

## 1. LEG 203 SUMMARY<sup>1</sup>

Shipboard Scientific Party<sup>2</sup>

### ABSTRACT

The Leg 203 science program is part of a multidisciplinary project that primarily represents the interests of the National Science Foundation's component of the international Dynamics of Earth and Ocean Systems (DEOS) planning effort, and the International Ocean Network. 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 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 in 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

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<sup>1</sup>Examples of how to reference the whole or part of this volume.

<sup>2</sup>Shipboard Scientific Party addresses.

lithosphere. To satisfy the secondary objective, we drilled a second uncased hole (Hole 1243B; 5°18.0543'N, 110°4.2544'W) fitted with a re-entry 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.

## **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 and temporal 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 sub-systems 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-à-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 and the United Kingdom, 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 for the initial installation of a moored observatory in the 2004–2005 time frame.

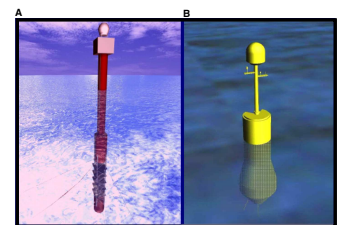
The location of Site 1243 also provided a rare window into the petrology, geochemistry, and paleomagnetic history of fast-spreading 10- to 12-Ma Pacific basement material. During Leg 203, 87 m of basement was cored and logged in Hole 1243B, one of only four Deep Sea Drilling Project (DSDP)/ODP sites 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 is reported in the Leg 203 *Initial Reports* volume.

## GEOLOGIC AND OCEANOGRAPHIC SETTING

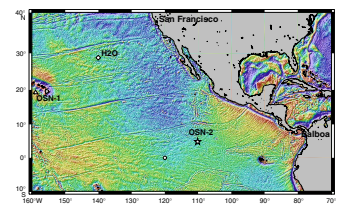
Site 1243 in the eastern equatorial Pacific (Fig. F2) is in a particularly interesting location for understanding the interplay between ocean chemistry, productivity, climate, and plate tectonics in a fast-spreading environment. The climatic implications were studied in detail with a series of 11 holes 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 Hole 1243A (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,

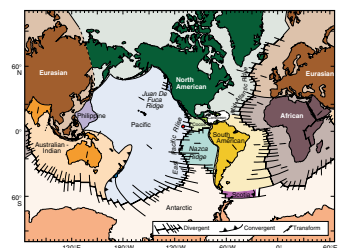
F1. Artist's renderings of deep-water DEOS observatory, p. 15.



F2. Location of Site 1243, p. 16.



F3. The proposed drilling site for Leg 203, p. 17.



the two-way traveltime (TWT) for compressional (*P*-) 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 *P*-wave arrivals.

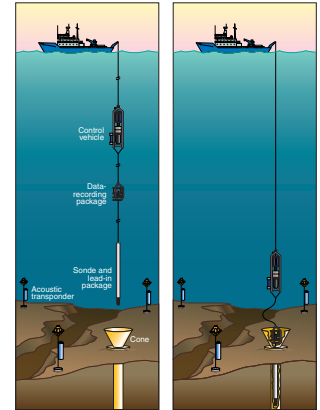
There is every reason to believe that the crustal section at the site is quite typical of Pacific oceanic crust. Figure F4 illustrates the installation of the seismic component of an observatory at site OSN-1 south of Oahu; a similar procedure will be followed at proposed sites for the Hawaii-2 Observatory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

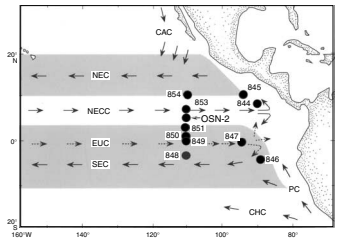
Today, the ITCZ is always north of the equator in the eastern Pacific. The equatorial current system (Fig. F5) is dependent upon the seasons, with the ITCZ at its most northerly position (~10°N) from August to December. Figure F6A illustrates a superposition of the winds on dynamic sea height from satellite 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 in transport throughout the water column.

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 tectonic theory, led to the concept of “plate stratigraphy” (Berger, 1973; Winterer, 1973; Berger and Winterer, 1974),

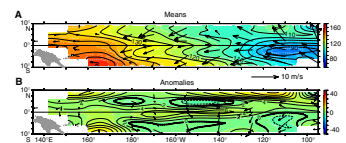
**F4.** Deployment of a borehole seismometer within a cased ODP hole, p. 18.



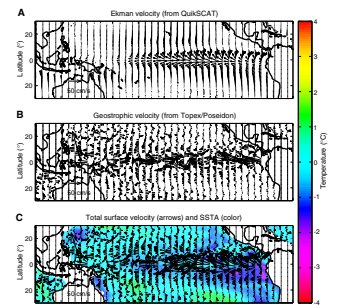
**F5.** Generalized circulation of the eastern equatorial Pacific, p. 19.



**F6.** Dynamic sea height from satellite altimetry, p. 20.



**F7.** Ekman velocity, geostrophic currents, and the sum of the currents box, p. 21.



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 U.S. National Oceanic and Atmospheric Administration (NOAA) 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.

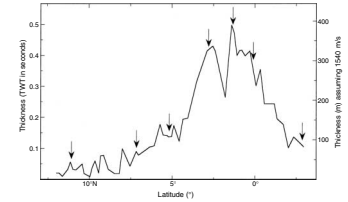
## **SCIENTIFIC OBJECTIVES**

Leg 203 addresses the second of three initiatives outlined in the ODP Long Range Plan—in situ monitoring of geological processes (JOIDES Planning Committee, 1996, pp. 49–51). 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 (JOIDES Planning Committee, 1996, pp. 52–54). The drilling is intimately tied to the use of seafloor observatories (JOIDES Planning Committee, 1996, pp. 63) and represents the partnership of ODP with the DEOS multidisciplinary ocean observatory planning effort in the United States and the United Kingdom 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 U.S. and the U.K. (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 United States, 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.

**F8.** Sediment thickness along the 110°W transect, p. 22.



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 upon 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 U.S.-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 teleseismic and regional 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).

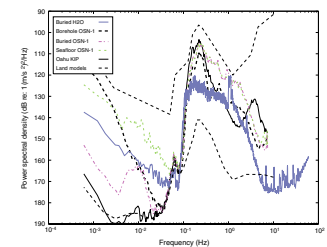
Global seismic tomography provides three-dimensional images of the lateral heterogeneity in the mantle and is essential in addressing fundamental problems in subdisciplines of geodynamics, such as mantle convection, mineral physics, large-scale geoid anomalies, geochemistry of ridge systems, geomagnetism, 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.

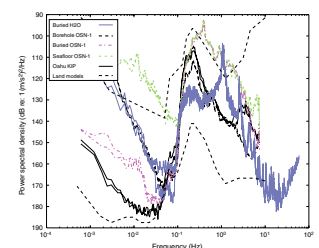
It is intended that the infrastructure to be installed at the observatory site will include the facility for real-time data telemetry and for in situ power generation. Because the equatorial observatory data will be available in real time, data will be incorporated into focal mechanism and centroid moment 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

**F9. Vertical component spectra, OSN-1, p. 23.**



**F10. Horizontal component spectra OSN-1, p. 24.**



10 dB quieter on vertical components and 30 dB quieter on horizontal components (Stephen et al., 1999; Collins et al., 2001). Shear (*S*-) 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, through collection and sharing of infrastructure. 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 provide 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 5 holes during ODP) and 3 holes with >100 m penetration. Furthermore, there are no boreholes off axis in "very fast" spreading crust. Thus, Leg 203 provides a reference section 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 >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 and Mével, 1996).

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**T1.** Holes drilled in Pacific fast-spreading crust, p. 30.

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## 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 to then core with the rotary core barrel (RCB) nearby Hole 1243B. Although we did not achieve crustal penetration to the desired 100 m, we managed to penetrate to 85 m in basement before drilling became too difficult to continue.

The close proximity of Site 1243 to Site 852 permitted 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 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 tool (DLL) 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.

## **PRINCIPAL RESULTS**

### **Cores**

The primary objective of Leg 203 was to drill and case a hole for future installation of an observatory, thus coring was limited to sampling a short section of basement rocks. The modest sample return from cor-

ing 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 85.3 m of basement penetration (based on the drillers estimate of the top of basement). Seventeen cores were taken in this interval. Recovery ranged from 1.6% (Core 203-1243B-16R) to 63.7% (Core 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).

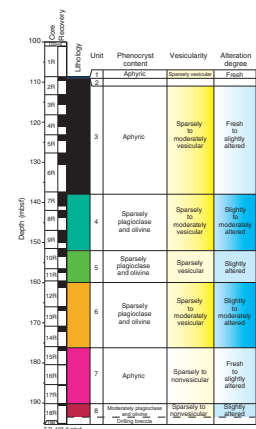
On the basis of hand specimens, thin section descriptions, and shipboard geochemical analyses, eight basement units were defined (Fig. F11). Units 1, 3, 4, 5, 6, 7, and 8 are volcanic basaltic units. Units 1, 3, and 7 are aphyric basalts. Units 4, 5, and 6 are sparsely plagioclase and olivine phyric 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 (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 =  $5.26 \pm 0.08$  km/s). Porosities range from 4% to 17% (mean =  $7.7 \pm 0.7\%$ ). Wet bulk densities range from 2.52 to 2.82 g/cm<sup>3</sup> (mean =  $2.69 \pm 0.02$  g/cm<sup>3</sup>), whereas the grain densities range from 2.64 to 2.98 g/cm<sup>3</sup> (mean =  $2.85 \pm 0.02$  g/cm<sup>3</sup>).

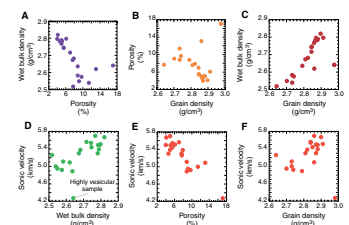
The relationships among these properties are summarized in Figure F12. Except for two samples that have particularly high porosities, wet bulk densities decrease markedly with increasing porosity. We also observe a marked decrease in grain density with increasing porosity and a strong increase in wet 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

F11. Basement lithology, Hole 1243B, p. 25.



F12. Physical properties of basalt samples recovered, Hole 1243B, p. 26.



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. F13). 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.

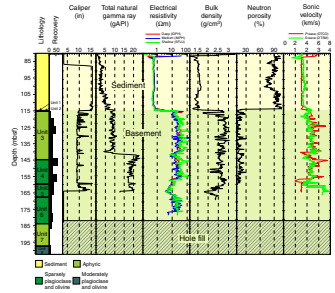
The WST was used to conduct a check shot–VSP seismic survey through the basement section in Hole 1243B. Data were recorded at eight stations; except for the interval between stations seven and eight (at the top of the basement section), the stations were located 10 m apart and 5–16 shots were stacked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

Results are shown in Figure F14, 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, 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.

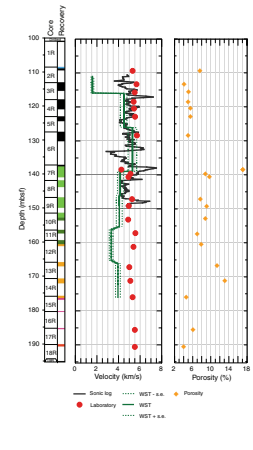
The inclination log of Hole 1243A shows that the hole is within 1° of vertical throughout its entire depth. The cement-bond log indicated a good bond in the lowest 40 m of the hole but essentially no bonding above that level, suggesting that the cement was lost into cavities and the generally porous 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. F15). These occurred at depths of 4010 mbrf (125 mbsf), 4027 mbrf (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

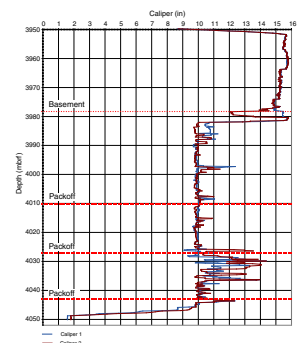
F13. Plot of downhole measurements in sediment and basement sections, Hole 1243B, p. 27.



F14. Porosities and measured sonic velocities in basalt samples, Hole 1243B, p. 28.



F15. Downhole caliper log, Hole 1243B, p. 29.



1243A. This suggests that the large volume of cement used to complete casing Hole 1243A 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 rather than San Francisco and despite two significant technical challenges. The first of these stemmed from the failure to seat 16-in casing into a hole with an 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 successful logging, using triple combo and FMS-sonic tool strings, and by a WST in a VSP configuration. In the case of the first two tool strings, multiple trips were made to authenticate measurements. 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.

The rocks recovered from Hole 1243B were largely from pillow basalts and comprised both aphyric and sparsely plagioclase and olivine phyrlic 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

into basement for the installation of broadband seismometers in a future observatory. We 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.

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**Figure F1.** Artist's renderings of deepwater Dynamics of Earth and Ocean Systems (DEOS) observatory buoys resulting from (A) 2001 U.S. National Science Foundation (NSF)-supported DEOS design study and (B) 2001 U.K. 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 bi-directional 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 U.S. design is a spar buoy with three-point mooring optimized for deepwater deployment in tropical through temperate climates. The U.K. design is a hybrid design with two-point mooring optimized for deepwater deployment in particularly harsh extreme northern and southern latitudes.

**A**

**B**

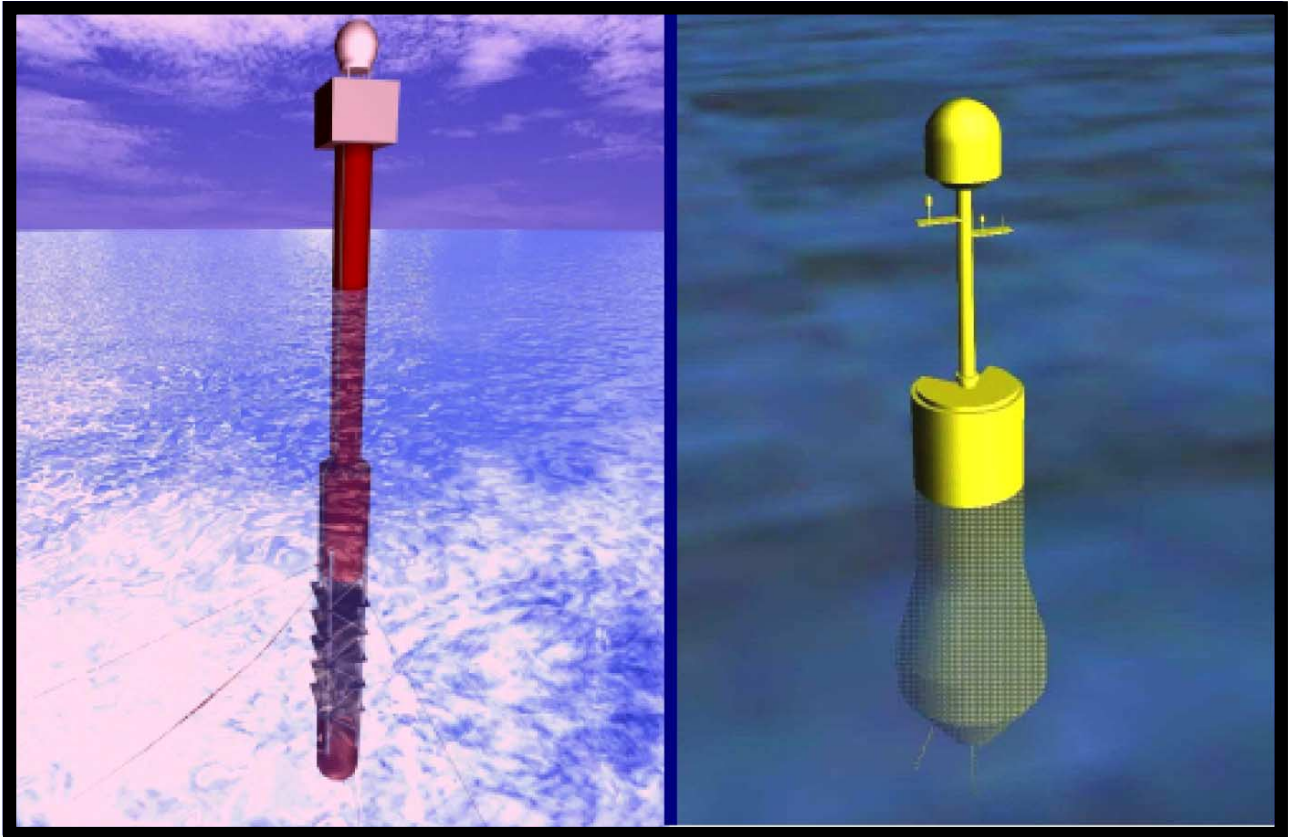


Figure F2. Location of Site 1243 (Ocean Seismic Network [OSN]-2; star) is shown superimposed on a free-air gravity-anomaly map derived from Geosat and ERS-1 data (courtesy of David Sandwell and Walter Smith). Other sites shown are the Hawaii-2 Observatory (H2O; diamond), where an observatory hole was 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.

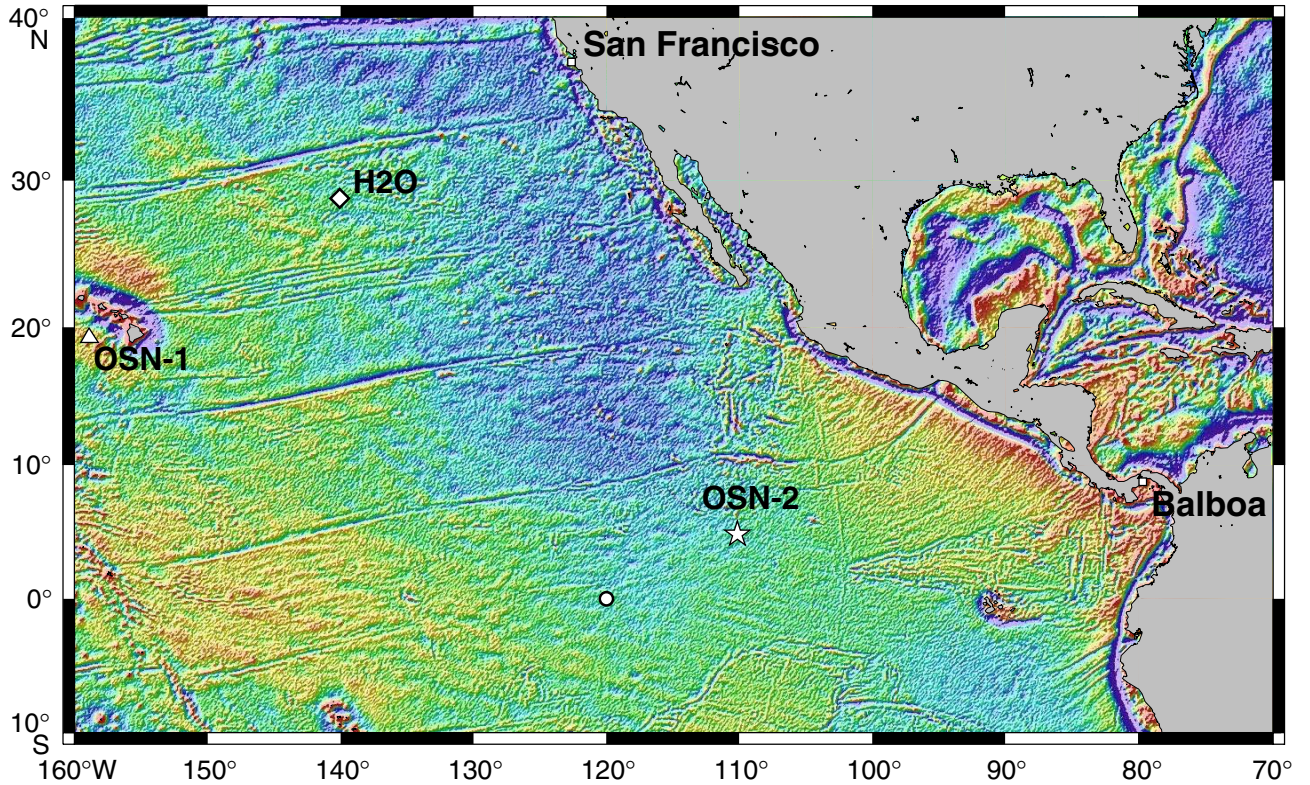




Figure F3. The proposed drilling site for Leg 203 (solid circle) superimposed on a tectonic map of the world.

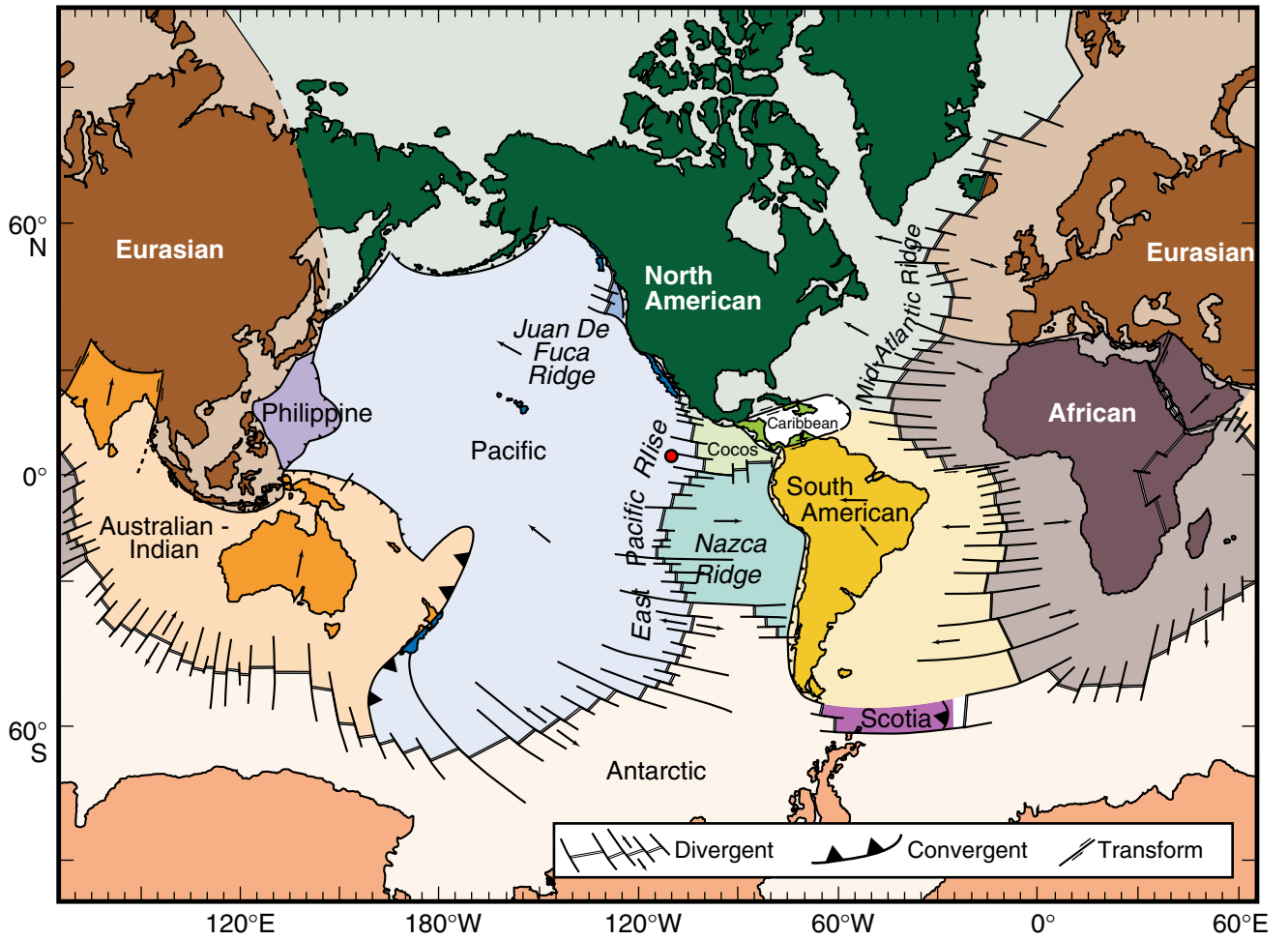
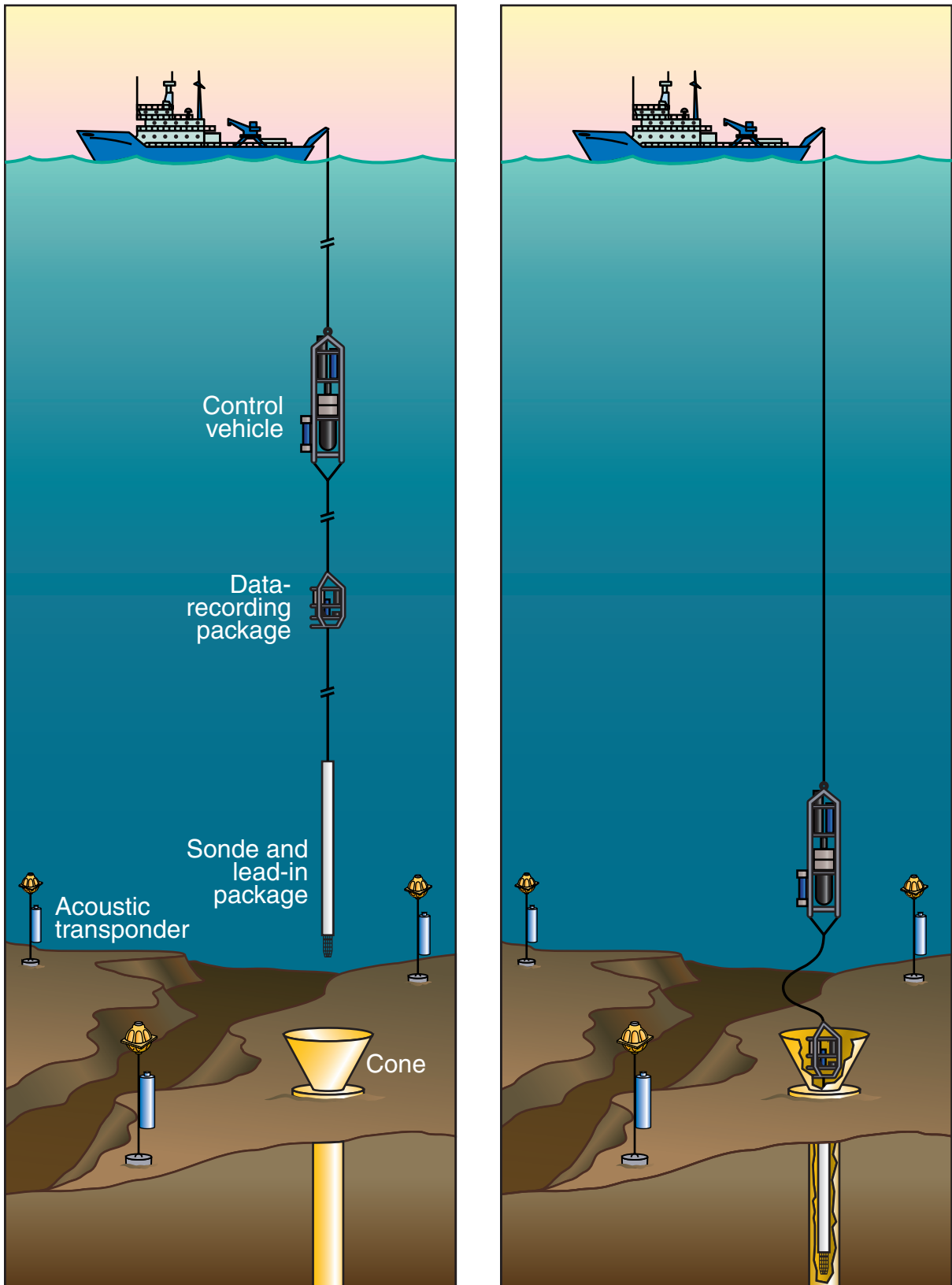


Figure F4. Deployment of a borehole seismometer within a cased ODP hole with a reentry cone using a wireline reentry system.



**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 F1 of Shipboard Scientific Party (1992).

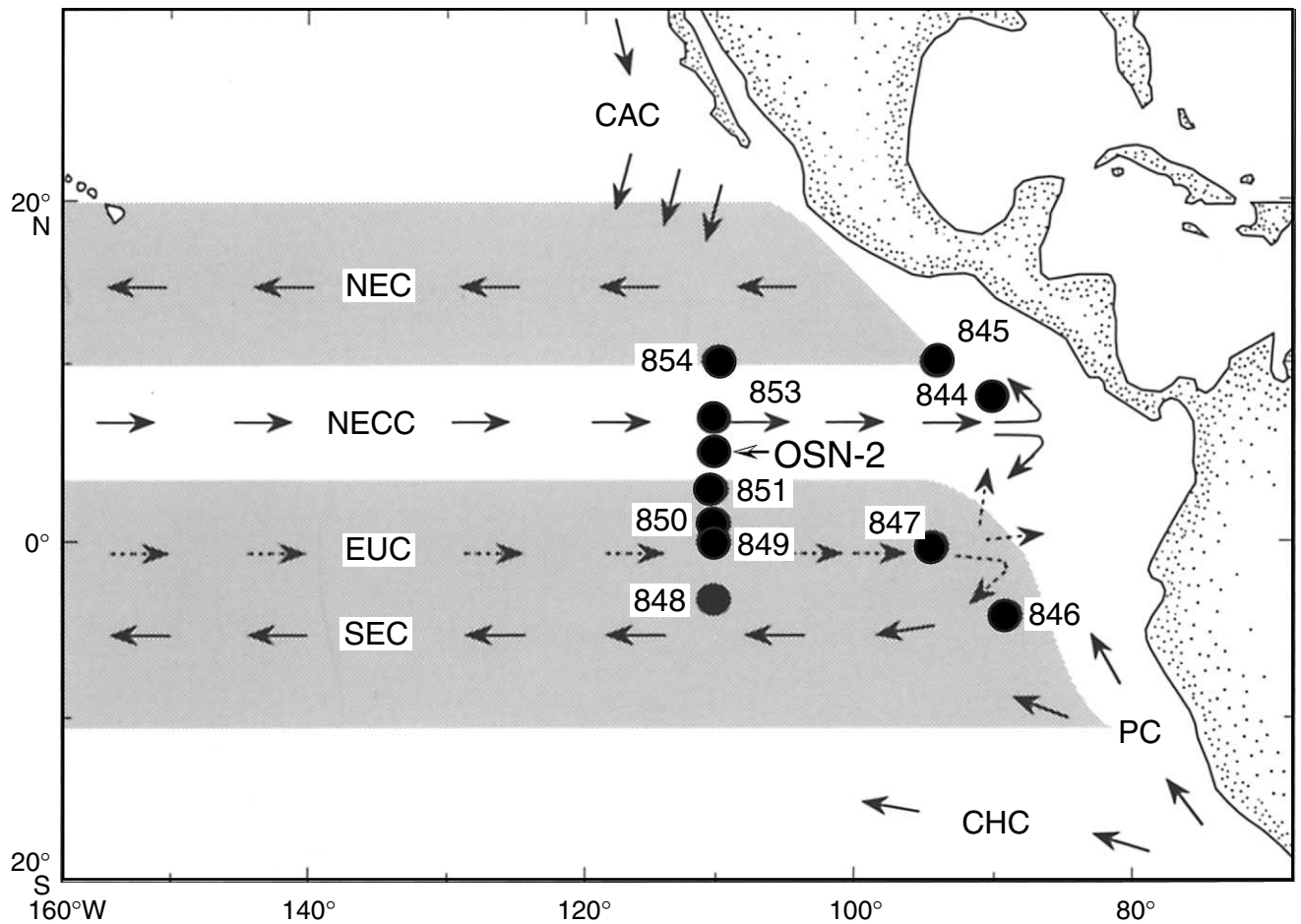


Figure F6. Dynamic sea height from satellite altimetry superimposed upon the wind field for a recent period. The residual shows the different current regimes. A. Means. B. Anomalies.

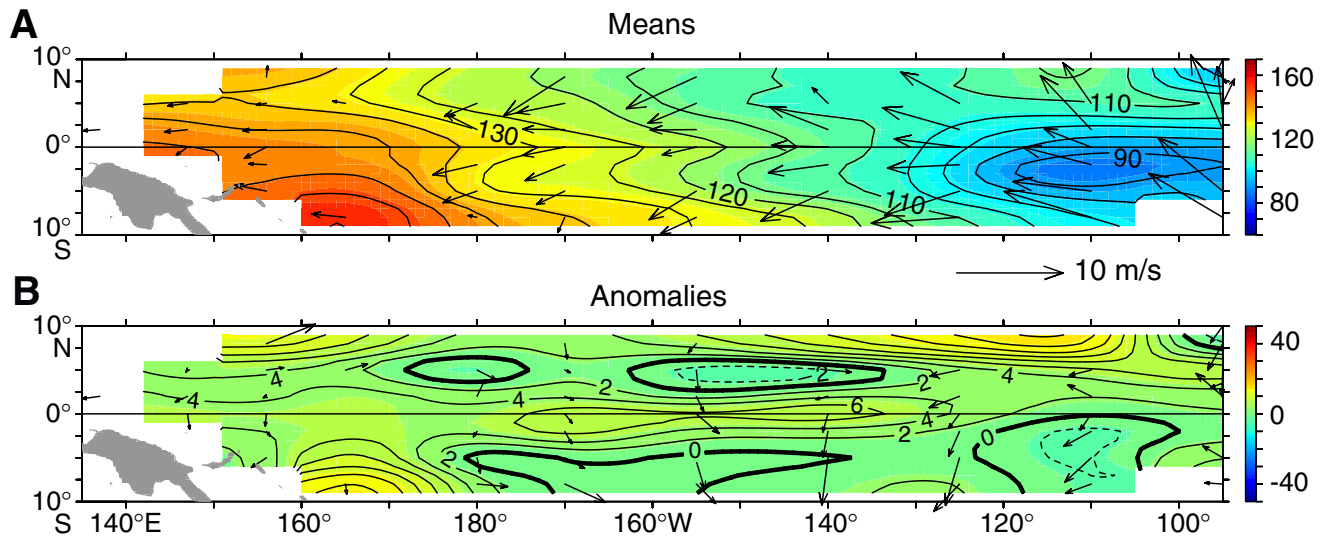


Figure F7. A. Ekman velocity from satellite scatterometer measurements. B. Geostrophic currents from Topex/Poseidon. C. The sum of the currents box superimposed upon sea-surface temperature anomalies (SSTA). The surface currents in the vicinity of Site 1243 (OSN-2) are  $\approx 1$  kt. The Equatorial Countercurrent is well to the south. QuikSCAT data courtesy of M. Bourassa, Center for Ocean-Atmospheric Prediction Studies, Florida State University. Topex/Poseidon 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](http://www.esr.org)).

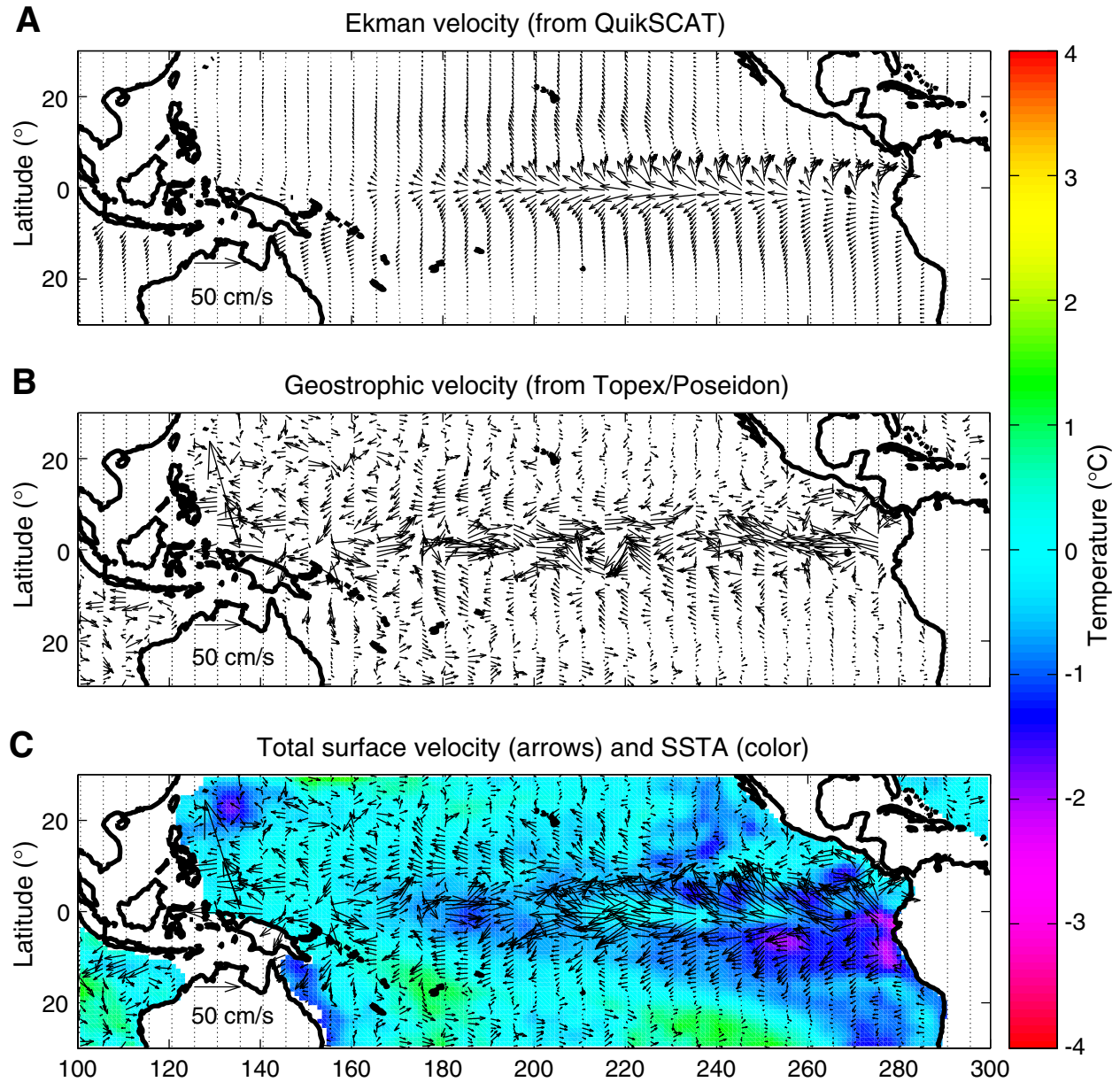
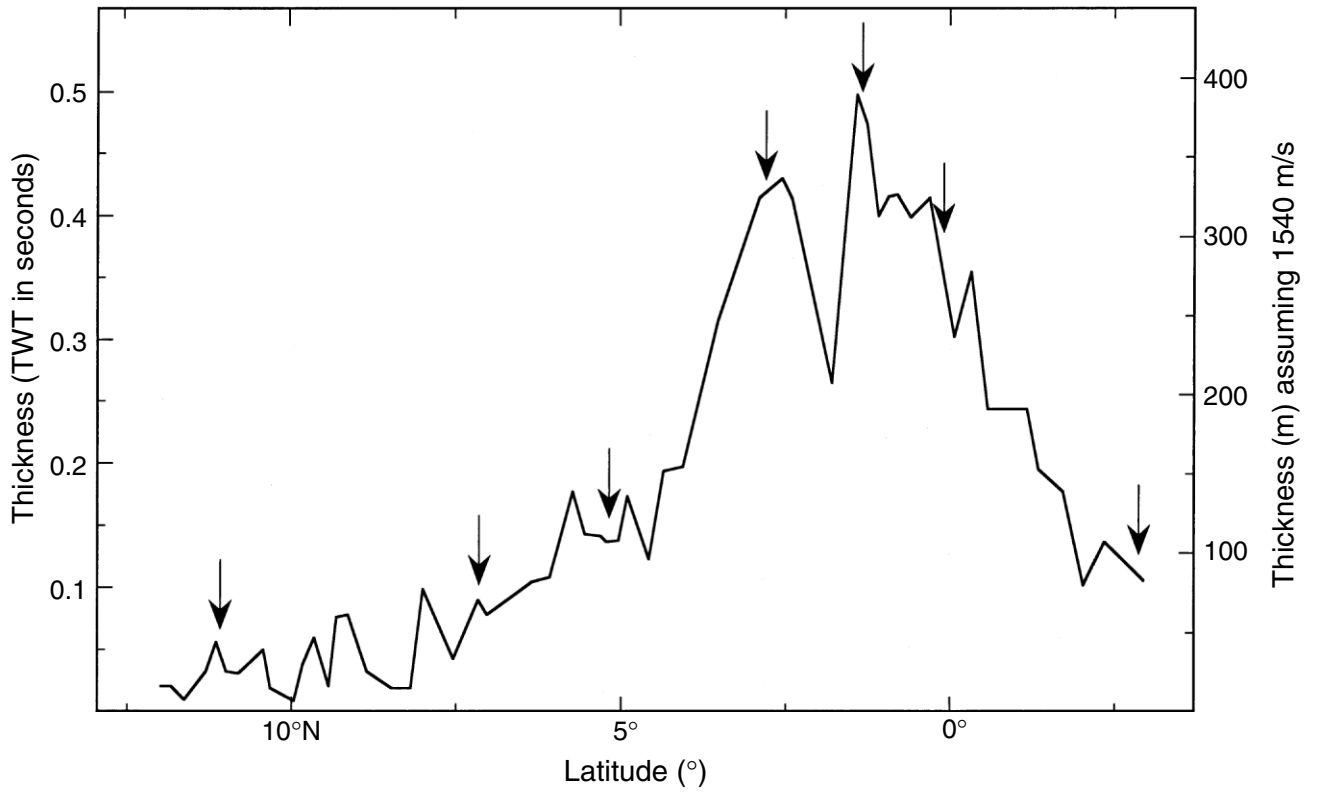
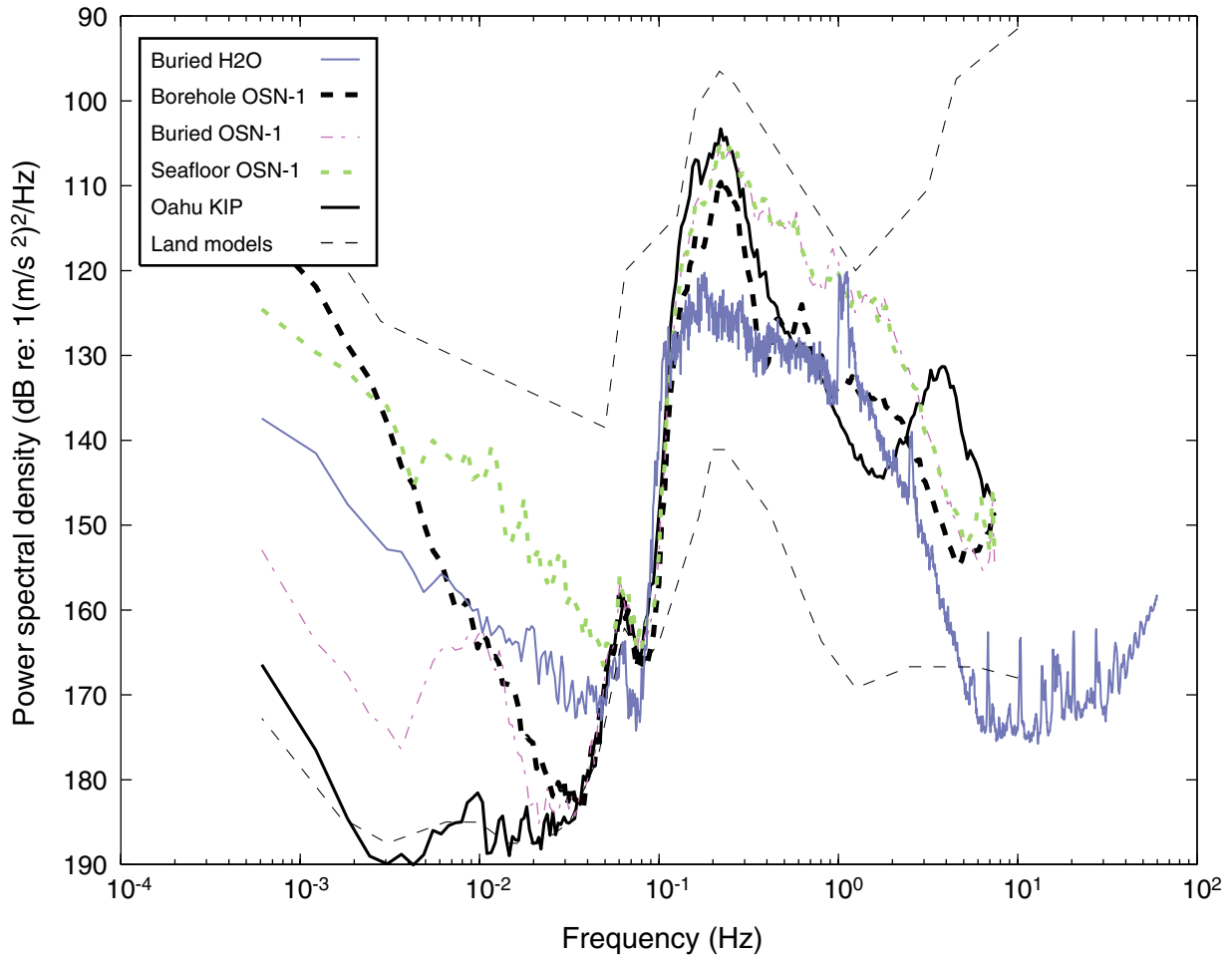


Figure F8. Sediment thickness along the 110°W transect collected during the *Thomas Washington* Venture I cruise. The locations of the various drill sites shown in Figure F9, p. 23, are superimposed. TWT = two-way traveltime.



**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 *S*-wave resonances (Scholte modes).

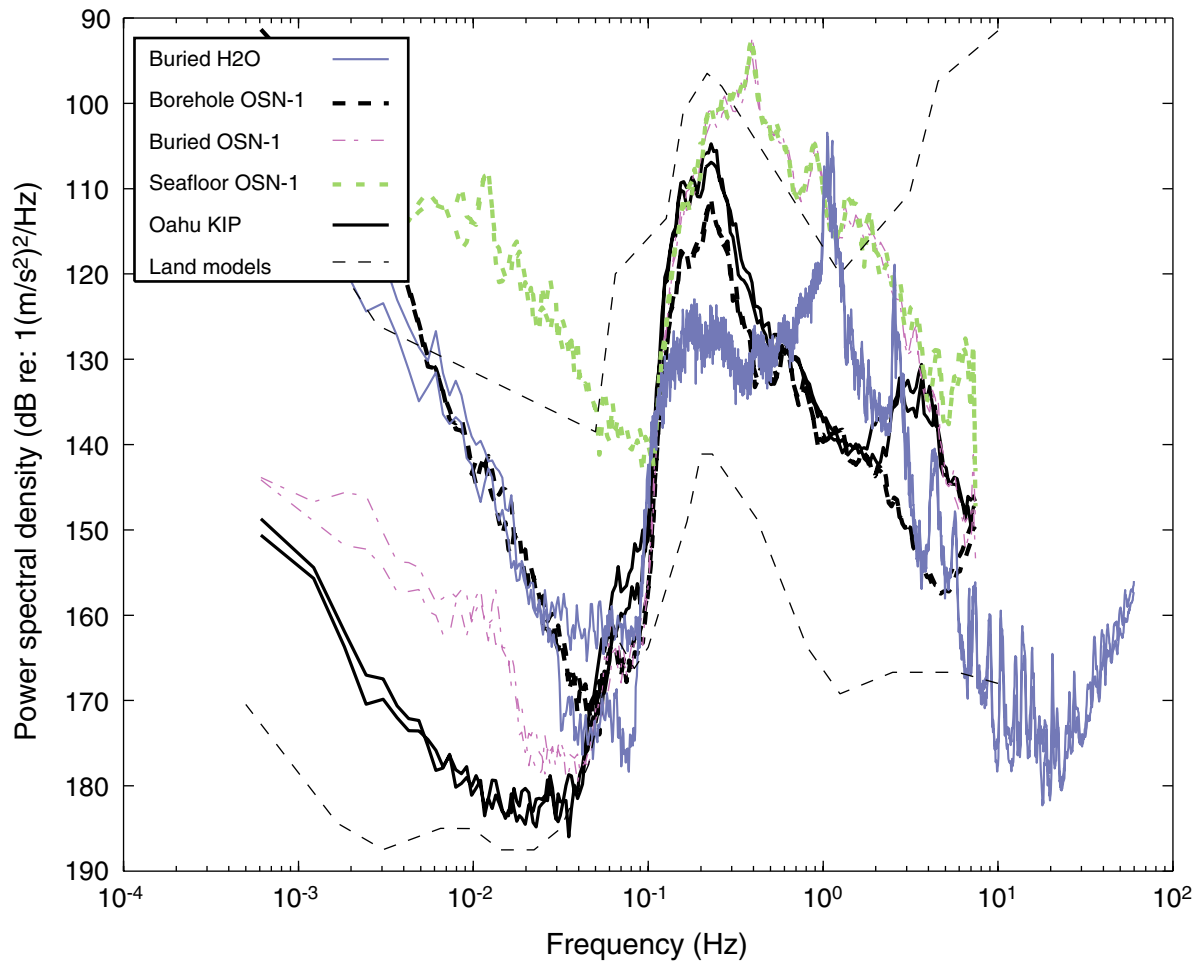




Figure F11. Basement lithology from Hole 1243B. T.D. = total depth.

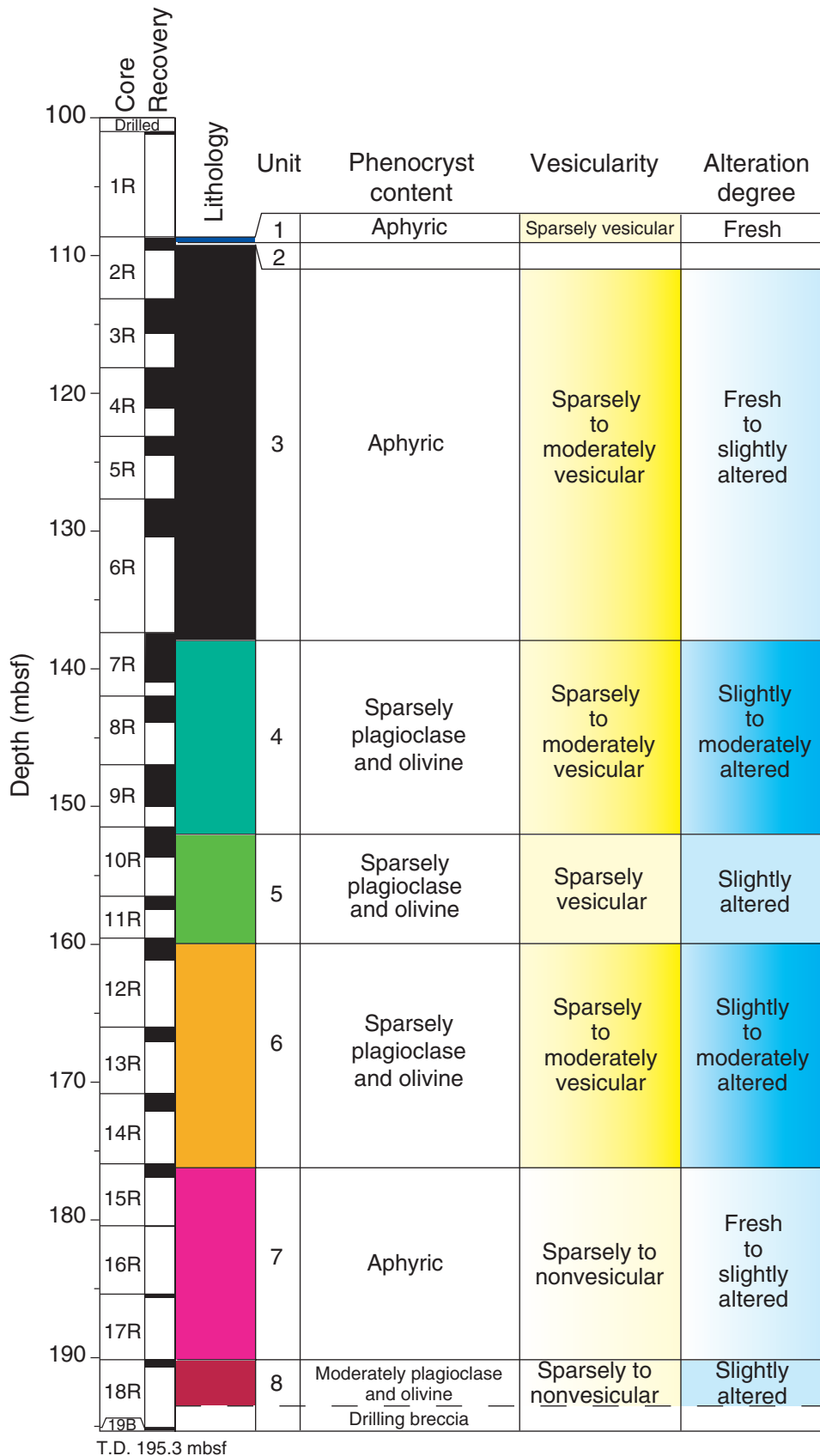
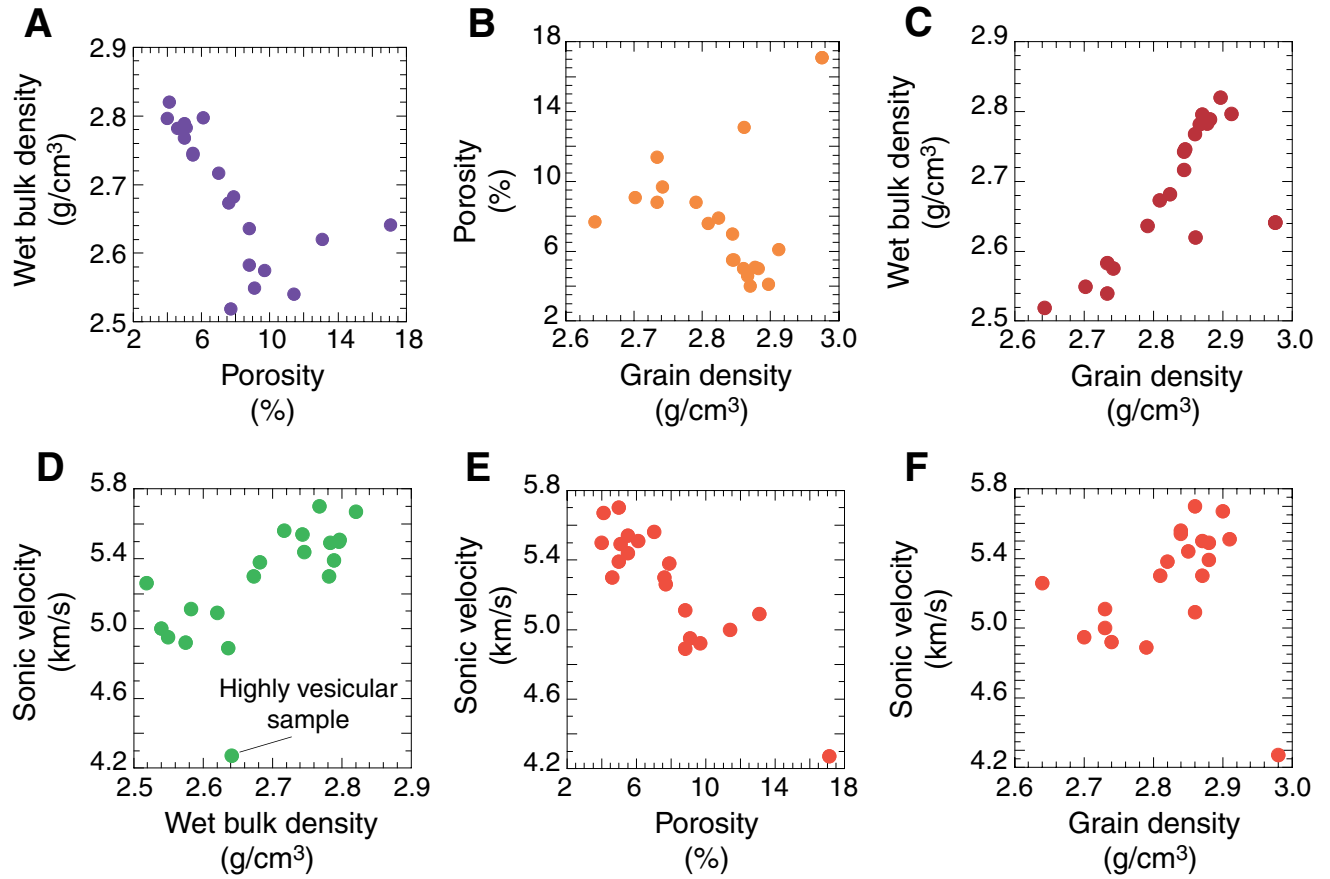


Figure F12. Physical properties of basalt samples recovered from Hole 1243B. A. Wet bulk density vs. porosity. B. Porosity vs. grain density. C. Wet bulk density vs. grain density. D. Sonic velocity vs. wet bulk density. E. Sonic velocity vs. porosity. F. Sonic velocity vs. grain density.



**Figure F13.** Composite plot of downhole measurements in the sediment and basement section of Hole 1243B. Note that log depths are based on wireline measurements, whereas core depths are based on drill pipe measurements. 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.

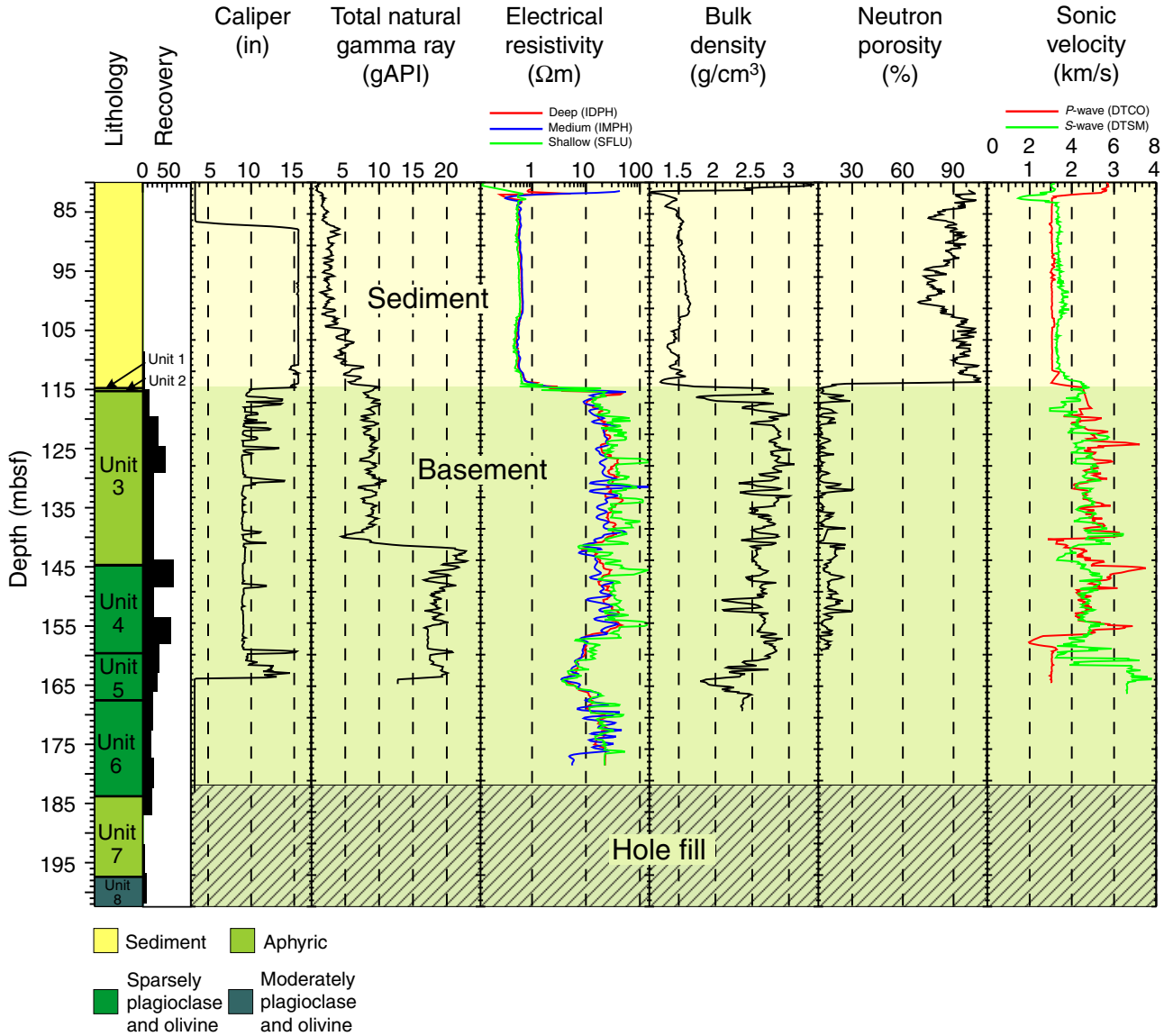


Figure F14. Porosities and measured sonic velocities in basalt samples recovered from Hole 1243B, plotted with the downhole sonic log and interval velocities computed from the WST survey. Also shown is the lithostratigraphy column. Logging and Well Seismic Tool (WST) depths have been adjusted to the coring depths. s.e. = standard error.

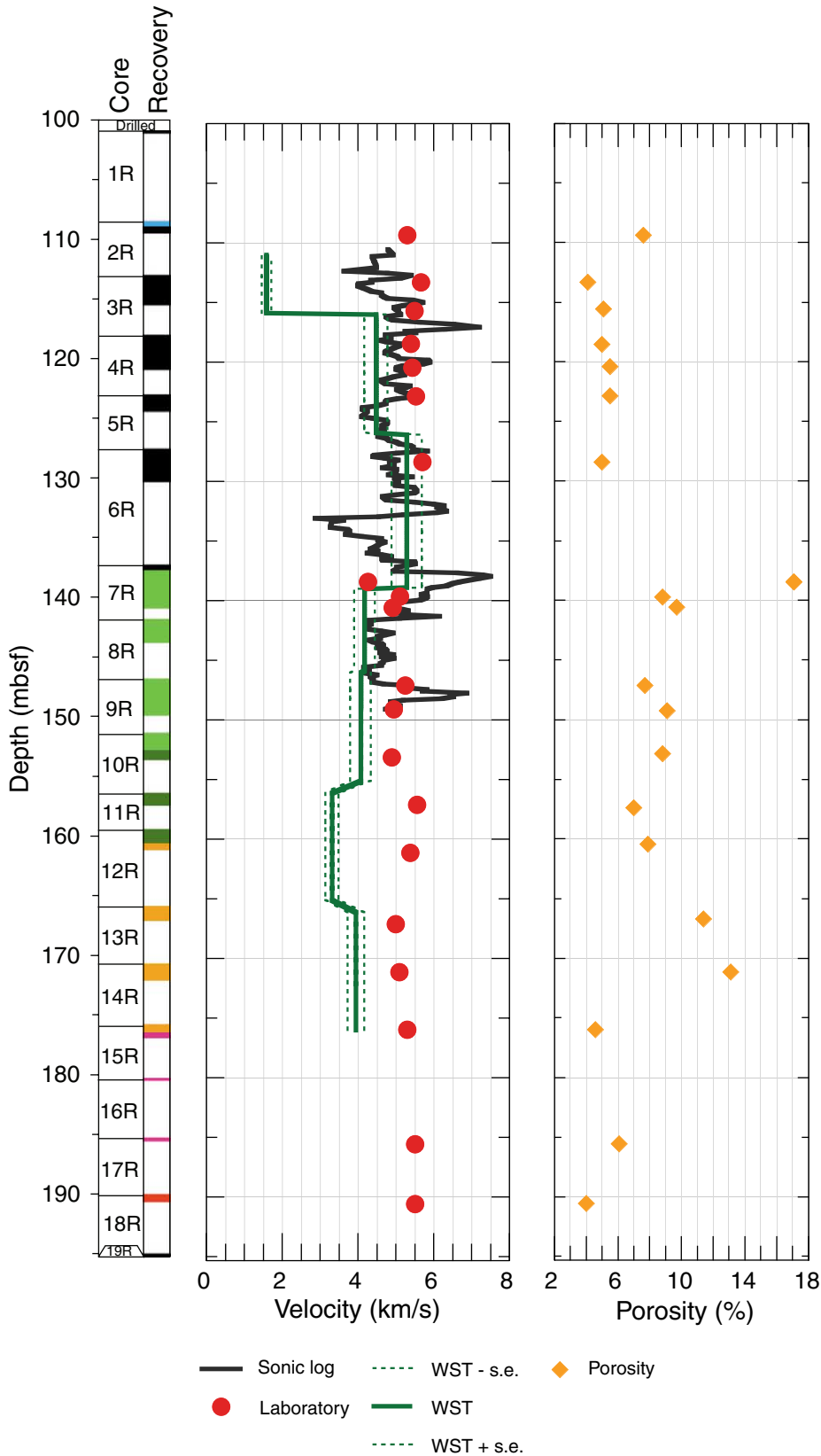
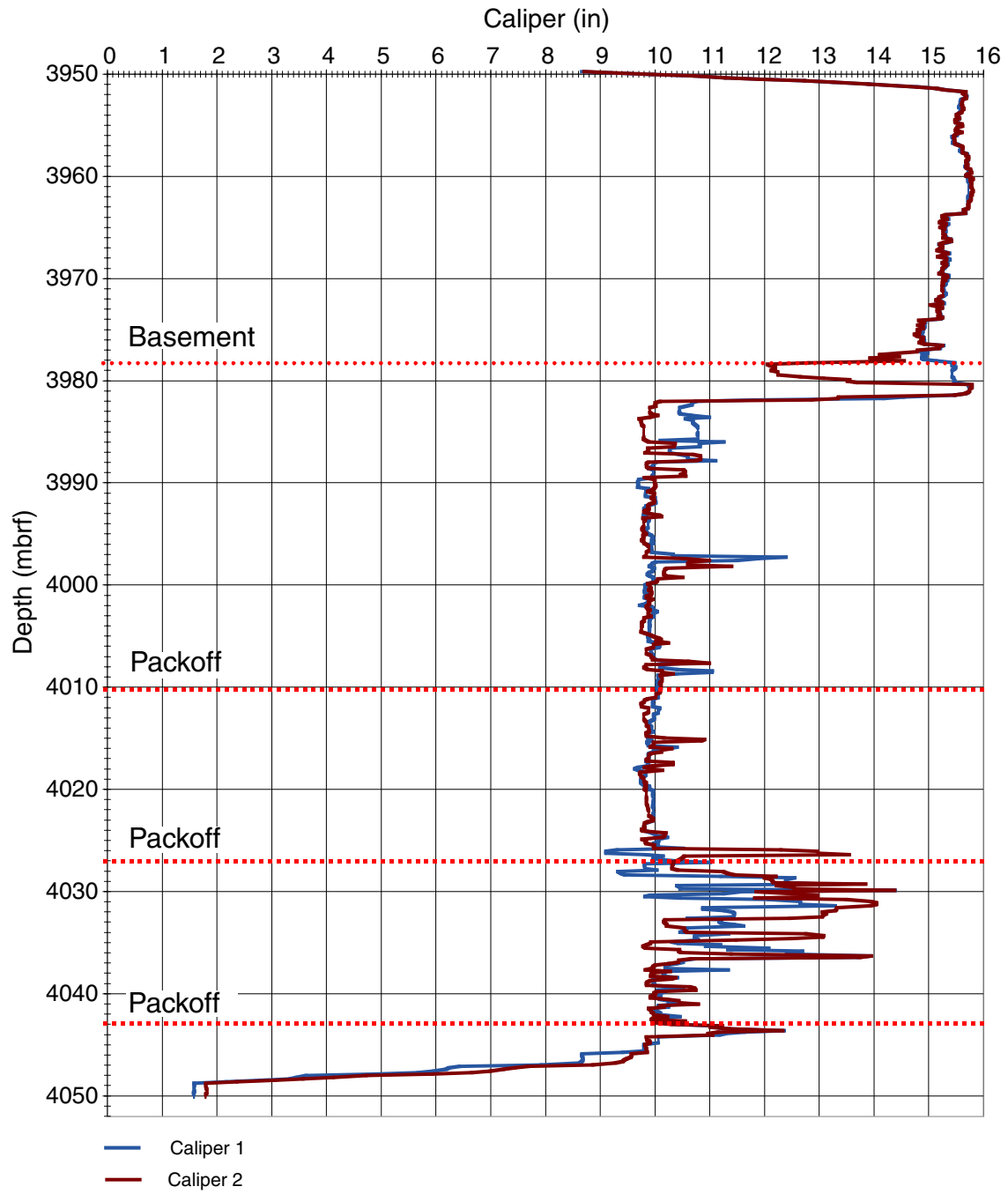


Figure F15. Downhole caliper log from Hole 1243B.



**Table T1.** Summary of DSDP and ODP holes with penetration greater than 10 m in Pacific crust.

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

Notes: \* = foot of Patton Escarpment. † = OSN-1. ‡ = reentry cone.  
 \*\* = H2O. †† = OSN-2. DSDP = Deep Sea Drilling Project, ODP = Ocean Drilling Program. This table is also available in [ASCII](#).