastic properties and high-resolution resistivity images of the borehole wall; and
3. The Well Seismic Tool (WST) for check shot and vertical seismic profile (VSP) seismic survey.

The triple combo tool string is a combination of five tools, beginning with the Hostile Environment Gamma Ray Sonde (HNGS) on top. This tool measures the natural radioactivity of a formation, including the measurement for K, Th, and U contents. It is applicable for determining the formation's mineralogy and geochemistry, especially for the detection of ash layers and clay intervals, as well as for different lithostratigraphic units and their boundaries. The Accelerator Porosity Sonde (APS) measures the total rock porosity of a formation and is able to define differences in the crustal structure. In combination with the Hostile Environment Litho-Density Sonde (HLDS), which measures the formation's density, this tool yielded information about the drilled lithology, especially where core information is missing. This is particularly germane to Hole 1243B because the core recovery was almost entirely basement material with a 25% total recovery rate. The HLDS also measures the photoelectric effect, which gives additional information about the matrix composition. Either the Dual Induction Tool (DIT) or the Dual Laterolog (DLL) tool can be used to measure rock resistivity. The DIT provides an indirect measurement of the resistivity and the spontaneous rock potential as well as the conductivity of the formation at three invasion depths, whereas the DLL measures the direct resistivity at two invasion depths. The last tool of the triple combo tool string was the Lamont-Doherty Earth Observatory Temperature/Acceleration/Pressure (TAP) tool. Unfortunately, the TAP tool did not return any data.

The main components of the second tool string (FMS-sonic) are the FMS and the Dipole Sonic Imager (DSI). Applications are mainly identification of structural characteristics, estimation of fracture porosity, and the creation of a seismic impedance log. The FMS tool obtains a high-resolution microresistivity picture of the borehole wall, mainly leading to the identification of lithologic units and tectonic features (e.g., presence of fractures and faults, their orientations, and their degree of alteration). The FMS tool also incorporates a caliper log, which is used for hole size estimation and to infer the degree of mechanical competence of the hole walls.

The WST was also used in Hole 1243B. The WST provides a complete check shot survey, a depth-traveltime plot, and a rudimentary VSP survey. A set of seismic interval velocities were obtained that showed a velocity structure within the basement that was in broad agreement with the sonic logs.

OPERATIONS

After departing Balboa, Panama, at 1515 hr (CDT) on 3 June 2002, we cleared the Bridge of the Americas then made full speed for Site 852, the intended site of the OSN-2 observatory. Torrential rain in the doldrums was superseded by fine equatorial weather. The 1921-nmi transit from Panama was completed in 179 hr at an average speed of 10.75 kt. The *JOIDES Resolution* arrived on location at 0015 hr on 11 June. A brief seismic survey was conducted, comprising four parallel east-west lines, each separated by 0.5 nmi in the north-south direction (Fig. F11). At the conclusion of the final east-west survey line, a north-south line was run 2 nmi southward to replicate an earlier site survey line. The survey was completed, and the ship was at the intended location of Site 1243 (5°18.0660′N, 110°04.5798′ W) by 0600 hr on 11 June. The hole was relocated ~0.5 mi north of Site 852 based on the results of the site survey. The new location placed the site farther from a 100-m-deep trough to the west (Fig. F12).

From 0600 hr on 11 June 2002 to 0245 hr on 12 June, a jet-in test was conducted in preparation for installing the reentry cone and casing. We stopped the jet-in test at 58 meters below seafloor (mbsf), pulled out of the hole, and cleared the seafloor at 2000 hr on 11 June.

After recovering the drill string, we offset 20 m to the south to 5°18.0541′N, 110° 04.5798′W in preparation for spudding Hole 1243A. The reentry cone and four joints (48 m) of 20-in casing were made up, and the reentry cone was lowered through the moonpool at 0800 hr on 12 June. The seafloor was reached at 1600 hr, the reentry cone was installed, and the drill string was released at 1815 hr. Satisfactory placement of the reentry cone was confirmed with the vibration isolated television (VIT) camera.

After tripping back to the surface to remove the running tool, we returned to the hole with an 18½-in bit. Reentry was achieved at 0943 hr on 13 June. It was a textbook reentry, with an elapsed time of 8 min. We then drilled down below the 20-in casing, reaching the sediment basement contact at 121 mbsf. Basement drilled well, with penetration rates ranging from 0.8 to 2.0 m/hr. Drilling concluded at 0745 hr on 14 June at a depth of 134 mbsf. We then made a wiper trip and prepared to install the 16-in casing.

At 1630 hr on 14 June, the crew commenced rigging up the casing tools to run the 16-in casing into basement. The target depth for the 16-in casing was 126 mbsf (4008 meters below rig floor [mbrf]) in order to isolate the 73 m of sediment and the top 5 m of basement as we drilled deeper. Reentry 2 occurred at 0440 hr on 15 June. The driller washed down through the 20-in casing and sediment and took weight at the basement contact at 4003 mbrf (121 mbsf). It took ~1 hr to work the 16-in casing cement shoe through the basement contact. On repeated attempts to pass through the interval from 120 to 123 mbsf, the casing (17-in outside diameter) became stuck and overpulls of up to 40 klb were required to free it, as it became wedged in the 18½-in basement open hole.

On the last attempt to land the casing in the reentry cone, it became stuck firmly and took 100 klb of overpull to free it. In light of these difficulties, we decided to pull out of the hole. On recovery, the cement shoe on the 16-in casing was found to have been damaged severely in attempting to get the casing to bottom. The 10 joints of casing were laid down by 1900 hr on 15 June.

The operations plan was then revised to complete Hole 1243A without coring, as a cased hole with only 20- and 10¾-in casing. The target depth for the 10¾-in casing was 216 mbsf. Following completion of Hole 1243A, we planned to drill, RCB core, and log a second hole to 200 mbsf to obtain cores across the sediment/basement interface and into the basement. Time estimates showed that this plan could be achieved within the available time, despite the change in location of the end of Leg 203 port call. (On 13 June, we were advised that the port call had been changed from San Francisco, California, to Victoria, British Columbia, Canada, in anticipation of a longshoremen's strike in San Francisco in early July. This change added almost 4 days more to the transit from Site 1243 to port.)

The third reentry of Hole 1243A took place at 0405 hr 16 June. We washed down to 134 mbsf and then drilled ahead in basement to a depth of 224 mbsf at an average rate of 3 m/hr. At 180–184 mbsf, the drill string packed off and required 60 klb overpull to free it, but otherwise no problems were encountered.

After cleaning the hole and displacing it with 250 bbl of sepiolite, we then prepared to set the 10¾-in casing. Reentry 4 was achieved with the casing at 2050 hr on 18 June. The casing landed in the hole at 2345 hr, and cementing was completed by 0200 hr on 19 June. This required 100 bbl of cement and is one of the largest cement jobs done by ODP to date. We pulled out of the hole, and the running tool was back on the rig floor at 1000 hr on 19 June. We then made a cleanout trip in preparation for the future installation of the OSN-2 seismometer. Reentry 5 was achieved at 2109 hr on 19 June, and after circulating the casing clean with seawater, we pulled out of the hole, clearing the seafloor at 0025 hr on 20 June. The depth of the hole, measured to the cement, is 199 mbsf (Fig. F13).

The ship was offset 600 m to the east with the drill pipe and VIT camera down, and Hole 1243B was spudded at 0245 hr on 20 June at 5°18.0543′N, 110°4.2544′W in a water depth of 3868 m. We washed down through the sediment section to 102 mbsf, then pulled the center bit and commenced RCB coring. To improve recovery, we took half cores (4.5 m). At a depth of 142 mbsf, the hole packed off, requiring 40 klb of overpull to free it. We continued to have problems with packing off, and core recovery dropped. After repeated hole problems and poor recovery, the decision was made after Core 203-1243B-18R to abandon further attempts to core deeper. The final core returned to the surface with 5.3 m of fine black basalt cuttings.

After abandoning further attempts to core deeper in Hole 1243B because of deteriorating hole conditions, we prepared the hole for logging. Triple combo and FMS-sonic logs were run in Hole 1243B followed by a WST log in the basement section of the hole. Poor hole conditions prevented successful running of the WST in the sediment section. Eight WST receiver stations were run from bottom to top of the basement section. We then dropped a free-fall funnel in Hole 1243B and offset the ship back to Hole 1243A where we ran both inclination and cement bond logs in order to determine the characteristics of the cased hole in anticipation of future installation of the seismometer. Because the intervals to be logged at both Holes 1243B and 1243A were short, we had time to make more than one traverse with each suite of logging tools (except the WST and inclinometer) in order to verify that we were getting consistent, good quality data.

After completing the cement bond log in Hole 1243A, we snagged the first beacon dropped at Site 1243, which had ceased operating, with a grapple on the VIT frame. The VIT frame and beacon were back on deck at 0915 on 25 June, and we began the final trip out of the hole. The second (active) beacon was retrieved at 1300 hr on 25 June, and we completed tripping pipe at 1330 hr, bringing operations at Site 1243 to a conclusion. The *JOIDES Resolution* got under way for Victoria, British Columbia, Canada, at 1530 hr on 25 June, arriving there at 0700 on 7 July.

PRINCIPAL RESULTS

Cores

The primary objective of Leg 203 was to drill and case a hole for future installation of an observatory, coring was limited to sampling a short section of basement rocks. The modest sample return from coring Hole 1243B was significant, however, given the sparse catalog of deep basement rocks from young Pacific seafloor. Some sediment was recovered in Core 203-1243B-1R (102–108 mbsf) of the same lithologies and colors as oozes recovered during Leg 138. The ooze consists dominantly of coccoliths with a few percent planktonic foraminifers, discoasters, radiolarians, Fe oxide globules, and glass.

The driller first felt basement at 110 mbsf, and the first basement rocks were recovered from Hole 1243B in Core 203-1243B-2R (108–113 mbsf). Basement was drilled and cored to a total depth of 195.3 mbsf, which represents 87.1 m of basement section. Seventeen cores were taken in this interval. Recovery ranged from 1.6% in Core 203-1243B-16R to 63.7% in Core 203-1243B-7R, averaging 25% (this recovery statistic does not include 5.3 m of drilling breccia/cuttings recovered in the deepest core, recorded as Core 203-1243B-19R).

On the basis of hand specimens, thin section descriptions, and shipboard geochemical analyses, eight basement units were defined (Fig. F14). Units 1, 3, 4, 5, 6, 7, and 8 are volcanic basaltic units. Units 1, 3, and 7 are aphyric basalts. Units 4, 5, and 6 are sparsely plagioclase and olivine phyric basalts. Unit 8 consists of moderately plagioclase and olivine phyric basalt. Unit 2 is represented by a piece of limestone. All the basement basaltic units are interpreted as pillow lavas based on the presence of glassy margins and associated vesicular zones. No evidence of thicker massive lava flows was found in the cores. This interpretation of the environment of eruption is further confirmed by downhole measurements in Hole 1243B. Inductively coupled plasma–atomic emission spectroscopy analyses conducted on board indicate that all units are tholeiitic except Unit 4, which consists of alkali basalt. The basement units range in thickness from 0.065 m (Unit 2) to 11.175 m (Unit 3). At the bottom of Hole 1243B, 5.3 m of drilling breccia was recovered. This consists of finely broken angular fragments of pillow basalts (Core 203-1243B-19R).

Wet bulk density, grain density, porosity, and sonic velocity were measured on minicores, which were also used for paleomagnetic measurements. The sonic velocities range from 4.3 to 5.7 km/s (mean = 5.26 ± 0.08 km/s). Porosities range from 4% to 17% (mean = 7.7 ± 0.7%). Wet bulk densities range from 2.52 to 2.82 g/cc (mean = 2.69 ± 0.02 g/cc), whereas the grain densities range from 2.64 to 2.98 g/cc (mean = 2.85 ± 0.02 g/cc).

The relationships among these properties are summarized in Figure F15. Except for two samples that have particularly high porosities, wet bulk densities decrease markedly with increasing porosity. We also observe a marked decrease in grain density with increasing porosity and a strong increase in wet bulk density with increasing grain density. Lower grain densities are likely to reflect the abundance of low-temperature, low-density alteration products, such as clay minerals, in the samples. Hence, taken together, these relationships suggest that higher porosities are associated with higher permeabilities, which in turn lead to higher degrees of hydrous alteration. Velocities decrease with increasing porosity and with decreasing grain density. Thus, if the grain density is a function of alteration, the seismic velocities in these samples reflect the combined effects of porosity (cracks) and alteration on the properties of the rocks.

Paleomagnetic measurements appear to indicate that the basaltic cores recovered from Hole 1243B record a stable component of magnetization with both normal and reversed inclinations after removal of the pervasive drilling-induced remagnetization. Shipboard alternating-field (AF) and thermal demagnetization studies indicate that even at the highest AF demagnetization level (up to 70 mT) not all of the drilling-induced magnetization was removed and that thermal demagnetization is generally more effective for removing this component. Preliminary data from isothermal remanent magnetization acquisition experiments, unblocking temperatures, and coercivity determinations suggest that magnetite and titanomagnetite are the most likely magnetic carriers in these cores. The lava sequence recovered at Site 1243 may have recorded a reversal sequence (normal-reversed-normal). These hypotheses will be tested in subsequent shore-based investigations.

Logging

Logging results in Hole 1243B clearly show the sediment/basement interface (Fig. F16). Compared to the sediment section above, within the basement the triple combo suite shows high resistivity and density but only a small increase in the gamma ray spectrum down to ~140 mbsf. At 140 mbsf, the gamma ray energy increases substantially. This corresponds to both the top of lithologic Unit 4 and the level at which we first encountered drilling problems. Below 140 mbsf, the gamma ray values remain high and resistivity also stays high down to 155 mbsf (approximately the top of lithologic Unit 5). Below 155 mbsf, resistivity drops somewhat, but relatively high gamma ray values persist down to the bottom of the logged interval. It is clear from the logging results that there are significant differences between the upper 30 m of basement and the rocks below.

The WST was used to conduct a check shot–VSP seismic survey through the basement section in Hole 1243B. Data were recorded at eight stations; except for the interval between stations seven and eight (at the top of the basement section), the stations were located 10 m apart and 5–16 shots were stacked at each station to improve the signal-to-noise ratio.

Results are shown in Figure F17, which shows good agreement between the velocities in the laboratory samples, the sonic log, and the well seismic data. The laboratory velocities are, on average, slightly higher (5.26 km/s) than the velocities recorded by the sonic log, which average 4.72 km/s. The difference between the laboratory velocities and the sonic log probably reflects the presence of cracks in the formation that are not present in the laboratory samples. The WST interval velocities (average = 4.60 km/s) are slightly lower than the sonic log velocities. This difference could result from the presence of large-scale cracks affecting the seismic measurements but not the sonic log, which measures a smaller sample of the rock.

The FMS logs are still being analyzed and will be finalized postcruise.

The inclination log of Hole 1243A shows that the hole is within 1° of vertical throughout its entire depth. The cement-bond log indicated a good bond in the lowest 40 m of the hole but essentially no bonding above that level, suggesting that the cement was lost into cavities and the generally porous formation.

The downhole caliper logs from Hole 1243B indicate lithologic boundaries and poor hole conditions associated with at least three incidents of lost rotation and circulation (pack offs) during drilling (Fig. F18). These occurred at depths of 4010 mbsf (125 mbsf), 4027 mbsf (142 mbsf), and 4043 mbrf (158 mbsf). The lowest pack off depth corresponds to the same depth (in meters below the sediment/basement interface) at which a pack off was encountered when drilling Hole 1243A. This suggests that the large volume of cement used to complete casing Hole1243A and the relatively low height the cement rose during injection may be due to infilling of the same highly fractured basaltic unit revealed in the logs from Hole 1243B and in core materials recovered from that hole.

SUMMARY

During Leg 203, we accomplished our stated goals: to establish a cased legacy hole with ~100 m basement penetration and to obtain cores and logs representative of the section from the sediment/basement interface to the bottom of the hole. This was accomplished despite the shortening of an already modest operational component of the leg by the decision to reroute the ship to Victoria, British Columbia, Canada, rather than San Francisco, California, and despite two significant technical challenges. The first of these stemmed from the failure to seat 16-in casing into a hole of 18½-in bore. This required us to adapt our operations plans rapidly and led us to complete Hole 1243A by drilling with an 18½-in rotary bit without coring. We then cemented 10¾-in casing in place to minimize risk to the integrity of the hole. To do so required the largest cementing job yet attempted by ODP into a formation that proved, near the bottom of the hole, to be porous and fractured.

That this primary objective was achieved so rapidly in the face of this technical challenge is a tribute to the responsiveness and skills of the operations team and rig crew. The decision to case Hole 1243A was made in tandem with the decision to follow cementing of the casing with a trip out and relocation of the ship 600 m east to a location shown in the Leg 203 seismic survey to be equivalent to Hole 1243A in terms of sediment cover and seismic structure. We jetted in at this location (Hole 1243B) to just above the sediment/basement interface and carried out RCB coring through 85 m of basement, achieving a recovery rate of 25% in 10- to 12-Ma mildly altered pillow basalt. This was followed by logging, using triple combo and FMS-sonic tool strings, and by a WST in a VSP configuration. Data were collected successfully. In the case of the first two tool strings, multiple trips to authenticate measurements were possible. The ship was relocated to Hole 1243A, and logs were obtained to confirm that the inclination of the hole was within tolerances for the future seismic package and that the cement bond quality was acceptable. Both conditions were found to be the case.

The rocks recovered from Hole 1243B were largely from pillow basalts and comprised both aphyric and sparsely plagioclase and olivine phyric basalts. Eight lithologic (basement) units were identified, of which seven were igneous and one (lithologic Unit 2) was represented by a single piece of limestone. There was no evidence of thicker massive lava flows in the material recovered or in the log analyses. All igneous units are tholeiitic with the exception of lithologic Unit 4, which consists of alkali basalt. The compressional seismic velocities measured in the samples were high, with a mean of 5.26 km/s. Although the sonic log and VSP velocities were lower, they were consistent with increasing integration of cracks and joints in the increasing wavelengths of the techniques applied. Paleomagnetic measurements indicate that the basaltic cores recovered from Hole 1243B, after the removal of the drilling-induced remagnetization, recorded a stable component of magnetization with both normal and possibly reversed inclinations.

Drilling in Hole 1243A met the objectives of Leg 203. We have a complete cased and cemented legacy hole penetrating nearly 100 m of basement for the installation of broadband seismometers in a future observatory. We have accomplished this in an area of considerable interest to other disciplines in the earth and ocean sciences, with the prospect of providing the infrastructure for a future DEOS multidisciplinary observatory. In addition, we were able to recover basalts in the upper oceanic crust in fast-spreading, young lithosphere in the Pacific, well in excess of the depth drilled during most previous legs.

REFERENCES

Adams, R.M., Bryant, K.J., McCarl, B.A., Legler, D.M., O'Brien, J., Solow, A., and Weiher, R., 1995. Value of improved long-range weather information. *Cont. Econ. Pol.,* 13:10–19.

Arrhenius, G., 1952. Sediment cores from the East Pacific. *In* Pettersson, H. (Ed.), *Rep. Swed. Deep-Sea Exped., 1947–1948,* 5:189–201.

Berger, W.H., 1972. Deep-sea carbonates: dissolution facies and age depth constancy. *Nature,* 236:392–395.

————, 1973. Cenozoic sedimentation in the eastern tropical Pacific. *Geol. Soc. Am. Bull.,* 84:1941–1954.

Berger, W.H., and Winterer, E.L., 1974. Plate stratigraphy and the fluctuating carbonate line. *In* Hsü, K.J., and Jenkyns, H.C. (Eds.), *Pelagic Sediments on Land and under the Sea.* Spec. Publ.—Int. Assoc. Sedimentol., 1:11–48.

Bramlette, M.N., 1961. Pelagic sediments. *In* Sears, M. (Ed.), *Oceanography.* Am. Assoc. Adv. Sci. Publ., 67:345–366.

Collins, J.A., Vernon, F.L., Orcutt, J.A., Stephen, R.A., Peal, K.R., Wooding, F.B., Spiess, F.N., and Hildebrand, J.A., 2001. Broadband seismology in the oceans: lessons from the Ocean Seismic Network pilot experiment. *Geophys. Res. Lett.,* 28:49–52.

Dick, H.J.B., and Mével, C.A., (Eds.) 1996. *The Ocean Lithosphere and Scientific Drilling into the 21st Century:* Durham, UK (InterRidge).

Forsyth, D., Dziewonski, A., and Romanowicz, B., 1995. Scientific objectives and required instrumentation. *In* Purdy, G.M., and Orcutt, J.A. (Eds.), *Broadband Seismology in the Oceans—Towards a Five-Year Plan:* Washington, D.C. (Joint Oceanographic Institutions), 8–18.

JOIDES Planning Committee, 1996. *Understanding our Dynamic Earth through Ocean Drilling: Ocean Drilling Program Long Range Plan into the 21st Century:* Washington, D.C. (JOI).

Kolbe, R.W., 1955. Diatoms from equatorial Atlantic cores. *Rep. Swed. Deep-Sea Exped., 1947–1948,* 7:149–184.

Menard, H.W., 1964. *Marine Geology of the Pacific:* New York (McGraw-Hill).

Parker, R.L., and Oldenburg, D.W., 1973. Thermal model of ocean ridges. *Nature,* 242:137–139.

Pringle, M.S., Sager, W.W., Sliter, W.V., and Stein, S. (Eds.), 1993. *The Mesozoic Pacific: Geology, Tectonics, and Volcanism.* Geophys. Monogr., Am. Geophys. Union, 77.

Purdy, G.M., 1995. A five year plan. *In* Purdy, G.M., and Orcutt, J.A. (Eds.), *Broadband Seismology in the Oceans—Towards a Five-Year Plan:* Washington, D.C. (Joint Oceanographic Institutions), 68–75.

Raitt, R.W., 1963. The crustal rocks. *In* Hill, M.N. (Ed.), *The Sea—Ideas and Observations on Progress in the Study of the Seas* (Vol. 3): *The Earth Beneath the Sea:* New York (Wiley-Interscience), 85–102.

Shipboard Scientific Party, 1992. Introduction. *In* Mayer, L., Pisias, N., Janecek, T., et al., *Proc. ODP, Init. Repts.,* 138 (Pt. 1): College Station, TX (Ocean Drilling Program), 5–12.

Stephen, R.A., Collins, J.A., and Peal, K.R., 1999. Seafloor seismic stations perform well. *Eos,* 80:592.

Winterer, E.L., 1973. Sedimentary facies and plate tectonics of the equatorial Pacific. *AAPG Bull.,* 57:265–282.

TABLE AND FIGURE CAPTIONS

Table T1. Summary of holes drilled in Pacific fast spreading crust.

Figure F1. Artist's renderings of deepwater Dynamics of Earth and Ocean Systems (DEOS) observatory buoys resulting from (**A**) 2001 United States (US) National Science Foundation (NSF)-supported DEOS design study and (**B**) 2001 United Kingdom (UK) Natural Environment Research Council (NERC)-supported DEOS design study. Both buoys and mooring systems are designed to provide stable, multiyear to decadal-scale support for long-term observatory measurements at the air/sea interface, within the water column, on the seafloor, and below. They are designed to maintain better than 95% quality of service of continuous medium bandwidth bidirectional satellite telemetry to shore stations and, through them, the Internet. They also generate 1.5–2.0 kw of continuous electrical power at the sea surface using (A) multiple diesel and (B) diesel or fuel-cell technologies. The US design is a spar buoy with three-point mooring optimized for deepwater deployment in tropical through temperate climates. The UK design is a hybrid design with two-point mooring optimized for deepwater deployment in particularly harsh extreme northern and southern latitudes.

Figure F2. Location of Site 1243 (Ocean Seismic Network [OSN]-2; star) is shown superimposed on a free-air gravity-anomaly map derived from Geosat and ERS-1 data (courtesy of David Sandwell and Walter Smith). Other sites shown are the Hawaii-2 Observatory (H2O; diamond), where an observatory hole was drilled during Leg 200 (Hole 1224D) (the OSN-1 observatory), where a hole was drilled and cased during Leg 138 (Hole 843B), and the notional site (circle) proposed by International Ocean Network (ION)/OSN documents to fill a coverage gap west of the Galapagos Islands. Hole 1243A replaces the notional site and fills the gap for the region. Additional second priority ION/OSN notional sites lie between Sites H2O and OSN-2.

Figure F3. The proposed drilling site for Leg 203 (solid circle) superimposed on a tectonic map of the world.

Figure F4. Deployment of a borehole seismometer within a cased ODP hole with a reentry cone using a wireline reentry system.

Figure F5. Generalized circulation of the eastern equatorial Pacific showing surface currents (solid arrows), subsurface currents (dashed arrows), California Current (CAC), North Equatorial Current (NEC), North Equatorial Countercurrent (NECC), Equatorial Undercurrent (EUC), South Equatorial Current (SEC), Chile Current (CHC), and Peru Current (PC). Shaded areas illustrate the general latitudinal extent of the SEC and NEC. Solid circles = Leg 138 sites (Site 1243A is very near Site 852). Modified from figure 1 of Shipboard Scientific Party (1992).

Figure F6. **A, B.** Dynamic sea height from satellite altimetry superimposed upon the wind field for a recent period. The residual shows the different current regimes.

Figure F7. **A.** Ekman velocity from satellite scatterometer measurements. **B.** Geostrophic currents from Topex/Poseidon. **C.** The sum of the currents box superimposed upon sea-surface temperature anomalies (SSTA). The surface currents in the vicinity of Site 1243 (OSN-2) are ≈1 kt. The Equatorial Countercurrent is well to the south. QuikSCAT data courtesy of M. Bourassa, Center for Ocean-Atmospheric Prediction Studies/Florida State University. Topex/Posiedon sea surface height (SSHgt) analysis courtesy of L. Miller, NOAA. Sea-surface temperature data courtesy of R. Reynolds, NOAA. Surface velocity calculation courtesy of G. Lagerloef and J. Gunn, Earth and Space Research (**www.esr.org**).

Figure F8. Sediment thickness along the 110°W transect collected during the *Thomas Washington* Venture I cruise. The locations of the various drill sites shown in Figure F9 are superimposed. TWT = two-way traveltime.

Figure F9. Vertical component spectra from the seafloor, buried, and borehole installations at Ocean Seismic Network (OSN)-1 are compared with the spectra from the buried installation at Hawaii-2 Observatory (H2O) and the Kipapa, Hawaii (KIP) GSN station on Oahu. Site H2O has extremely low noise levels above 5 Hz and near the microseism peak from 0.1 to 0.3 Hz. Site H2O has high noise levels below 50 mHz. Otherwise, Site H2O levels are comparable to the OSN borehole and KIP levels. The sediment resonances at Site H2O near 1 and 3 Hz are very prominent.

Figure F10. Horizontal component spectra from the seafloor, buried, and borehole installations at Ocean Seismic Network (OSN)-1 are compared with the spectra from the buried installation at Hawaii-2 Observatory (H2O) and the Kipapa, Hawaii (KIP) GSN station on Oahu. The sediment resonance peaks in the 0.3–8 Hz band are up to 35 dB louder than background and far exceed the microseism peak at 0.1–0.3 Hz. The fact that the resonant peaks are considerably higher for horizontal components than for the vertical component is consistent with the notion that these are related to shear wave resonances (Scholte modes).

Figure F11. Track chart for the Ocean Seismic Network (OSN)-2 site survey. WP = way point.

Figure F12. Lines 5–6 (see Fig. F11) from the site survey, migrated, showing the locations of Holes 1243A and 1243B. UTC = Universal Time Coordinated.

Figure F13. Schematic representation of Hole 1243A.

Figure F14. Basement lithology from Hole 1243B. T.D. = total depth.

Figure F15. Physical properties of basalt samples recovered from Hole 1243B. **A.** Wet bulk density vs. porosity. **B.** Porosity vs. grain density. **C.** Wet bulk density vs. grain density. **D.** Sonic velocity vs. wet bulk density. **E.** Sonic velocity vs. porosity. **F.** Sonic velocity vs. grain density.

Figure F16. Composite plot of downhole measurements in the sediment and basement section of Hole 1243B. The core lithology has been shifted down 6.3 m to match the logging-derived depths. gAPI = American Petroleum Institute gamma ray units, IDPH = deep induction phasor-processed resistivity, IMPH = medium induction phasor-processed resistivity, SFLU = spherically focused resistivity measurement, DTCO = Delta-T *P*-wave, DTSM = Delta-T *S*-wave.

Figure F17. Porosities and measured sonic velocities in basalt samples recovered from Hole 1243B, plotted with the downhole sonic log and interval velocities computed from the WST survey. Also shown is the lithostratigraphy column. Logging and Well Seismic Tool (WST) depths have been adjusted to the coring depths. s.e. = standard error, T.D. = total depth.

Figure F18. Downhole caliper log from Hole 1243B.

Table T1. Summary of holes drilled in Pacific fast-spreading crust.

Site/Hole	Leg	Age (Ma)	Location	Basement penetration (m)	Sediment thickness (m)
163	DSDP 16	72	11°N, 150°W	18	176
420	DSDP 54	3.4	9°N, 106°W	29	118
421	DSDP 54	3.4	9°N, 106°W	29	85
429A	DSDP 54	4.6	9°N, 107°W	21	31
469*	DSDP 63	17	33°N, 121°W	58	391
470A	DSDP 63	15	29°N, 118°W	48	167
471	DSDP 63	12	23°N, 112°W	82	741
472	DSDP 63	15	23°N, 114°W	25	112
483B	DSDP 65	1.7	23°N, 109°W	157	110
597B**	DSDP 92	29	19°S, 130°W	25	48
597C‡	DSDP 92	29	19°S, 130°W	91	53
599B	DSDP 92	8	19°S, 120°W	10	41
843B**	ODP 136	95	19°N, 159°W	71	243
1224D††	ODP 200	46	28°N, 142°W	36	29
1224F	ODP 200	46	28°N, 142°W	145	29
1243A‡‡	ODP 203	12	18°N, 110°W	107	117
1243B	ODP 203	12	18°N, 110°W	85	113

Notes: * = foot of Patton Escarpment, † = fast spreading rate (55 mm/m.y.), ‡ = reentry cone, ** = OSN-1, †† = H2O, ‡‡ = OSN-2. DSDP = Deep Sea Drilling Project, ODP = Ocean Drilling Program.

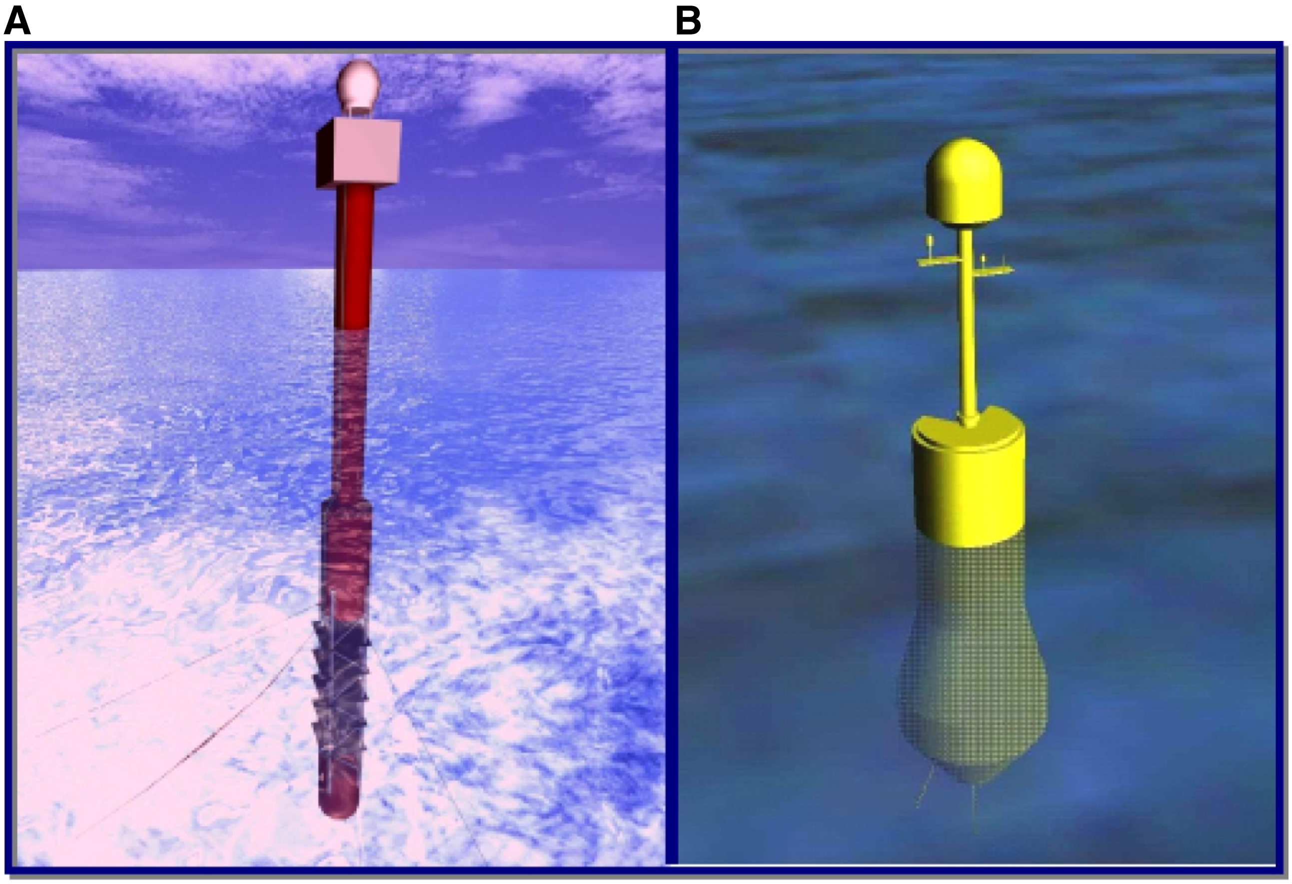

Figure F1

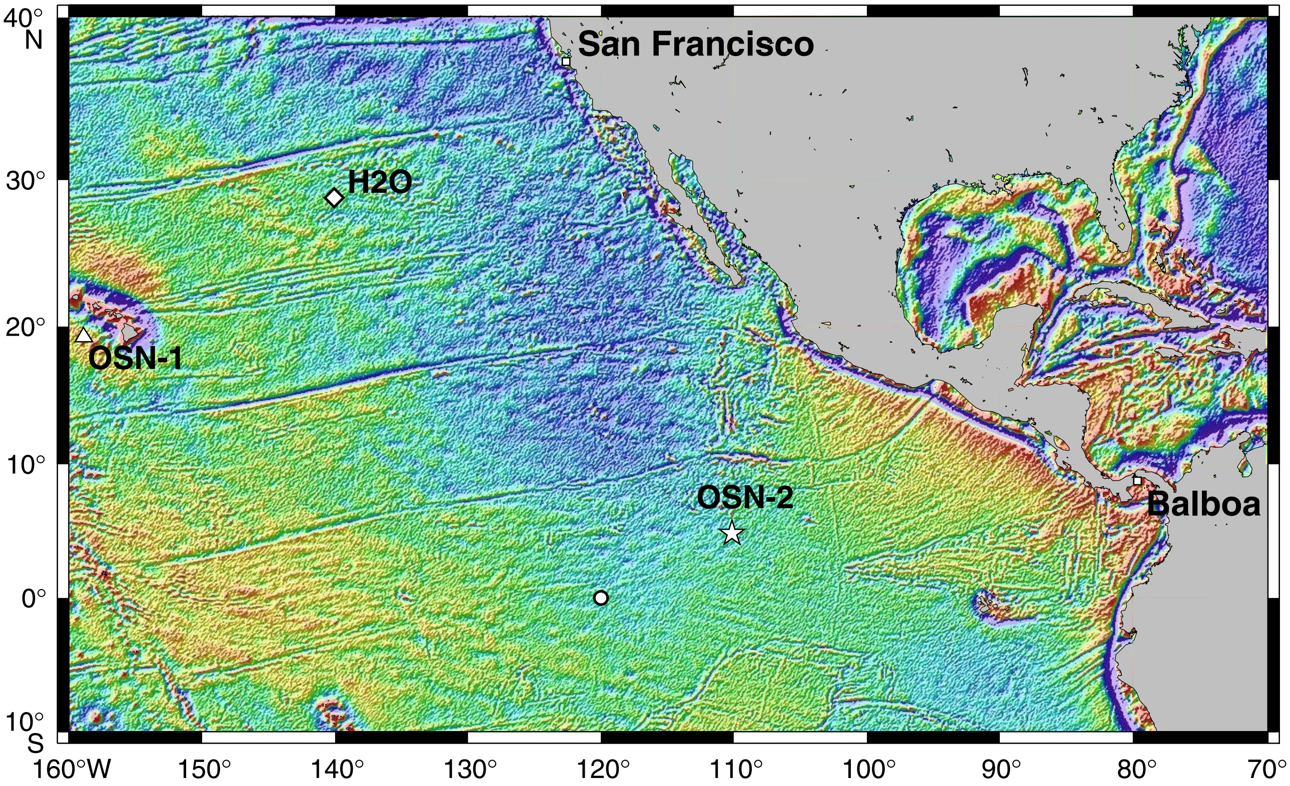
San Francisco
H2O
OSN-1
OSN-2
Balboa
40° N
30°
20°
10°
0°
10° S
160°W
150°
140°
130°
120°
110°
100°
90°
80°
70°

Figure F2

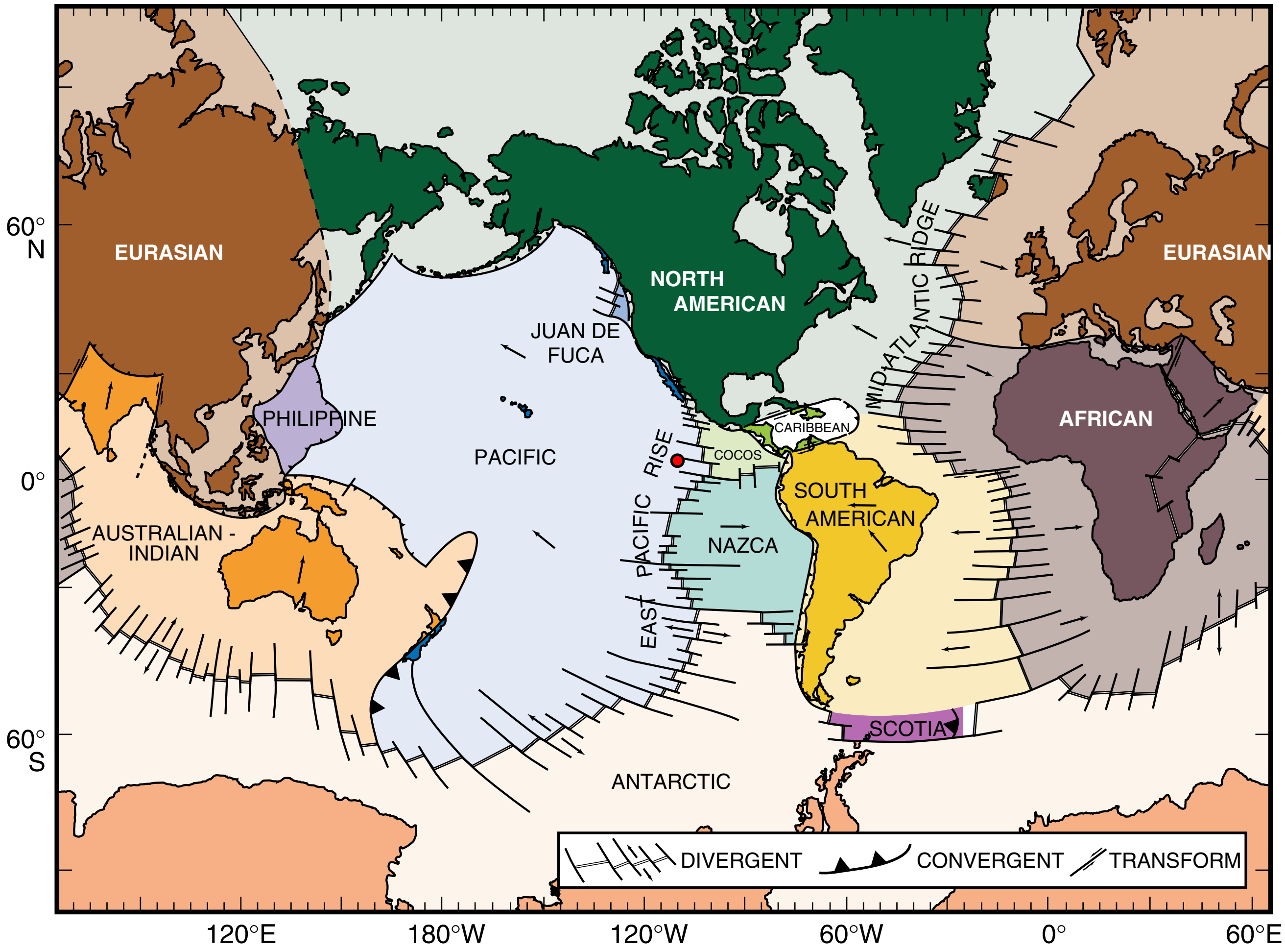
EURASIAN
NORTH AMERICAN
EURASIAN
JUAN DE FUCA
PHILIPPINE
CARIBBEAN
AFRICAN
PACIFIC
COCOS
EAST PACIFIC RISE
SOUTH AMERICAN
AUSTRALIAN - INDIAN
NAZCA
MID-ATLANTIC RIDGE
SCOTIA
ANTARCTIC
DIVERGENT
CONVERGENT
TRANSFORM
60° N
0°
60° S
120°E
180°W
120°W
60°W
0°
60°E

Figure F3

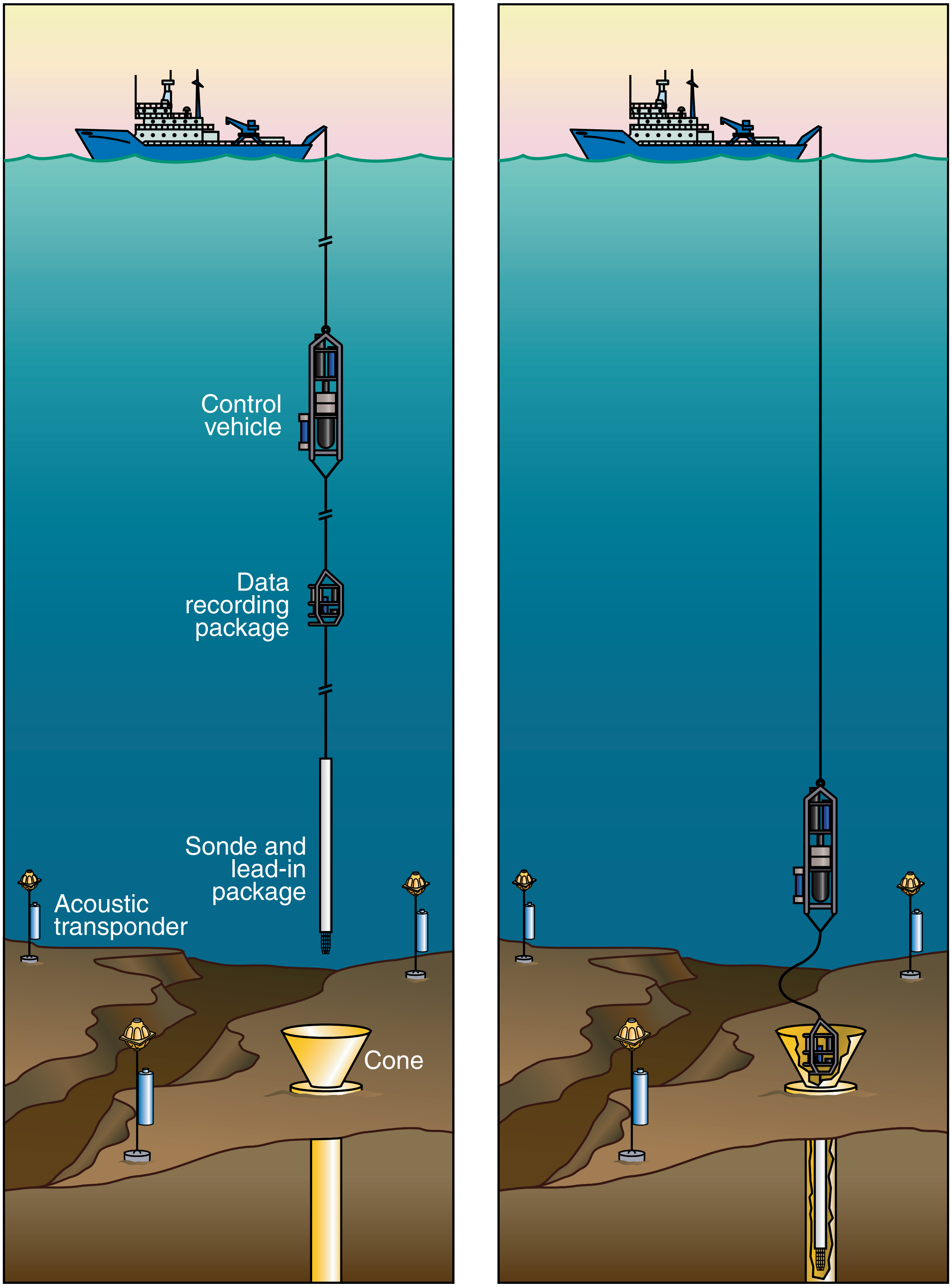
Control vehicle
Data recording package
Sonde and lead-in package
Acoustic transponder
Cone

Figure F4

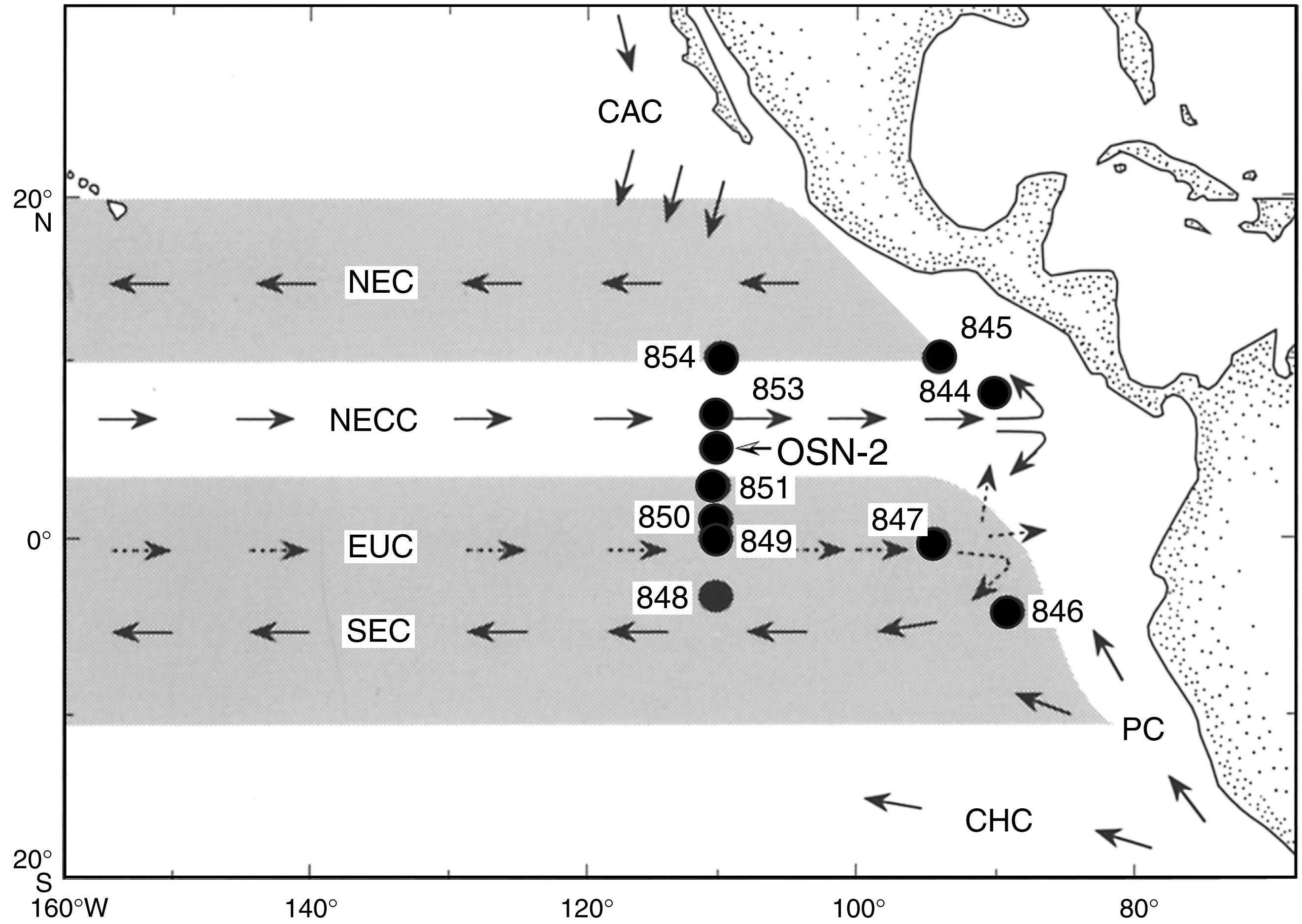
CAC
NEC
NECC
EUC
SEC
PC
CHC
854
853
OSN-2
851
850
849
848
845
844
847
846
20°
N
0°
20°
S
160°W
140°
120°
100°
80°

Figure F5

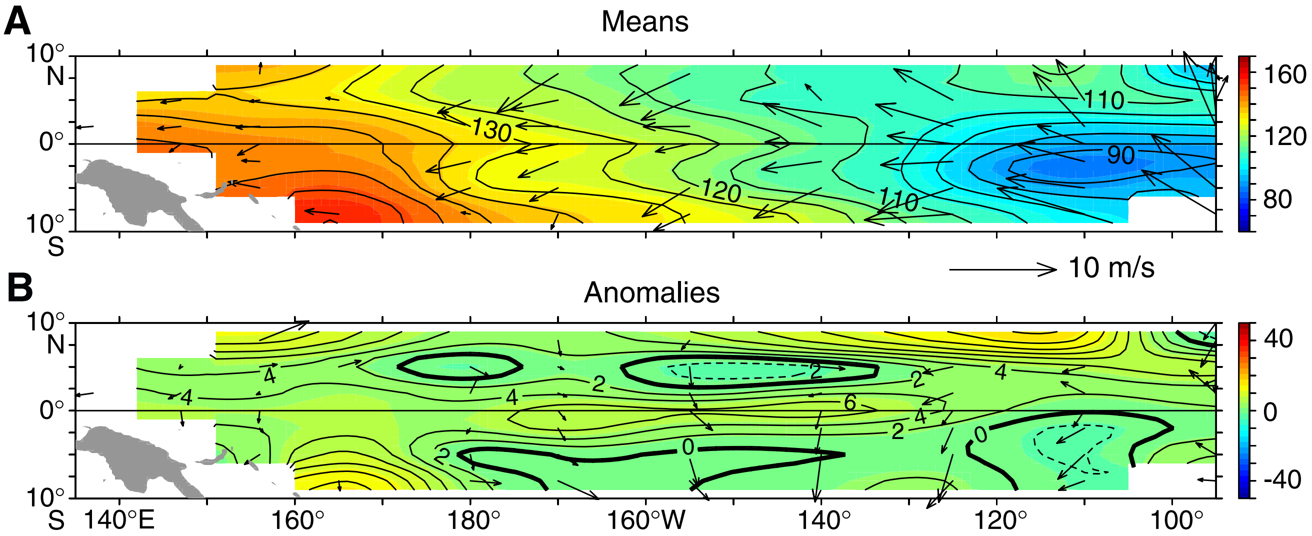
A
Means
10°
N
0°
10°
S
130
120
110
110
90
160
120
80
10 m/s
B
Anomalies
10°
N
0°
10°
S
4
4
2
4
2
6
4
2
4
2
0
0
40
0
-40
140°E
160°
180°
160°W
140°
120°
100°

Figure F6

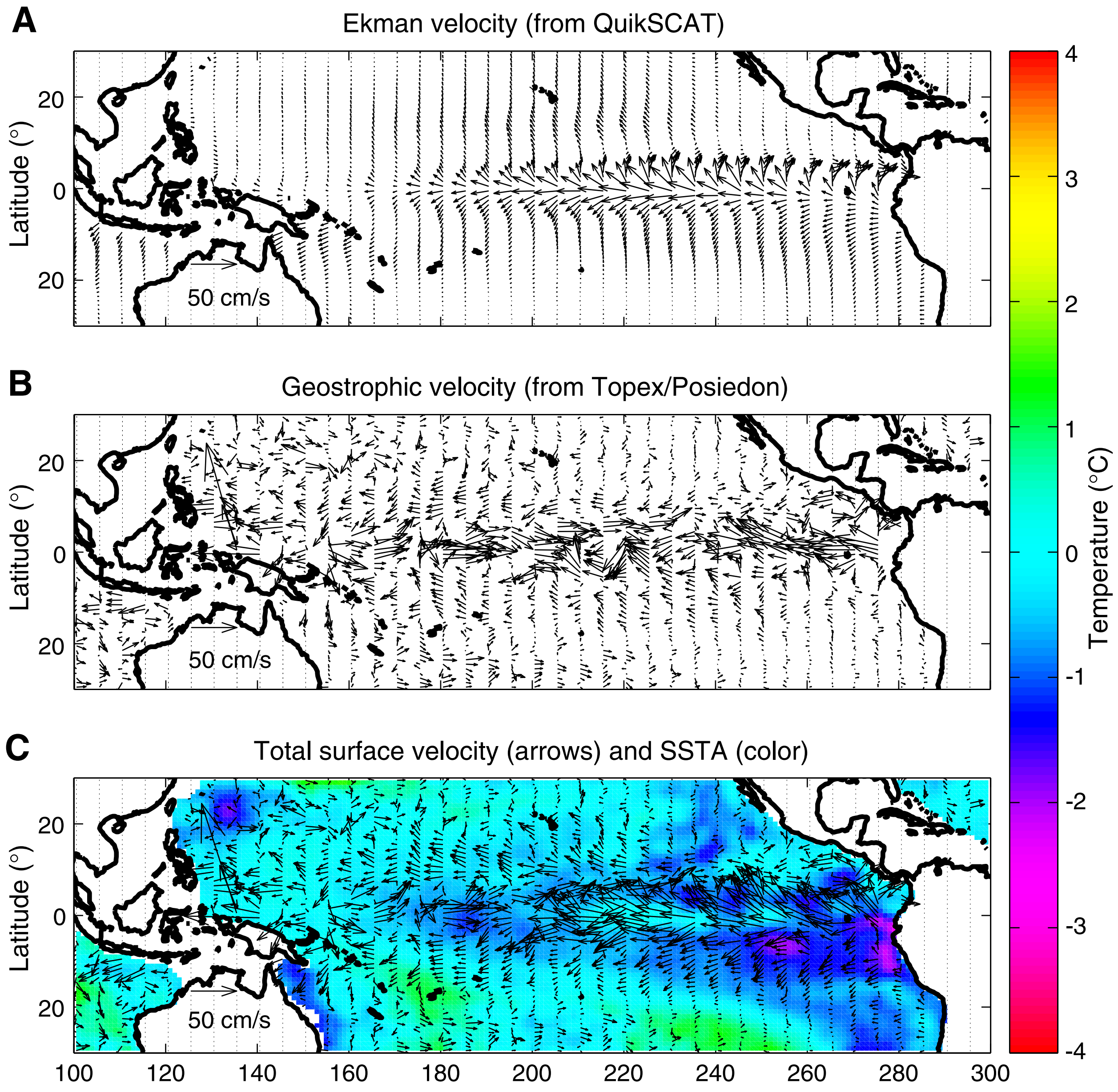
A
Ekman velocity (from QuikSCAT)
B
Geostrophic velocity (from Topex/Posiedon)
C
Total surface velocity (arrows) and SSTA (color)
Latitude (°)
20
0
20
50 cm/s
100
120
140
160
180
200
220
240
260
280
300
Temperature (°C)
4
3
2
1
0
-1
-2
-3
-4

Figure F7

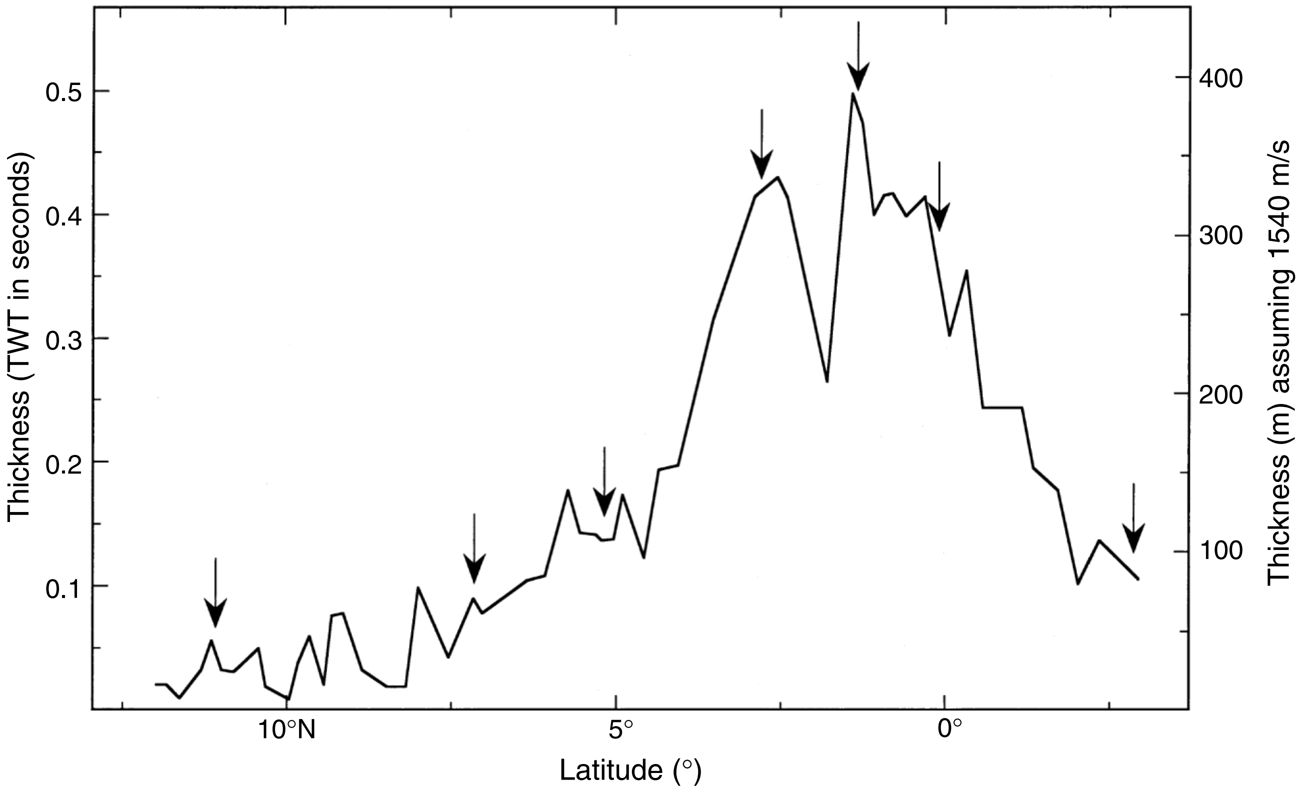
Thickness (TWT in seconds)
0.5
0.4
0.3
0.2
0.1
Thickness (m) assuming 1540 m/s
400
300
200
100
10°N
5°
0°
Latitude (°)

Figure F8

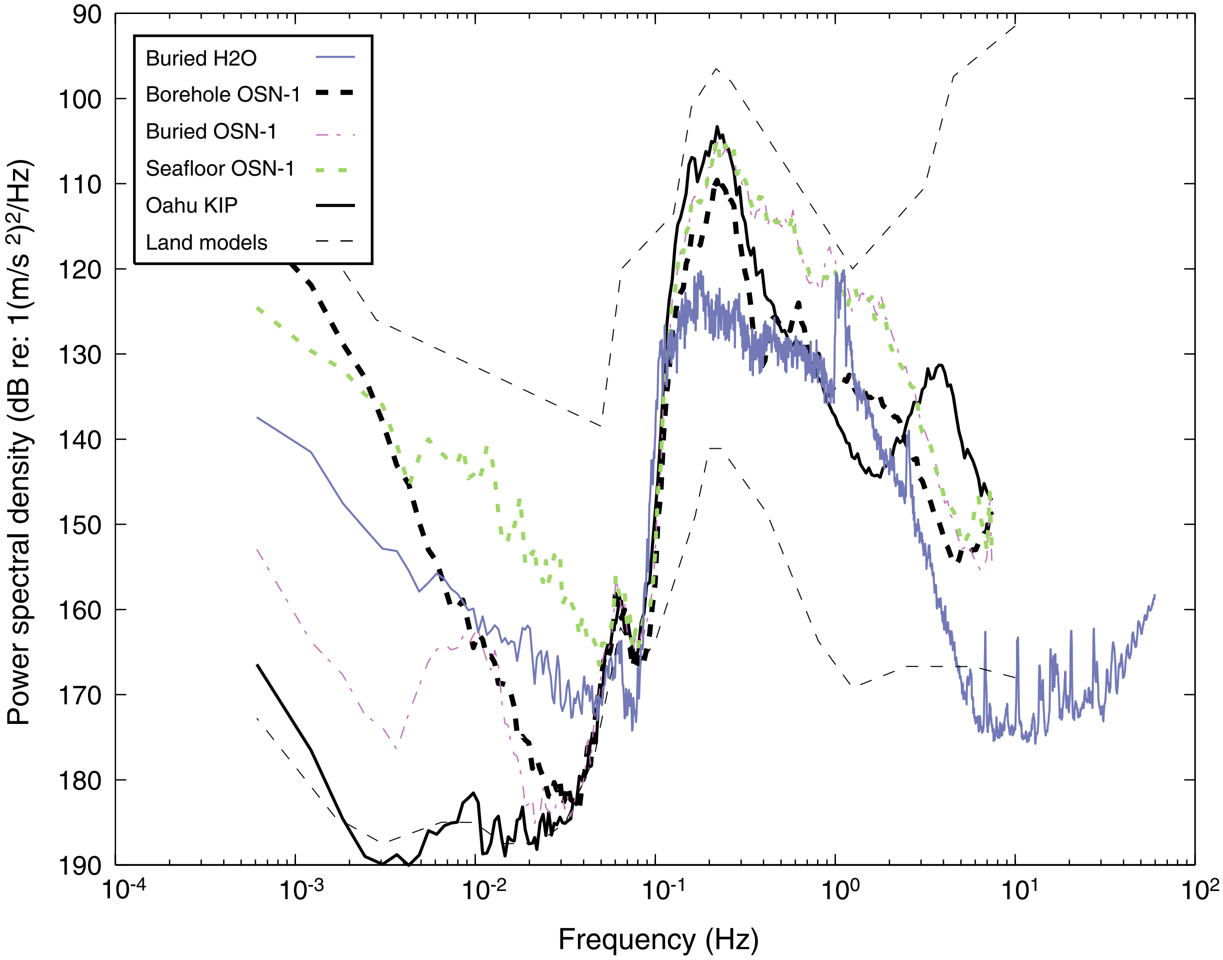
Buried H2O
Borehole OSN-1
Buried OSN-1
Seafloor OSN-1
Oahu KIP
Land models
90
100
110
120
130
140
150
160
170
180
190
Power spectral density (dB re: 1(m/s ²)²/Hz)
10⁻⁴
10⁻³
10⁻²
10⁻¹
10⁰
10¹
10²
Frequency (Hz)

Figure F9

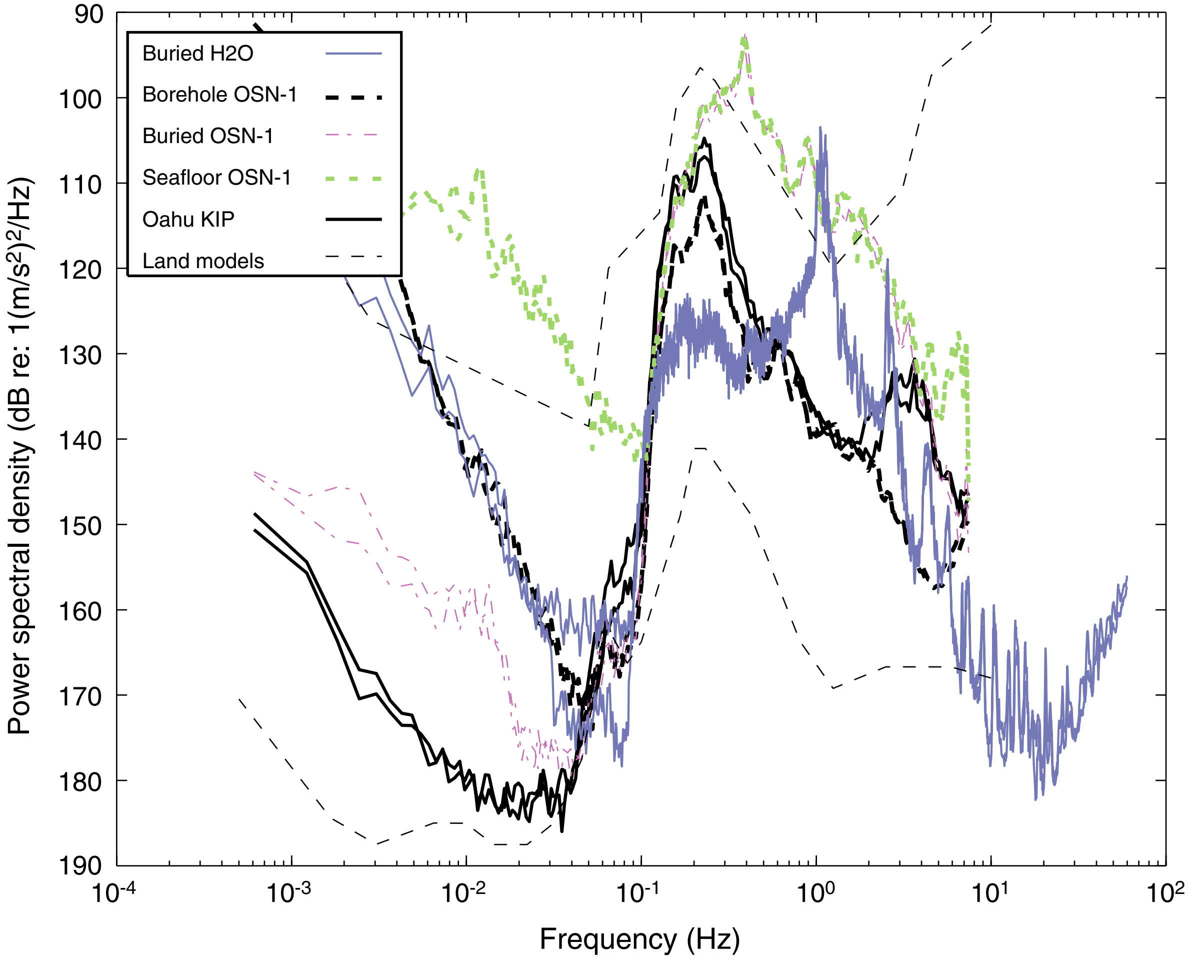
Buried H2O
Borehole OSN-1
Buried OSN-1
Seafloor OSN-1
Oahu KIP
Land models
Power spectral density (dB re: 1(m/s^2)^2/Hz)
90
100
110
120
130
140
150
160
170
180
190
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency (Hz)

Figure F10

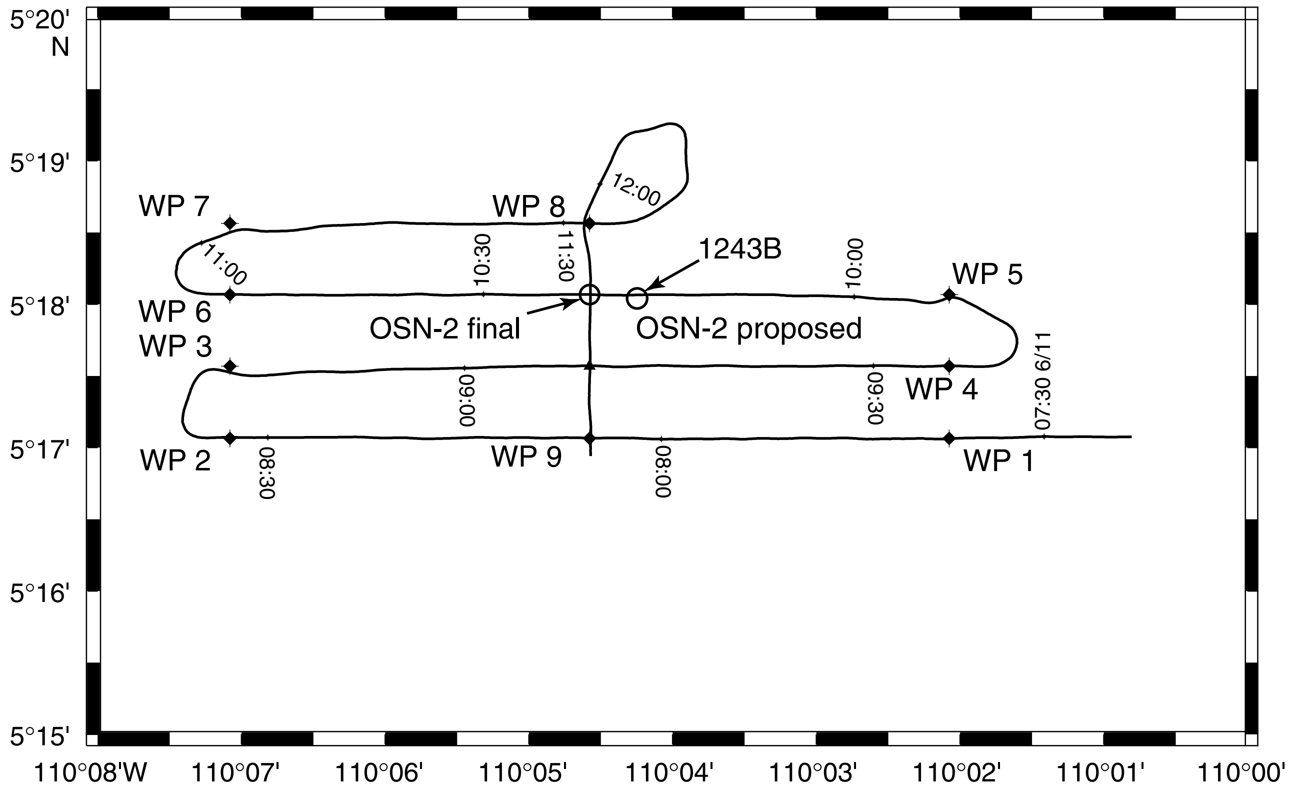
5°20' N
5°19'
5°18'
5°17'
5°16'
5°15'
110°08'W
110°07'
110°06'
110°05'
110°04'
110°03'
110°02'
110°01'
110°00'
WP 1
WP 2
WP 3
WP 4
WP 5
WP 6
WP 7
WP 8
WP 9
1243B
OSN-2 final
OSN-2 proposed
07:30 6/11
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
12:00

Figure F11

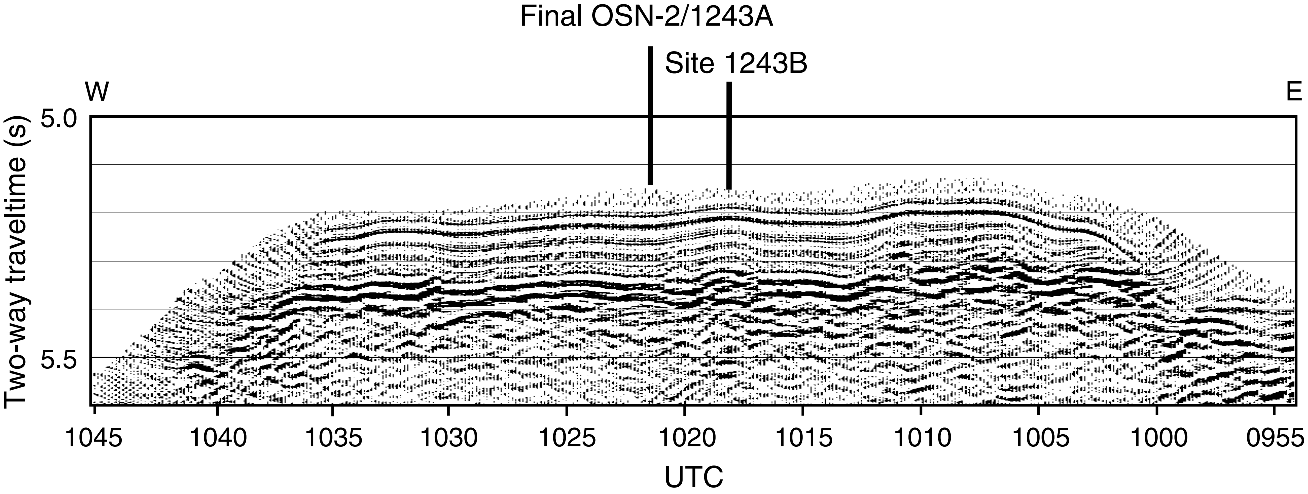
Final OSN-2/1243A
Site 1243B
W
E
Two-way traveltime (s)
5.0
5.5
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
0955
UTC

Figure F12

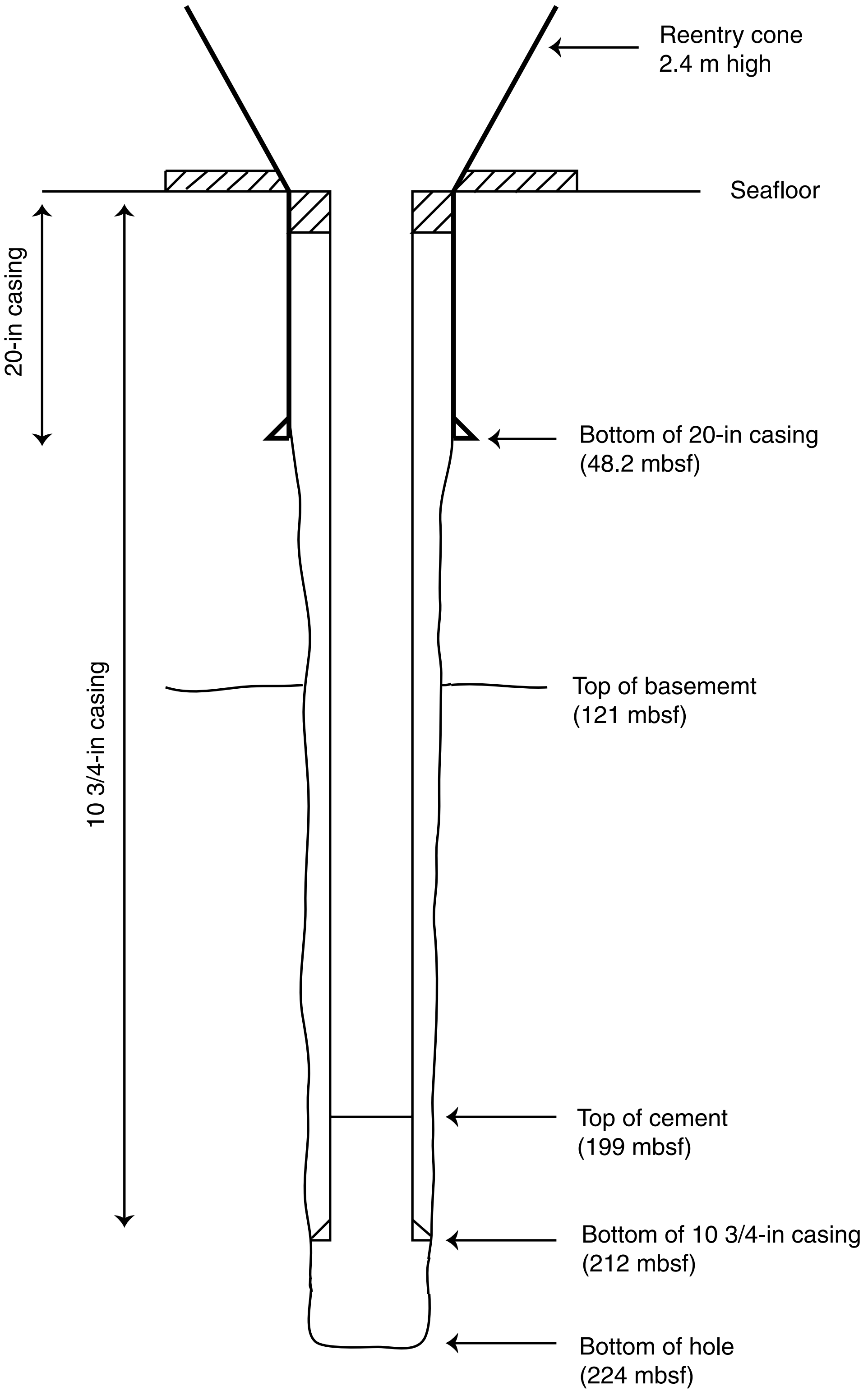
Reentry cone
2.4 m high
Seafloor
20-in casing
10 3/4-in casing
Bottom of 20-in casing
(48.2 mbsf)
Top of basememt
(121 mbsf)
Top of cement
(199 mbsf)
Bottom of 10 3/4-in casing
(212 mbsf)
Bottom of hole
(224 mbsf)

Figure F13

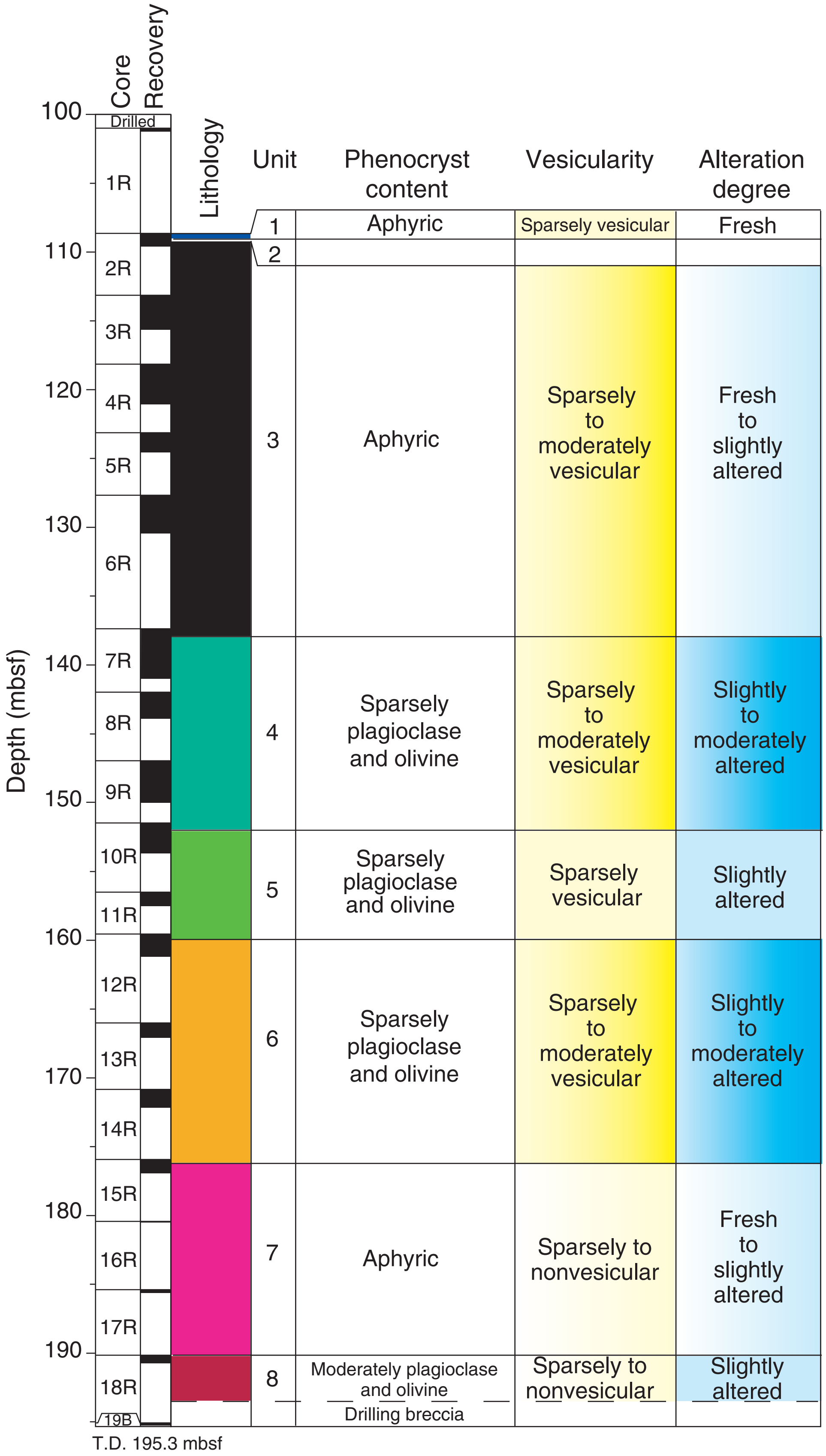
Core
Recovery
Lithology
Unit
Phenocryst content
Vesicularity
Alteration degree
Depth (mbsf)
100
110
120
130
140
150
160
170
180
190
Drilled
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
18R
19B
1
Aphyric
Sparsely vesicular
Fresh
2
3
Aphyric
Sparsely to moderately vesicular
Fresh to slightly altered
4
Sparsely plagioclase and olivine
Sparsely to moderately vesicular
Slightly to moderately altered
5
Sparsely plagioclase and olivine
Sparsely vesicular
Slightly altered
6
Sparsely plagioclase and olivine
Sparsely to moderately vesicular
Slightly to moderately altered
7
Aphyric
Sparsely to nonvesicular
Fresh to slightly altered
8
Moderately plagioclase and olivine
Sparsely to nonvesicular
Slightly altered
Drilling breccia
T.D. 195.3 mbsf

Figure F14

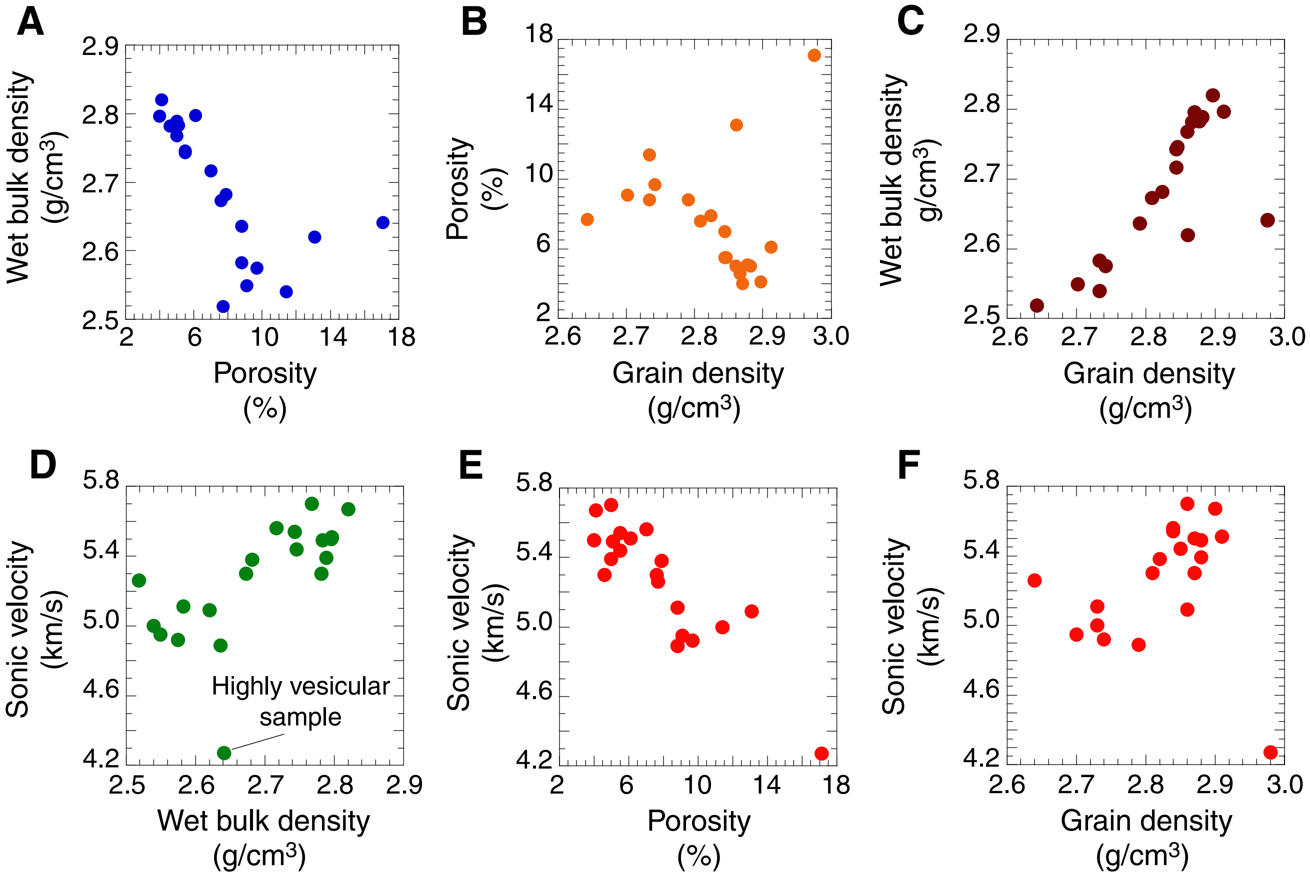
A
Wet bulk density
(g/cm^3)
2.9
2.8
2.7
2.6
2.5
2
6
10
14
18
Porosity
(%)
B
Porosity
(%)
18
14
10
6
2
2.6
2.7
2.8
2.9
3.0
Grain density
(g/cm^3)
C
Wet bulk density
g/cm^3)
2.9
2.8
2.7
2.6
2.5
2.6
2.7
2.8
2.9
3.0
Grain density
(g/cm^3)
D
Sonic velocity
(km/s)
5.8
5.4
5.0
4.6
4.2
2.5
2.6
2.7
2.8
2.9
Wet bulk density
(g/cm^3)
Highly vesicular
sample
E
Sonic velocity
(km/s)
5.8
5.4
5.0
4.6
4.2
2
6
10
14
18
Porosity
(%)
F
Sonic velocity
(km/s)
5.8
5.4
5.0
4.6
4.2
2.6
2.7
2.8
2.9
3.0
Grain density
(g/cm^3)

Figure F15

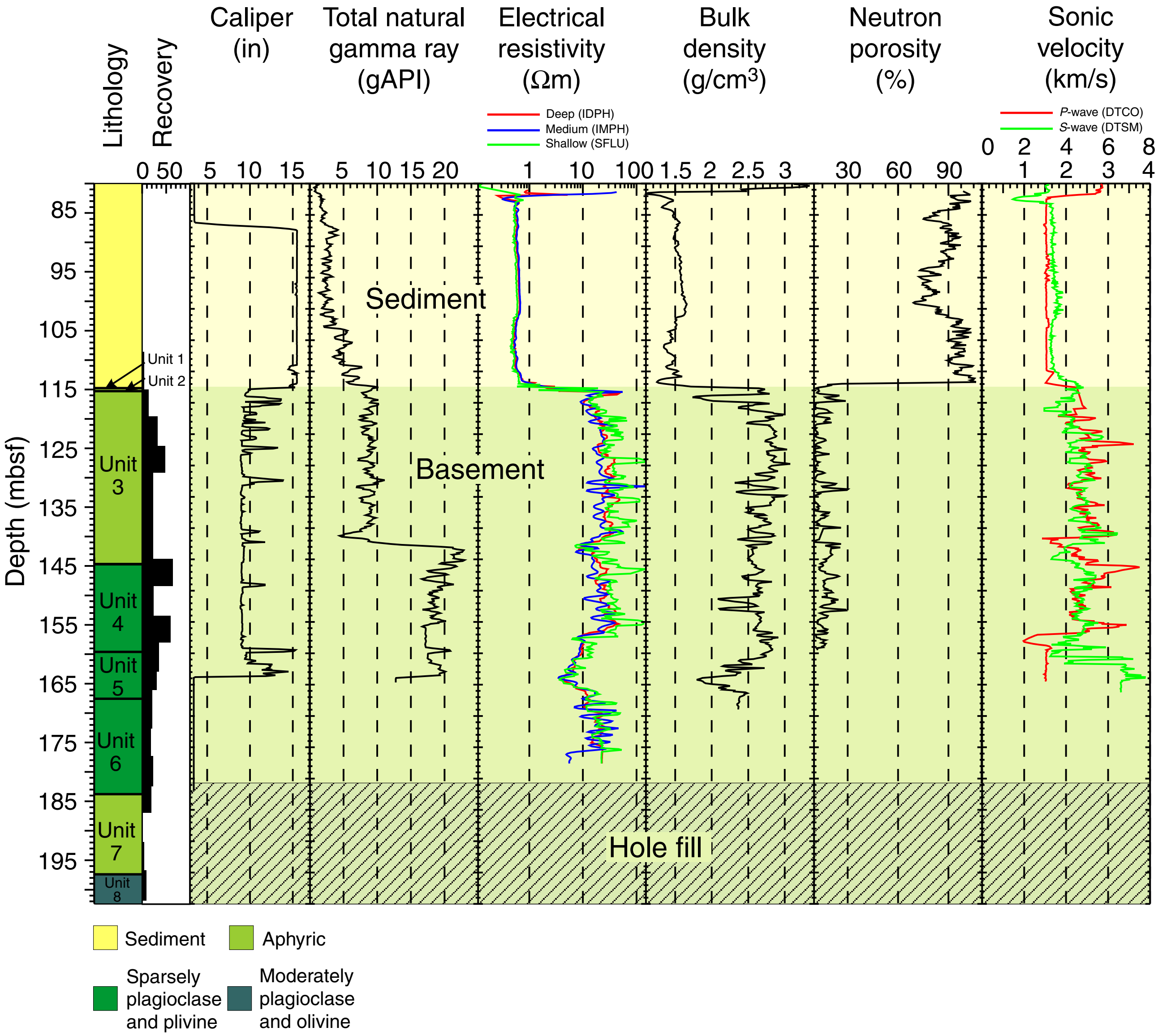
Lithology
Recovery
0 50
Caliper (in)
5 10 15
Total natural gamma ray (gAPI)
5 10 15 20
Electrical resistivity (Ωm)
Deep (IDPH)
Medium (IMPH)
Shallow (SFLU)
1 10 100
Bulk density (g/cm3)
1.5 2 2.5 3
Neutron porosity (%)
30 60 90
Sonic velocity (km/s)
P-wave (DTCO)
S-wave (DTSM)
0 2 4 6 8
1 2 3 4
Depth (mbsf)
85
95
105
115
125
135
145
155
165
175
185
195
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Sediment
Basement
Hole fill
Sediment
Aphyric
Sparsely plagioclase and plivine
Moderately plagioclase and olivine

Figure F16

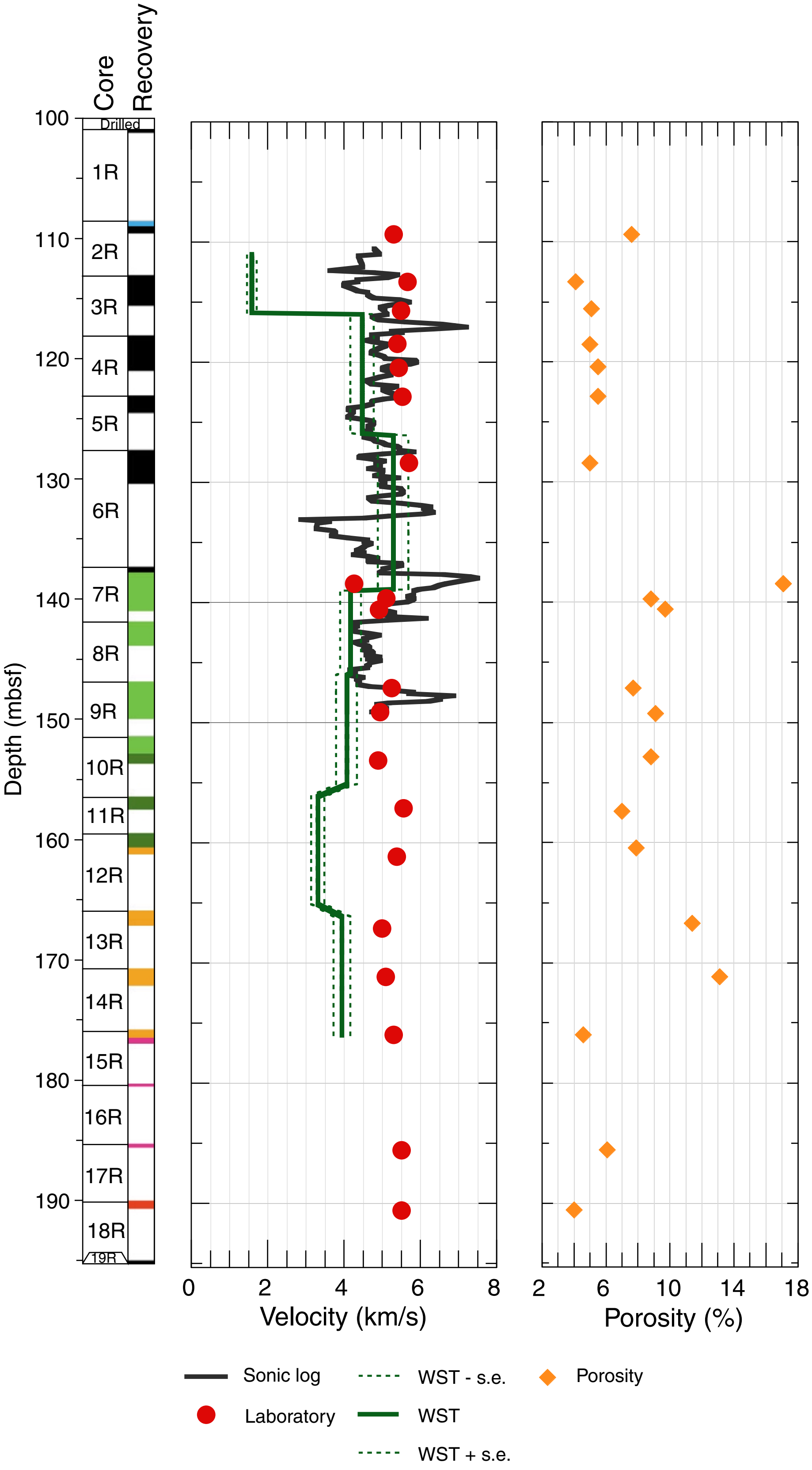
Core
Recovery
Depth (mbsf)
100
110
120
130
140
150
160
170
180
190
Drilled
1R
2R
3R
4R
5R
6R
7R
8R
9R
10R
11R
12R
13R
14R
15R
16R
17R
18R
19R
0
2
4
6
8
Velocity (km/s)
2
6
10
14
18
Porosity (%)
Sonic log
Laboratory
WST - s.e.
WST
WST + s.e.
Porosity

Figure F17

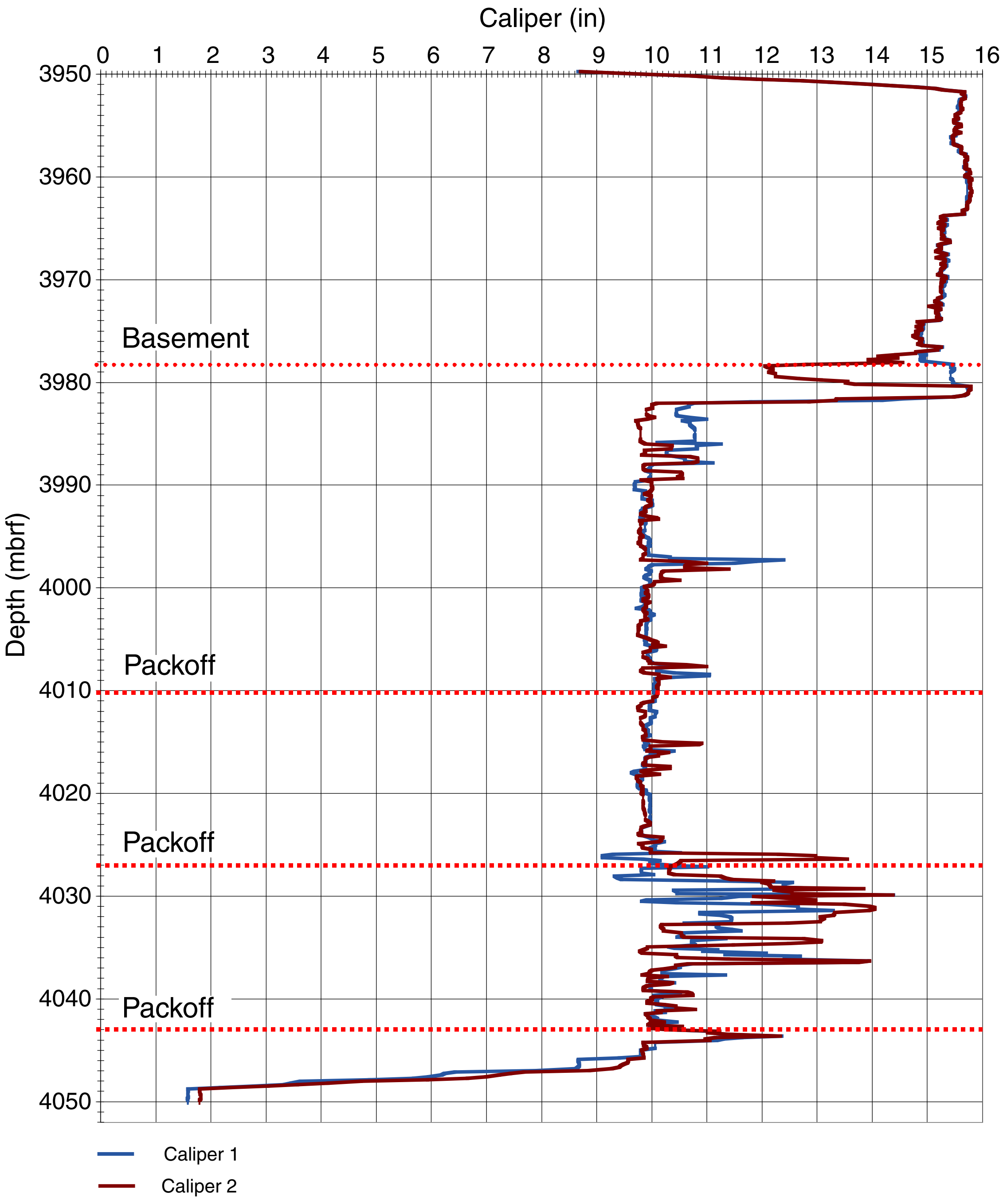
Caliper (in)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Depth (mbrf)
3950
3960
3970
3980
3990
4000
4010
4020
4030
4040
4050
Basement
Packoff
Packoff
Packoff
Caliper 1
Caliper 2

Figure F18