OCEAN DRILLING PROGRAM

LEG 203 SCIENTIFIC PROSPECTUS

DRILLING AT THE EQUATORIAL PACIFIC ION MULTIDISCIPLINARY OBSERVATORY

Professor John A. Orcutt
Cecil H. and Ida M. Green
Institute of Geophysics and
Planetary Physics
Scripps Institution of Oceanography
La Jolla CA 92093-0225
USA

Professor Adam Schultz
Department of Earth Sciences
Cardiff University
Cardiff CF10 3YE
United Kingdom

Dr. Jack Bauldauf
Deputy Director of Science Operations
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

Dr. Gary D. Acton
Leg Project Manager and Staff Scientist
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

December 2001

PUBLISHER'S NOTES

Material in this publication may be copied without restraint for library, abstract service, educational, or personal research purposes; however, this source should be appropriately acknowledged.

Ocean Drilling Program Scientific Prospectus No. 103 (December 2001).

Distribution: Electronic copies of this series may be obtained from the ODP Publications homepage on the World Wide Web 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)
European Science Foundation Consortium for Ocean Drilling (Belgium, Denmark, Finland, Iceland, Ireland, Italy, The Netherlands, Norway, Spain, Sweden, and Switzerland)
Institut National des Sciences de l'Univers–Centre National de la Recherche Scientifique (INSU-CNRS; France)
Marine High-Technology Bureau of the State Science and Technology Commission of the People's Republic of China
National Science Foundation (United States)
Natural Environment Research Council (United Kingdom)
Ocean Research Institute of the University of Tokyo (Japan)

ABSTRACT

We plan to drill one reentry hole at 5°17.566′N, 110°4.579′W in the western equatorial Pacific, the location of a future Dynamics of Earth and Ocean Systems (DEOS) multidisciplinary observatory. The drill site is located in 10- to 12-Ma lithosphere of the Pacific plate at a water depth of 3860 m. The hole will be drilled to a total depth of 226 m or more if time permits, which includes 116 m of sediment and at least 100 m of basement penetration. We intend to insert casing to the bottom of the hole and to grout the casing to the basement and sediments. This hole will be used subsequently 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 (GSN). Both seismometers will be digitized with a high dynamic range, 24-bit digitizer. 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 global 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 (OSN) 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 a majority of the oceanic lithosphere. This is a multidisciplinary project that primarily represents the interests of the multiagency DEOS program and the International Ocean Network (ION).

INTRODUCTION

Dynamics of Earth and Ocean Systems

The ocean and Earth sciences are on the threshold of a dual revolution involving new questions and novel technologies. Since Darwin's voyage on the *Beagle,* we have largely studied the ocean basins with ships that were used in an expeditionary mode designed to discover what is out there. The emphasis has been on understanding different regions of the oceans in the three dimensions of space. This approach has provided society with a broad understanding of the fundamental principles that regulate physical, chemical, biological, and geological processes in the ocean. However, timely advances in our knowledge of the oceans are now limited by the lack of sustained observations over extended periods and large areas.

The study of change extends across many disciplines of science 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 for all of these users. Many processes are characterized by very low signal-to-noise ratios (e.g., seismology or acoustic thermometry), and only long-term observations can be used to enhance these signal vis-à-vis noise processes. An observatory network requires the establishment of a permanent presence in the oceans; Leg 203 is a critical step in this direction.

Dynamics of Earth and Ocean Systems (DEOS) is a network of observatories focused on the ocean and the Earth beneath it. Whereas observatories have been commonly used on land for centuries for many purposes, long-term observations of natural phenomena in the oceans are rare. However, such time-series measurements are the only means for observing transients or changes. 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. The drilling at the equatorial Pacific International Ocean Network (ION) multidisciplinary observatory provides an ideal location for the initial installation of one of these moorings in the 2003–2004 time frame.

BACKGROUND AND GEOLOGICAL SETTING

Proposed Site OSN-2 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 during Leg 138. We will be returning to the immediate vicinity of Site 852 from that leg to develop a legacy hole for purposes of supporting a long-term seafloor observatory.

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, is in the range of 11–12 Ma (Figs. F2, F3); the age is also consistent with paleoceanographic results from Leg 138. The water depth is 3860 m. Based on seismic profiles (Figs. F4, F5, F6, F7) and drilling during Leg 138, the sediment at Site 852 is 116 m thick and overlies basement with relief, which is quite smooth, probably with much less than 100-m variability. Whereas sediment thicknesses of as much as 400 m could be used 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 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 two-way traveltime at Site 852 is only 0.15 s, for a frequency of 6.7 Hz, a frequency above that at which the broadband sensor's self-noise exceeds the seafloor noise level (probably 4–5 Hz). There is every reason to believe that the crustal section at the site will be quite typical of Pacific oceanic crust. Figure F8 illustrates the installation of the seismic component of an observatory at Ocean Drilling Program (ODP) Site OSN-1 south of Oahu; a similar procedure will be followed at proposed Sites H2O-1 and OSN-2.

The equatorial Pacific is a region of considerable interest in paleoceanography 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 trade winds 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 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 resultant Intertropical Convergence Zone (ITCZ) results from these effects (Fig. F9). 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°) from August to December. Figure F10 illustrates a superimposition of the winds on dynamic sea height from satellite altimetry measurements. Figure F10B shows the residual and demonstrates quite clearly the different current regimes discussed above. Figure F11 is a more complex plot showing the Ekman transport in Figure F11A, the wind driven geostrophic component in Figure F11B, and finally, the combination of the two currents in Figure F11C, superimposed on the temperature anomaly. In this case, the surface current at proposed Site OSN-2 is about a knot and the Equatorial Undercurrent lies well to the south. The actual current regime can be checked in the days before arriving on site, but in any case, should not present a problem for drilling.

The high productivity associated with the circulation system acting in conjunction with a component of the absolute motion of the Pacific plate in a northerly direction has resulted in a bulge in the sedimentation, which is asymmetric to the north (Fig. F12). Beginning with the Swedish Deep Sea Expedition, 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, 1971). The advent of the geomagnetic timescale, coupled with additional coring, increased the resolution of these studies substantially. 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, which monitors the development and growth of El Niño, is located at this longitude so that ocean weather conditions are well known. Furthermore, in the ideal world in which the National Oceanic and Atmospheric Administration (NOAA) and the University-National Oceanic Laboratory System (UNOLS) come to share ship time and programs, the maintenance of the surface mooring needed for the station would become a shared responsibility.

SCIENTIFIC OBJECTIVES

This proposal directly addresses the second of three initiatives outlined in the ODP Long Range Plan (JOIDES Long Range Plan, 1996): *In situ monitoring of geological processes* (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* (pp. 52–54). The drilling is intimately tied to the use of *seafloor observatories* (p. 63) and represents the partnership of ODP with DEOS, British DEOS (B-DEOS), and ION. (Page numbers refer to pages in the Long Range Plan.)

The Observatory

Drilling at the proposed equatorial Pacific observatory site addresses both teleseismic, whole-Earth seismic, and regional studies. The site is located in a region on the Earth's surface ~2000 km from another continental or island seismic observatory. For uniform coverage of seismic stations on the surface of the planet, which is necessary for whole-Earth imaging using modern tomographic inverse methods, a seafloor seismic observatory is required. This site is one of three high-priority prototype observatories for the Ocean Seismic Network (OSN) (Purdy and Orcutt, 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 in South America, those that pose a hazard to structures, are only observed at regional distances on land stations in South and Central America and Global Seismic Network (GSN) stations on the Galapagos Islands and Easter Island, which restricts the azimuthal information to an arc spanning ~180°. Observation of these earthquakes at regional distances to the west and constraint of earthquake source mechanisms requires seafloor stations. Since 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 F13 and F14 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 sediments. 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.

Basement Drilling on the Pacific Plate

As noted in the Leg 200 Prospectus, there are no deep boreholes (>100 m) in the Pacific plate, the largest modern tectonic plate. Table 1 summarizes the boreholes drilled on "normal" crust on the Pacific plate that have >10 m of basement penetration and crustal ages <100 Ma. Holes in seamounts, plateaus, aseismic ridges, and fracture zones were 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 years of deep ocean drilling and more than 1000 holes world wide, there have been only 12 holes with >10 m penetration into "normal" igneous Pacific plate: only one hole during ODP, and no holes with >100 m penetration. Furthermore, there are no boreholes off axis in "very fast" spreading crust. Having a reference station in "normal" 12-Ma ocean crust 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 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 more 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 at any single location is thus likely to provide fundamental information that can be extrapolated to a significant fraction of the Earth's surface (Dick and Mével 1996).

UNDERWAY GEOPHYSICS

Standard ODP practice is to collect magnetometer and 3.5- and 12-kHz echo-sounder data during transit to each site. Additionally, we will conduct a short (<6 hr) single-channel seismic reflection survey using a 80-in^3 Seismic Systems Inc. (SSI) water gun. The profile will run perpendicular (roughly east-west) to an existing north-south profile collected over Site 852 during Leg 138 (Shipboard Scientific Party, 1992b; Bloomer et al., 1992).

DRILLING STRATEGY

Proposed Site OSN-2 is positioned at ODP Leg 138, Site 852, to take advantage of the information previously obtained from geophysical surveys and coring at the site. Four holes were cored at this site with the advanced piston corer (APC), three of which penetrated through roughly the entire sediment column, which was ~116 m thick. Unfortunately, an attempt to sample basement in the last core from Hole 852C with the extended core barrel (XCB) failed to recover any basement material. The redundant coring resulted in recovery of a complete sedimentary section and makes it unnecessary to conduct further sediment coring, except at the sediment/basement contact, if time permits.

Given the tight time constraints, we plan to initiate operations in the hole intended to become the observatory by installing the reentry cone and two of the three casing strings (Table 2). We will first jet-in a reentry cone with 40–60 m of 20-in casing. Next, we plan to drill through the cement plug down to a depth of about 140 mbsf and then install and cement a 16-in casing string to a depth of 130 mbsf. This second casing string will extend through the sediment, the sediment/basement contact, and the upper ~14 m of basement; the latter is often rubbly and can cause hole instability.

Before proceeding with the third casing string, we will use the rotary core barrel (RCB) to drill through the cement plug and then core from 140 down to 216 mbsf or deeper if time permits. The hole will be logged as discussed below. The final step is to ream the hole with a 14.75-in bit down to the total depth (TD) cored and then install and cement 10.75-in casing to ~5 m above TD.

Should the initial port call require less than the planned 4 days and the transit to and operations at proposed Site OSN-2 are completed ahead of schedule, we plan to drill through the upper 80–90 m of sediment in a second hole and then begin RCB coring (Table 3). If we have slightly more than a day available, we should be able to core through the sediment/basement interface and down to ~140 mbsf, thus sampling all the section not previously recovered during Leg 138 or in the cased observatory hole. Again, if sufficient time is available, we plan to log this hole as described below.

LOGGING PLAN

Downhole logging at proposed Site OSN-2 will provide in situ information about a wide range of petrophysical properties. The planned logging program includes the deployment of two toolstrings (for further information, see **http://www.ldeo.columbia.edu/BRG**):

1. Standard logging toolstring (triple combination [triple combo] toolstring), including the tools for measurements of gamma ray activity, density, porosity, resistivity, and temperature; and
2. FormationMicroScanner/sonic toolstring, including the tools for measurement of elastic properties and high-resolution resistivity images of the borehole wall.

The triple combo toolstring 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 highly 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 lithodensity sonde (HLDS), which measures the formation's density, this tool will yield information about the drilled lithology, especially where core information is missing. In combination with the measurements for seismic velocity, density measurements are necessary for creating a synthetic seismogram. The HLDS also measures the photoelectric effect (PEF), which gives addition 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 (SP), as well as the conductivity of the formation in three invasion depths, whereas the DLL measures the direct resistivity in two invasion depths. The tools also differ in their response range, which is 0.2–2000 Ωm for the DIT and 0.2–40000 Ωm for the DLL. Based on core recovered during Leg 203, and contingent on the availability of funding, the decision about which tool to use may be made during Leg 203. The last tool of the triple combo toolstring is the Lamont-Doherty Earth Observatory temperature/acceleration/pressure (TAP) tool, which records the borehole temperature, acceleration, and pressure.

The main components of the second toolstring (FMS/sonic) are an FMS and a sonic tool, which for Leg 203 will be the dipole shear sonic imager (DSI). The special design of the latter tool makes it possible to measure a full waveform of the formation, including compressional wave (*P*-wave), shear wave (*S*-wave), and Stoneley wave (*St*-wave). Applications are mainly identifications of structural characteristics, estimation of fracture porosity, and the creation of a seismic impedance log, the basic measurement needed for a synthetic seismogram. Furthermore, the dipole technique of the tool is capable of measuring in "soft" as well as in "hard" formations, thus contributing to the scientific prospectus of similar depth penetrations in sediments and basement rocks. 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). Comparison of fractures detected from these log images could provide information on the lateral extension of the fracture system beyond the borehole and the significance of borehole-induced features vs. natural fractures. The FMS caliper log can also be used for hole size estimation.

Given the tight time constraints, it is unlikely that additional logging runs will be made, but use of two specialty tools, the well seismic tool (WST) and the ultrasonic borehole imager (UBI), are under consideration. The WST provides a complete check-shot survey, a depth-traveltime plot, and accurate estimates of the drilling depth. The UBI measures the amplitude and the transit time of an acoustic wave propagated into the formation. It provides high-resolution images with 100% borehole coverage, which aid in detecting small-scale fractures. Evaluation and orientation of fractures can provide information about local stress field and borehole geometry even within the casing. Use of the UBI, besides depending on scientific need and operation time, is contingent on availability of funds, which will be determined prior to Leg 203

SAMPLING PLAN

The Sample Distribution, Data Distribution, and Publications Policy is posted at **http://www-odp.tamu.edu/publications/policy.html.** The Sample Allocation Committee (SAC), which consists of the two co-chiefs, the staff scientist, the ODP onshore curator, and the curatorial representative onboard ship, will work with the entire science party to formulate a formal Leg 203-specific sampling plan for shipboard and postcruise sampling.

During Leg 203, we expect to recover <150 m of basalt and <100 m of sediment. All sample frequencies and sample volumes taken from the working half of the core must be justified on a scientific basis and will be dependent on core recovery, the full spectrum of other requests, and the cruise objectives. All sample requests must be made on the standard Internet sample request form and approved by the SAC. Leg 203 shipboard scientists may expect to obtain as many as 100 samples of no more than 15 cm^3 in size from basement cores. Additional samples may be obtained upon written request on shore after initial data are analyzed. Depending on the penetration and recovery during Leg 203, the number of samples taken may be increased by the shipboard SAC. For example, studies requiring only small sample volumes of 1 cm^3 or less (e.g., veins, fluid inclusions, etc.) may require >100 samples to characterize a long section of core. The SAC will review the appropriate sampling interval for such studies as the cores are recovered. Samples larger than 15 cm^3 may also be obtained with approval of the SAC. Requests for large samples must be specified on the sample request form. Sample requests may be submitted by shore-based investigators as well as the shipboard scientists. Based on sample requests received 2 months precruise, the SAC will prepare a temporary sampling plan, which will be revised on the ship as needed. Some redundancy of measurement is unavoidable, but minimizing redundancy of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

If some critical intervals are recovered (e.g., glass, fault gouge, veins, etc.), there may be considerable demand for samples from a limited amount of cored material. These intervals may require special handling, a higher sampling density, reduced sampling size, or continuous core sampling by a single investigator. A sampling plan coordinated by the SAC may be required before critical intervals are sampled.

REFERENCES

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.

Berger, W.H., 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.

Bloomer, S.F., and Shipboard Scientific Party, 1992. Underway geophysics. *In* Mayer, L., Pisias, N., Janecek, T., et al., *Proc. ODP, Init. Repts.,* 138 (Pt. 1): College Station, TX (Ocean Drilling Program), 43–63.

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., Mével, C.A., et al., 1996. Report of the ODP-InterRidge-IAVCEI workshop, Oceanic Lithosphere and Scientific Drilling into the 21st Century, 26–29 May, Woods Hole, MA.

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 (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 (JOI).

Mayer, L.A., Pisias, N.G., Mix, A.C., Lyle, M.W., Arason, P., and Mosher, D., 1992. Site surveys. *In* Mayer, L., Pisias, N., Janecek, T., et al., *Proc. ODP, Init. Repts.,* 138 (Pt. 1): College Station, TX (Ocean Drilling Program), 93–100.

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

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., and Orcutt, J.A. (Eds.), 1995. *Broadband Seismology in the Oceans—Towards a Five-Year Plan:* Washington (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, 1992a. 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.

————, 1992b. Site 852. *In* Mayer, L., Pisias, N., Janecek, T., et al., *Proc. ODP, Init. Repts.,* 138 (Pt. 2): College Station, TX (Ocean Drilling Program), 967–1021.

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.

FIGURE CAPTIONS

Figure F1. Schematic representation of a Dynamics of Earth and Ocean Systems (DEOS) observatory.

Figure F2. Location of proposed Site 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 a hole will be drilled and cased during Leg 200, the OSN-1 observatory, where a hole was drilled and cased during Leg 138, and the notional site (circle) proposed by ION/OSN documents to fill a coverage gap west of the Galapagos Islands. The proposed OSN-2 site 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. Port calls for the beginning and end of the Leg 203 are in Balboa and San Francisco (squares), respectively.

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

Figure F4. Survey trackline (line 9 collected by the *JOIDES Resolution* during Leg 138) showing the location of the seismic reflection profile in Figure 5. (Modified from figure 18 of Bloomer et al., 1992). Note that the latitudes in the original figure were apparently mislabeled, but have been corrected here. UTC = universal time coordinated.

Figure F5. Seismic reflection profile (line 9 collected by the *JOIDES Resolution* during Leg 138) through Site 852 where the OSN-2 hole will be drilled. The profile crosses the site twice as shown in the survey trackline (Fig. 4). (Modified from figure 19 of Bloomer et al., 1992). UTC = universal time coordinated.

Figure F6. A. Survey trackline from the *Thomas Washington* Venture 1 cruise is given in the inset (modified from figure 1 of Mayer et al., 1992). The open circles are stations numbers from the Venture 1 cruise. **B.** Detailed survey conducted over the Site 852/OSN-2 region during the Venture 1 cruise (modified from figure 3 of Shipboard Scientific Party, 1992b). The location of the seismic reflection profile in Figure 7 is given by the thick red line with positions along the track given in universal time coordinated (UTC).

Figure F7. Seismic reflection profile from the *Thomas Washington* Venture 1 cruise over Site 852. See Figure 6 for survey trackline. (Modified from figure 4 of Shipboard Scientific Party, 1992b). UTC = universal time coordinated.

Figure F8. Deployment of a borehole seismometer within a cased ODP hole with a reentry cone using a wireline reentry system.

Figure F9. 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), South Equatorial Current (SEC), Peru Current (PC), and Chile Current (CHC). Shaded areas illustrate the general latitudinal extent of the SEC and NEC. Solid circles are the Leg 138 sites, with proposed Site OSN-2 being located at Site 852. EUC = Equatorial Undercurrent. (Modified from figure 1 of Shipboard Scientific Party, 1992a).

Figure F10. 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 F11. **(A)** Ekman velocity from satellite scatterometer measurements, **(B)** geostrophic currents from Topex/Poseidon, and **(C)** the sum of the currents box superimposed upon sea-surface temperature anomalies (SSTA). The surface currents in the vicinity of proposed Site OSN-2 are ~1 kt. The Equatorial Countercurrent is well to the south.

Figure F12. Sediment thickness along the 110°W transect collected during the *Thomas Washington* Venture 1 cruise. The locations of the various drill sites shown in Figure 9 are superimposed.

Figure F13. Vertical component spectra from the seafloor, buried, and borehole installations at Site OSN-1 are compared with the spectra from the buried installation at Site H2O and the 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 (Kipapa, Hawaii) levels. The sediment resonances at Site H2O near 1 and 3 Hz are very prominent.

Figure F14. Horizontal component spectra from the seafloor, buried, and borehole installations at Site OSN-1 are compared with the spectra from the buried installation at Site H2O and the KIP GSN station on Oahu. The sediment resonance peaks in the band 0.3–8 Hz are up to 35 dB louder than background and far exceed the microseism peak at 0.1–0.3 Hz. 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 (or Scholte modes).

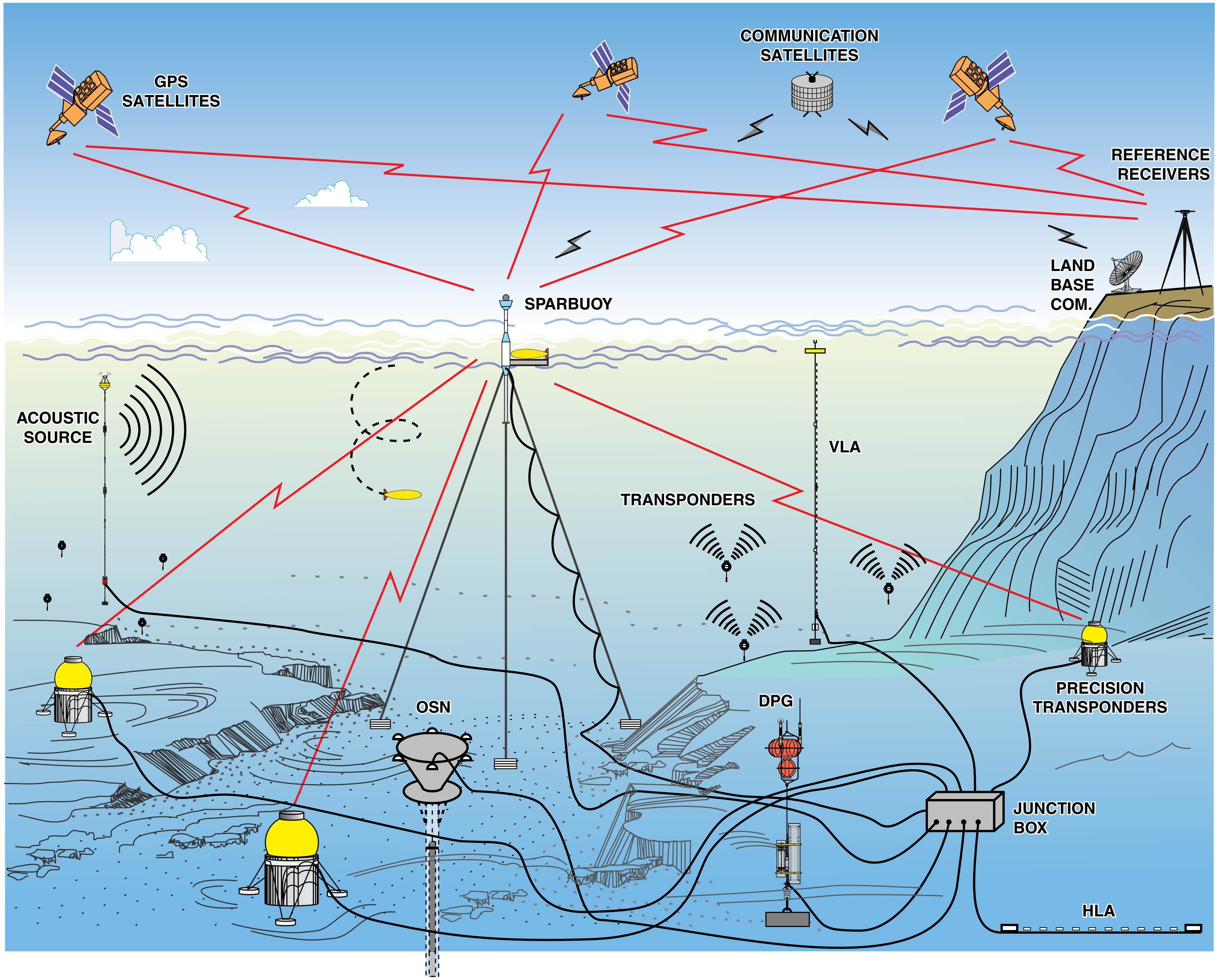
GPS
SATELLITES
COMMUNICATION
SATELLITES
REFERENCE
RECEIVERS
LAND
BASE
COM.
SPARBUOY
ACOUSTIC
SOURCE
VLA
TRANSPONDERS
OSN
DPG
PRECISION
TRANSPONDERS
JUNCTION
BOX
HLA

Figure F1

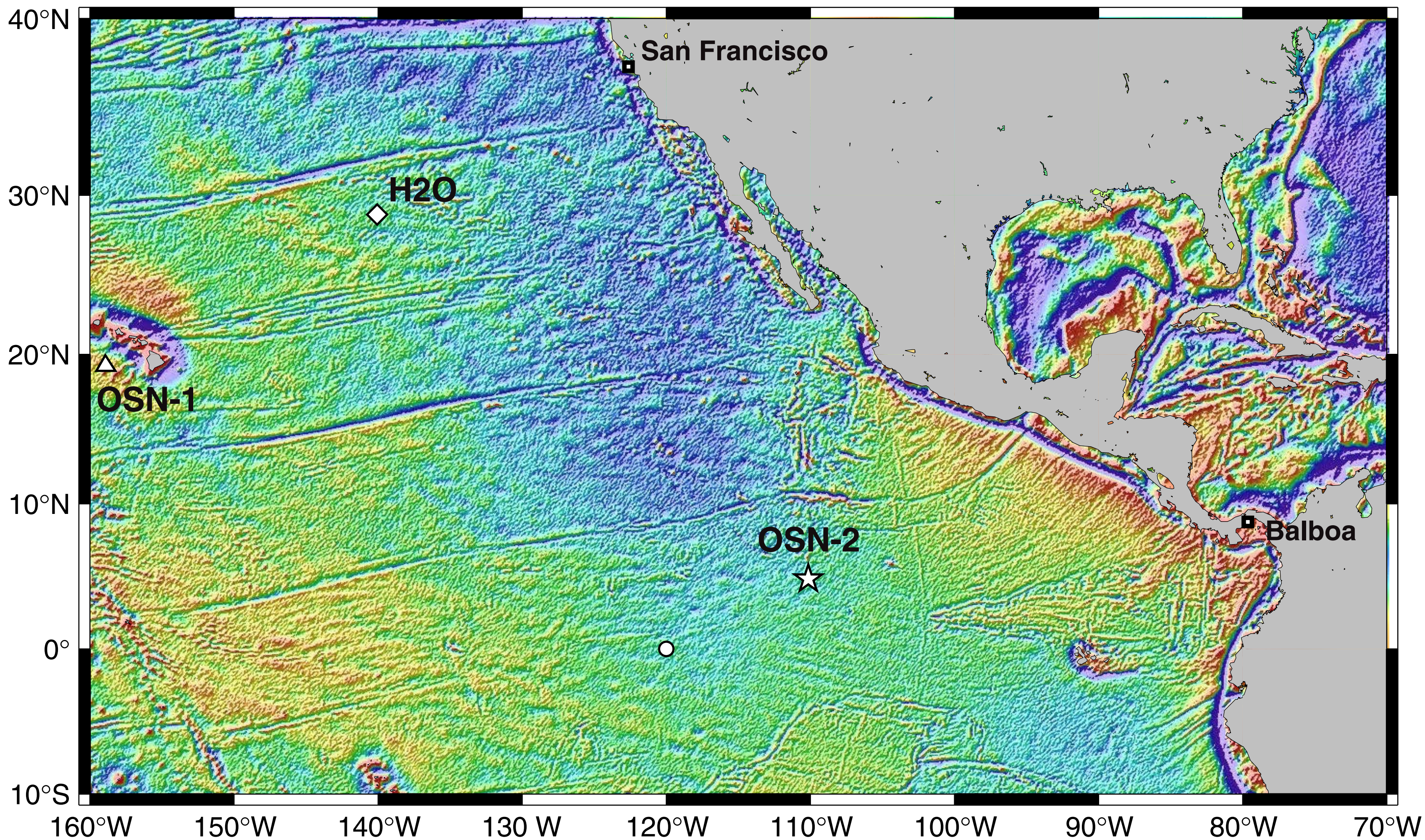
San Francisco
H2O
OSN-1
OSN-2
Balboa
40°N
30°N
20°N
10°N
0°
10°S
160°W
150°W
140°W
130 W
120°W
110°W
100°W
90°W
80°W
70°W

Figure F2

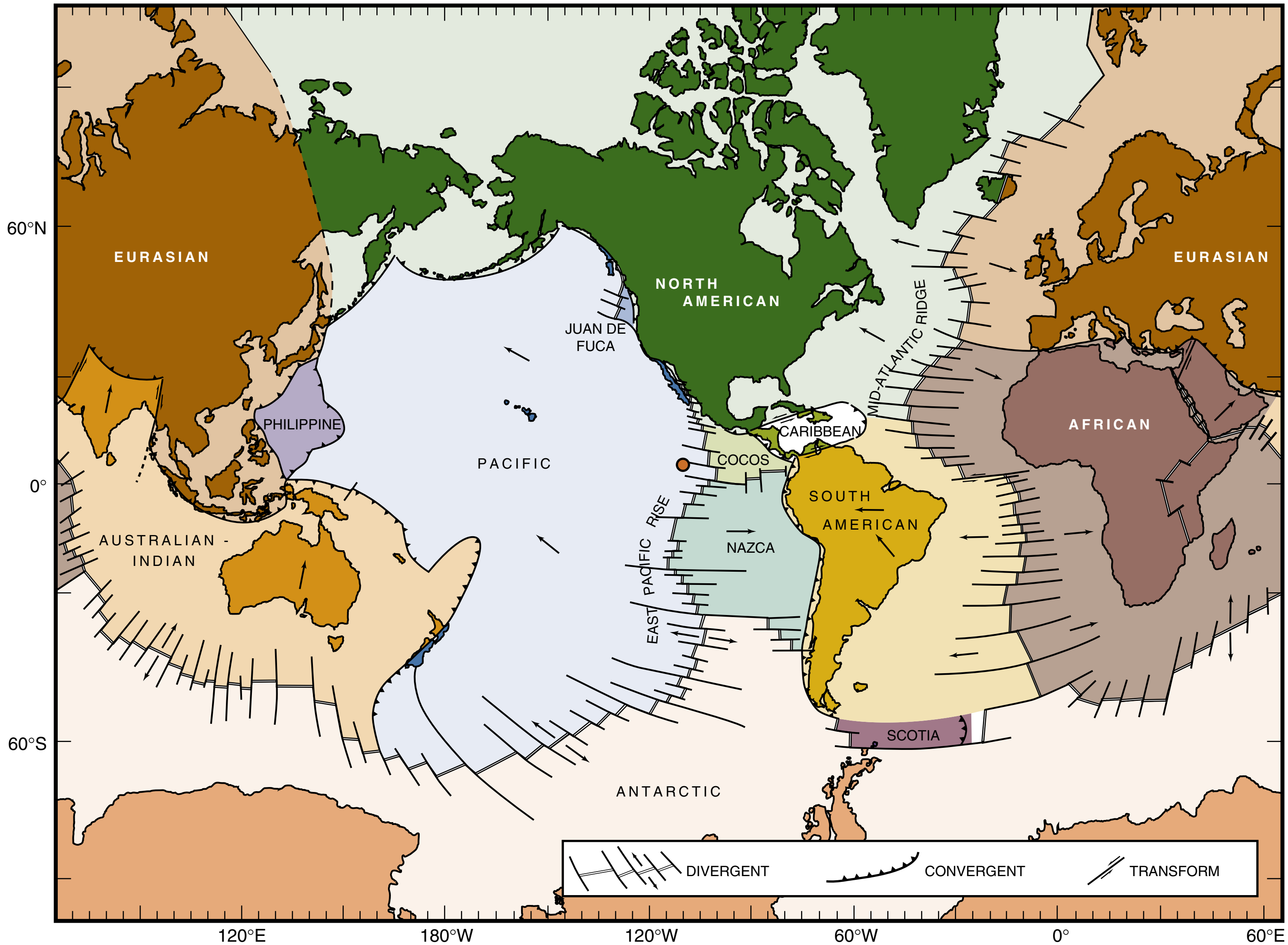
EURASIAN
NORTH AMERICAN
JUAN DE FUCA
PHILIPPINE
PACIFIC
CARIBBEAN
COCOS
SOUTH AMERICAN
NAZCA
EAST PACIFIC RISE
MID-ATLANTIC RIDGE
AFRICAN
EURASIAN
AUSTRALIAN - INDIAN
SCOTIA
ANTARCTIC
DIVERGENT
CONVERGENT
TRANSFORM
60°N
0°
60°S
120°E
180°W
120°W
60°W
0°
60°E

Figure F3

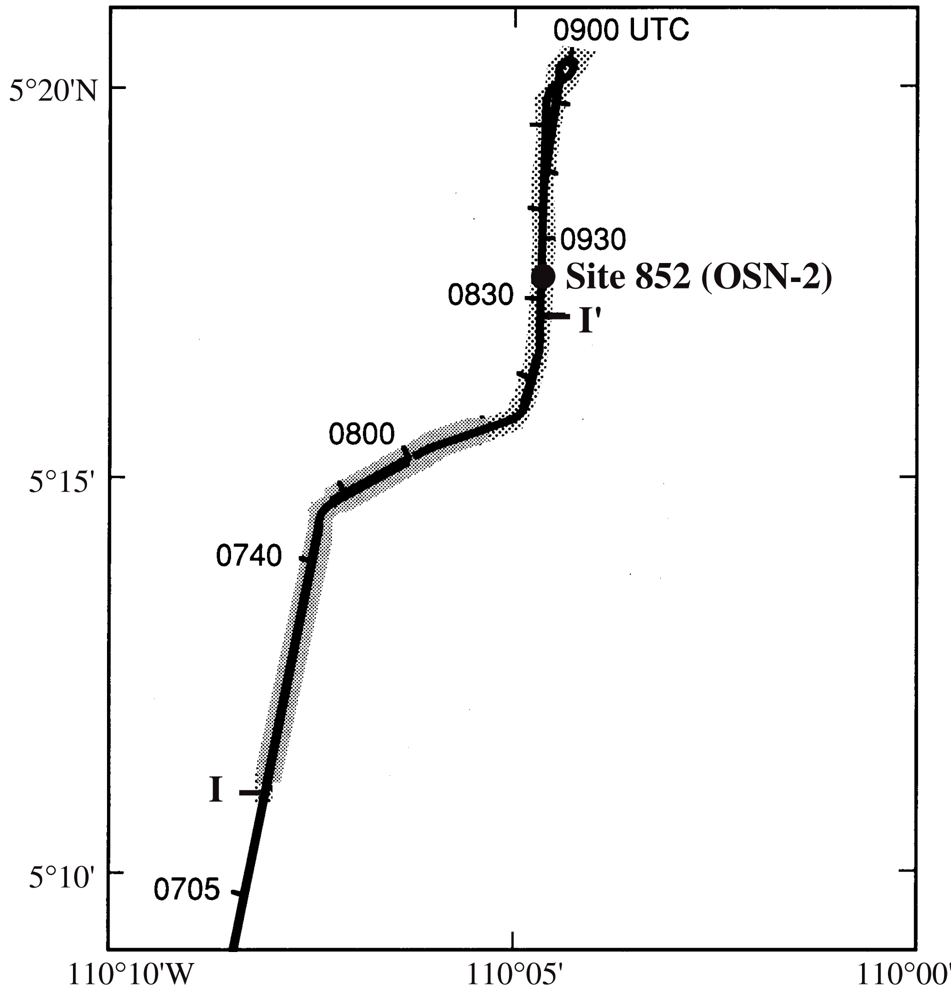
0900 UTC
5°20'N
0930
Site 852 (OSN-2)
0830
I'
0800
5°15'
0740
I
5°10'
0705
110°10'W
110°05'
110°00'

Figure F4

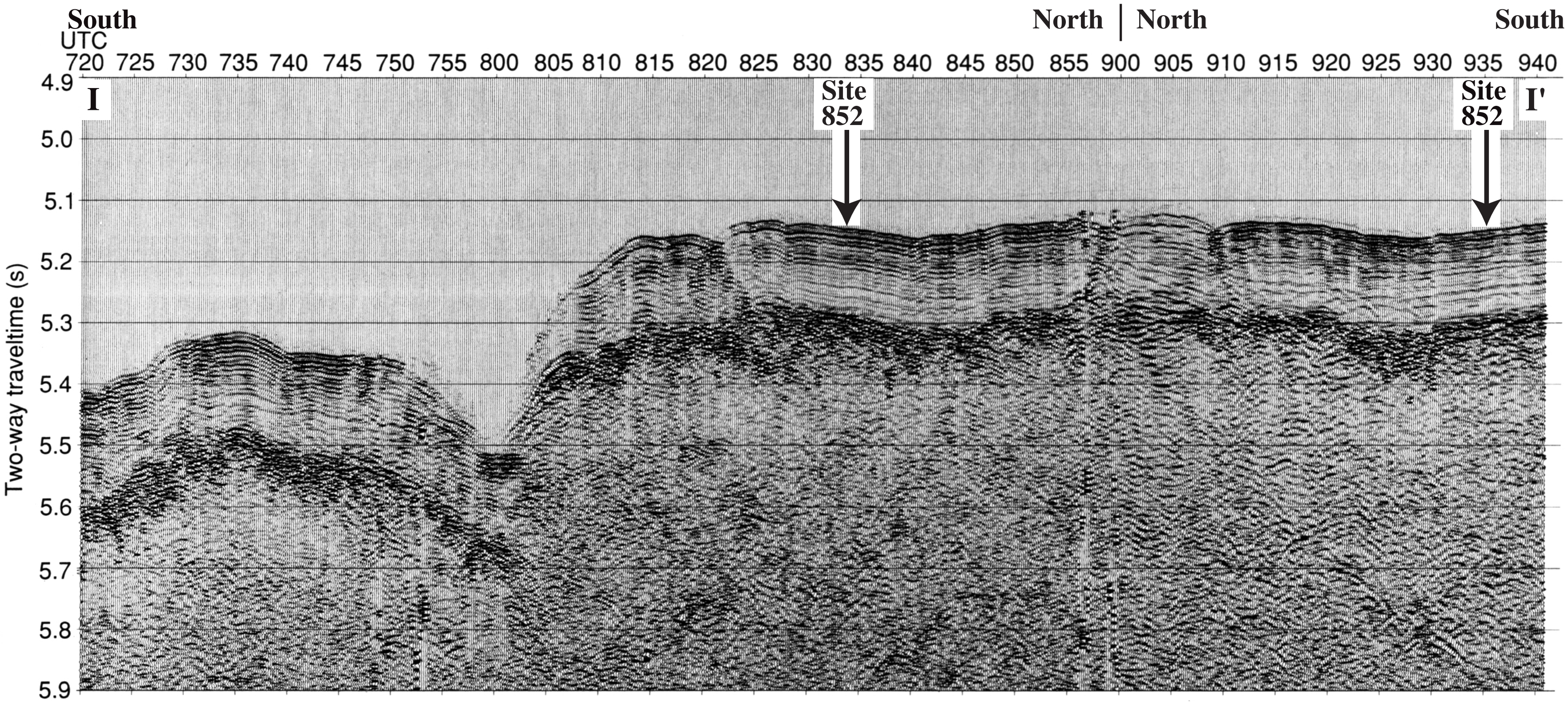
South
North
North
South
UTC
720 725 730 735 740 745 750 755 800 805 810 815 820 825 830 835 840 845 850 855 900 905 910 915 920 925 930 935 940
I
I'
Site 852
Site 852
Two-way traveltime (s)
4.9
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
5.8
5.9

Figure F5

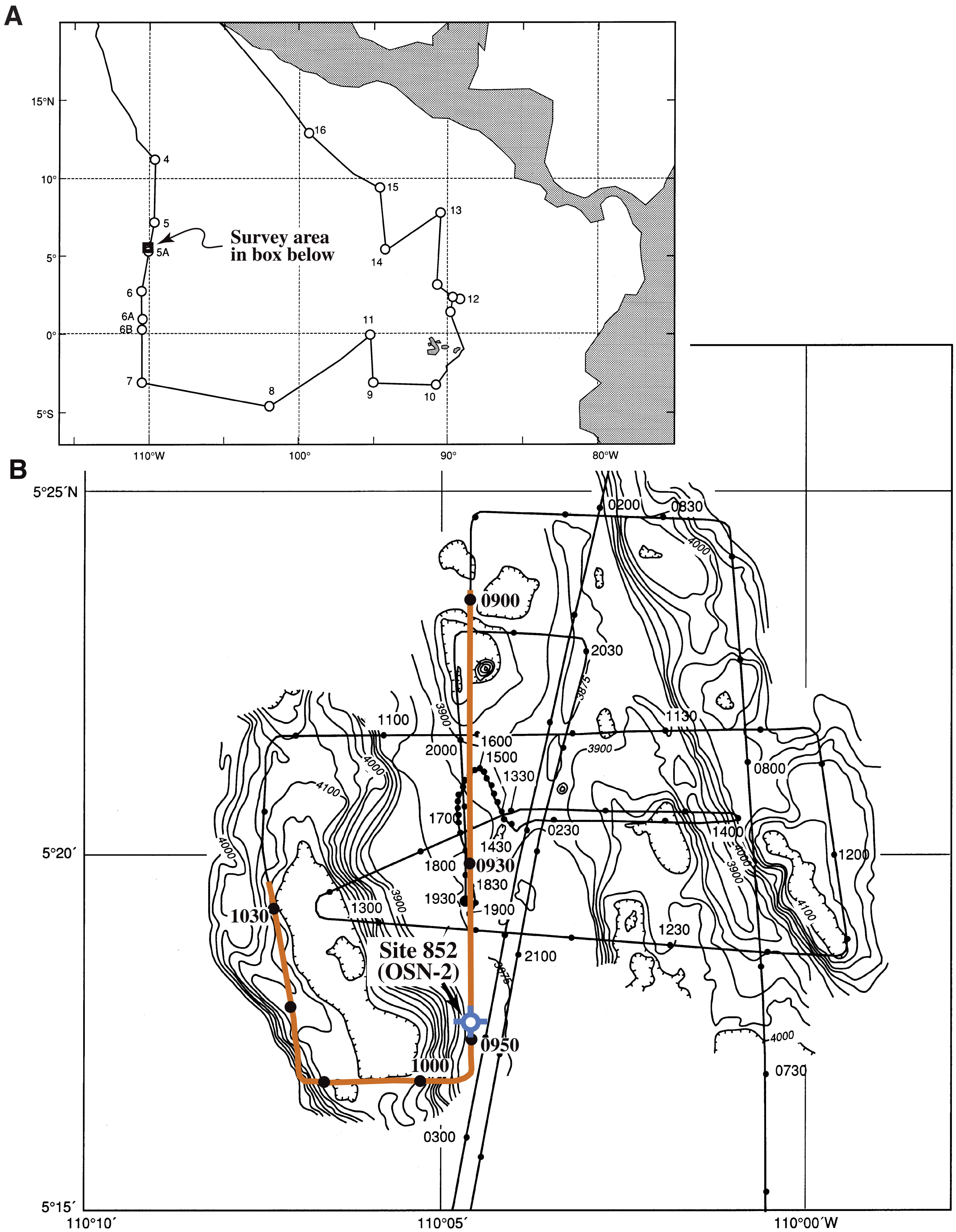
A
15°N
10°
5°
0°
5°S
110°W
100°
90°
80°W
16
15
14
13
12
11
10
9
8
7
6B
6A
6
5A
5
4
Survey area
in box below
B
5°25´N
5°20´
5°15´
110°10´
110°05´
110°00´W
0900
0930
0950
1000
1030
Site 852
(OSN-2)
0200
0830
2030
1100
1130
1600
2000
1500
1330
1700
1430
1800
1830
1930
1900
1300
0230
1400
1200
0800
1230
2100
0730
0300
3900
4000
4100
3875

Figure F6

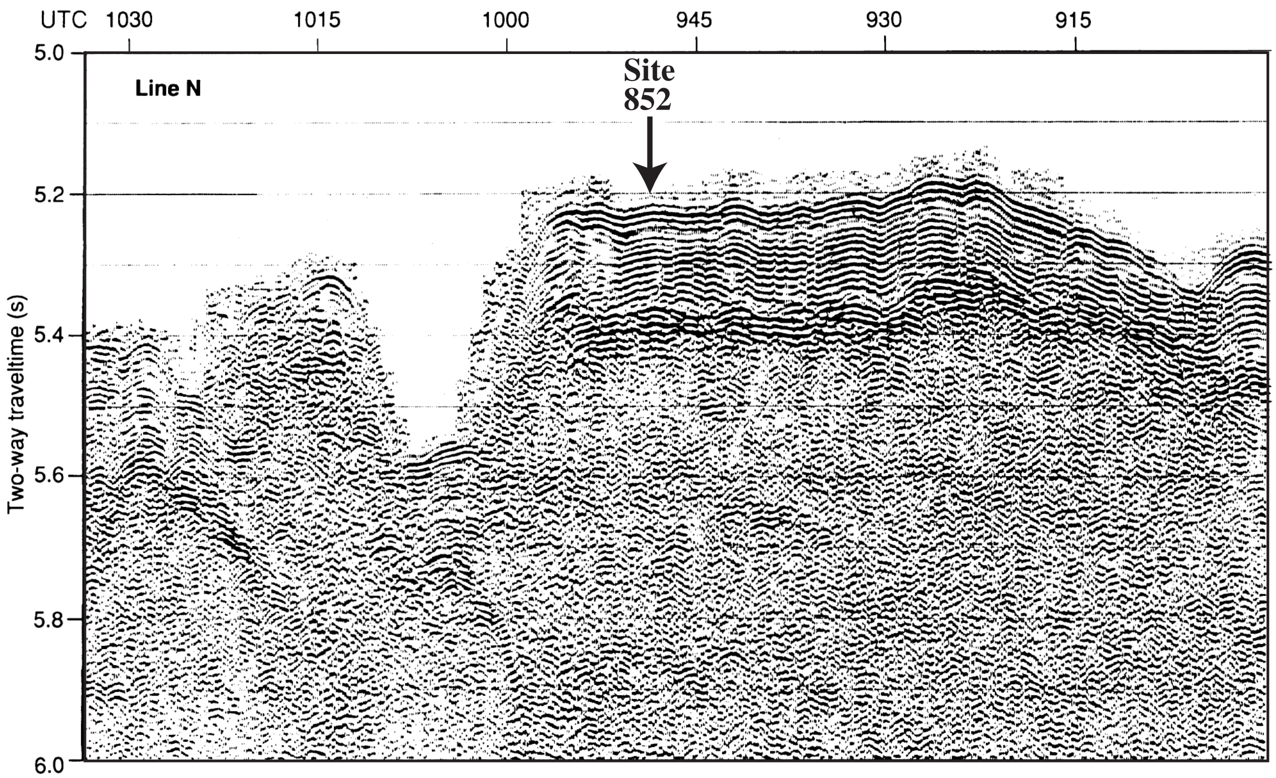
UTC
1030
1015
1000
945
930
915
Line N
Site 852
Two-way traveltime (s)
5.0
5.2
5.4
5.6
5.8
6.0

Figure F7

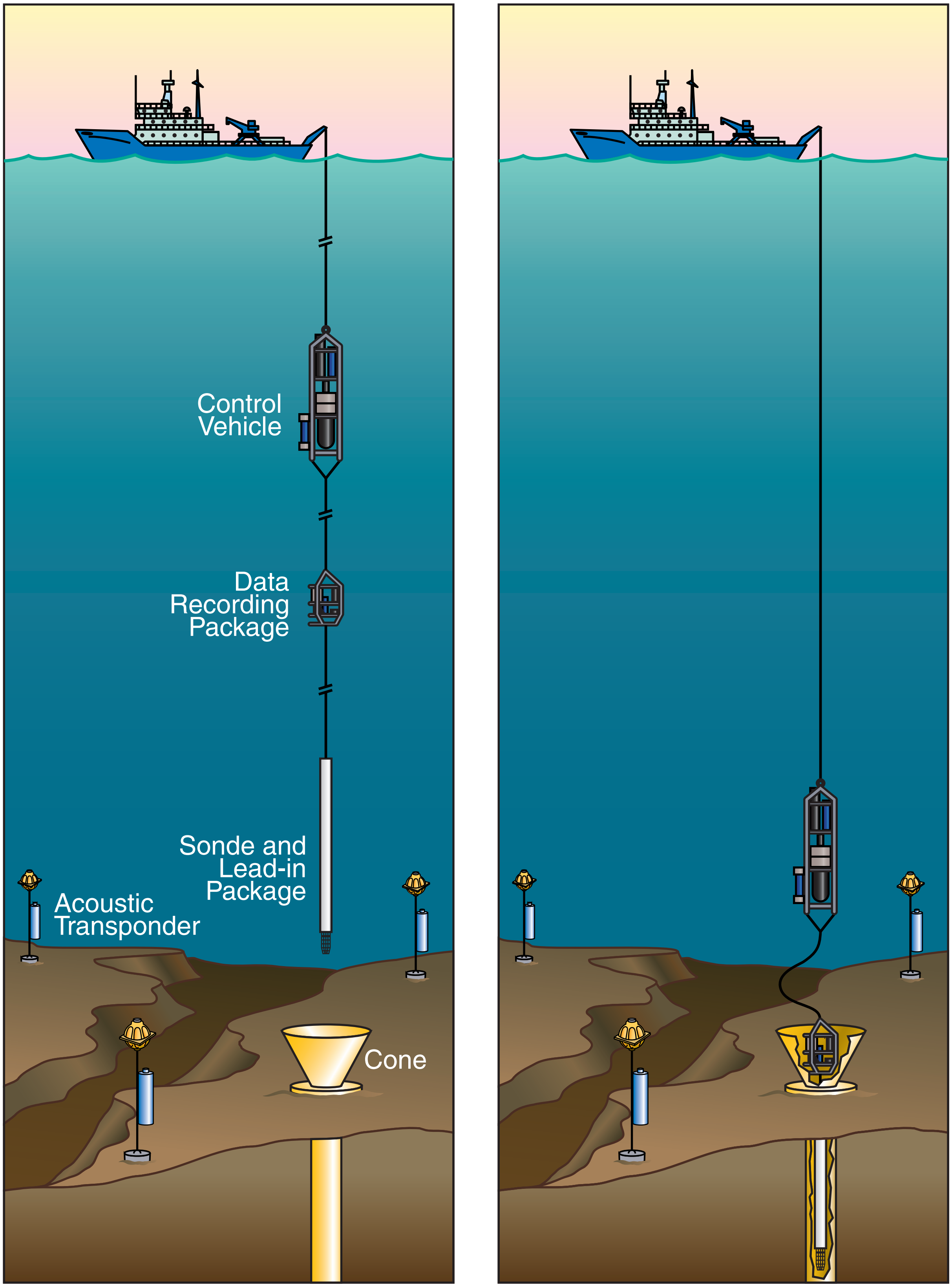
Control
Vehicle
Data
Recording
Package
Sonde and
Lead-in
Package
Acoustic
Transponder
Cone

Figure F8

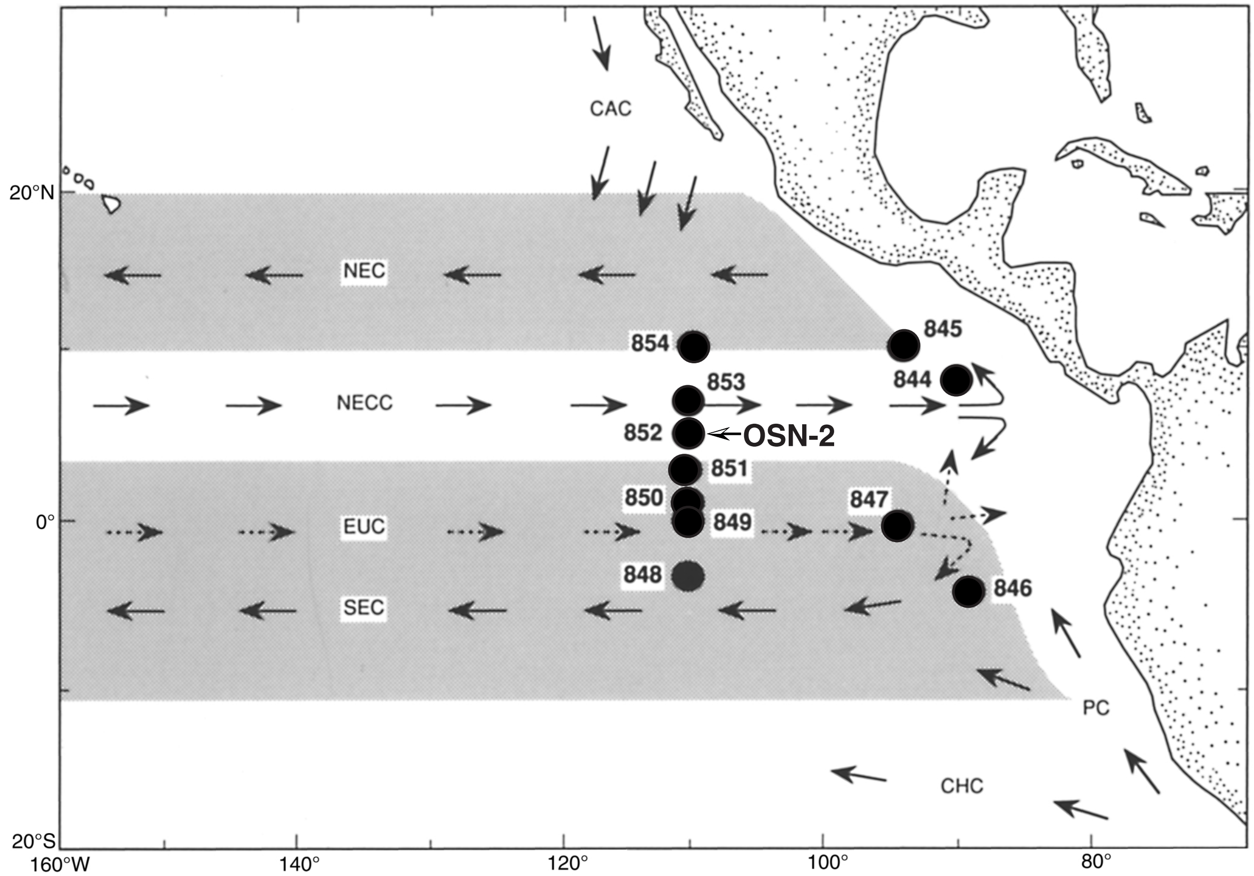
CAC
20°N
NEC
854
845
853
844
NECC
852
OSN-2
851
850
847
0°
EUC
849
848
846
SEC
PC
CHC
20°S
160°W
140°
120°
100°
80°

Figure F9

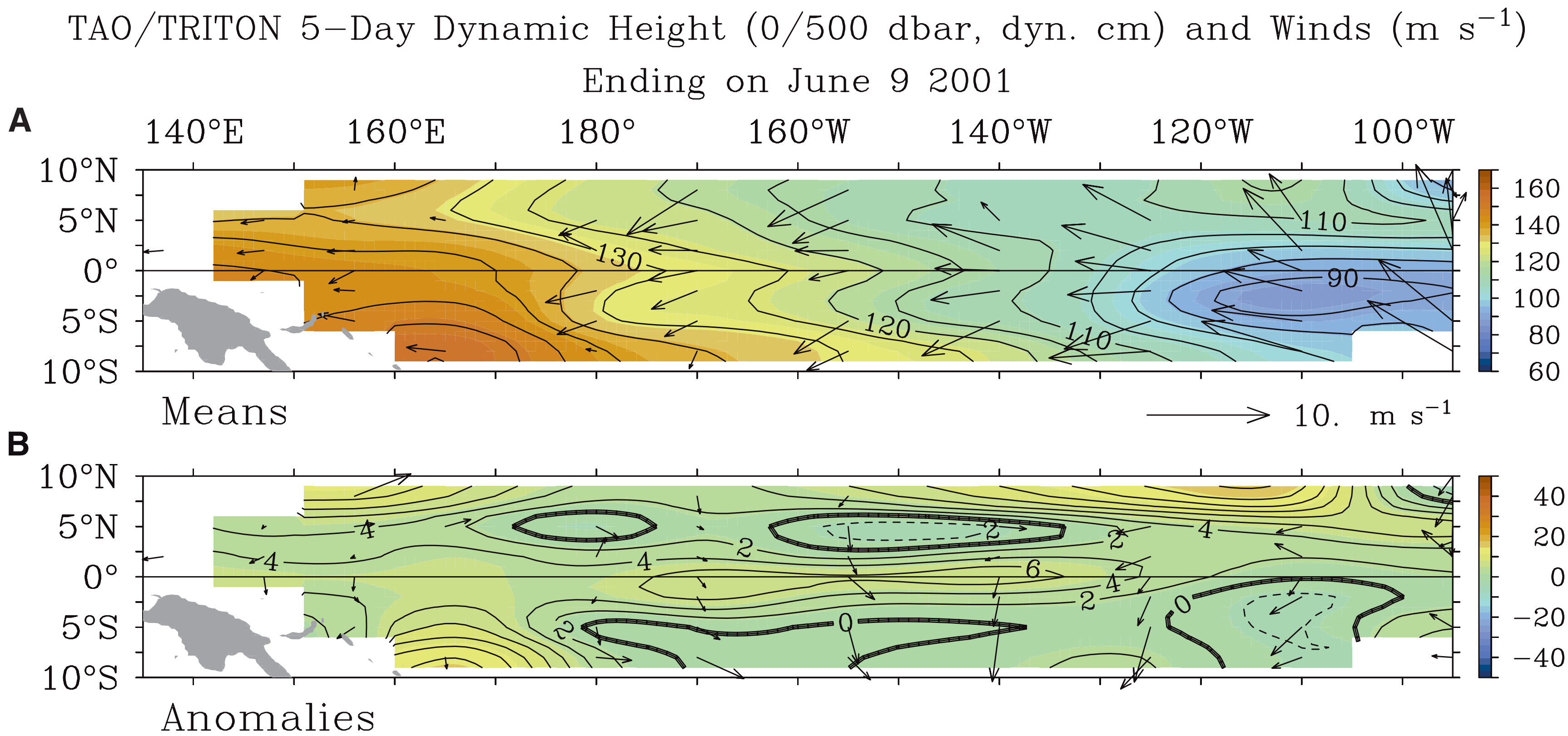
TAO/TRITON 5-Day Dynamic Height (0/500 dbar, dyn. cm) and Winds (m s−1)
Ending on June 9 2001
A
140°E
160°E
180°
160°W
140°W
120°W
100°W
10°N
5°N
0°
5°S
10°S
130
120
110
110
90
160
140
120
100
80
60
Means
10. m s−1
B
10°N
5°N
0°
5°S
10°S
4
4
4
2
2
2
6
4
2
0
0
2
4
40
20
0
−20
−40
Anomalies

Figure F10

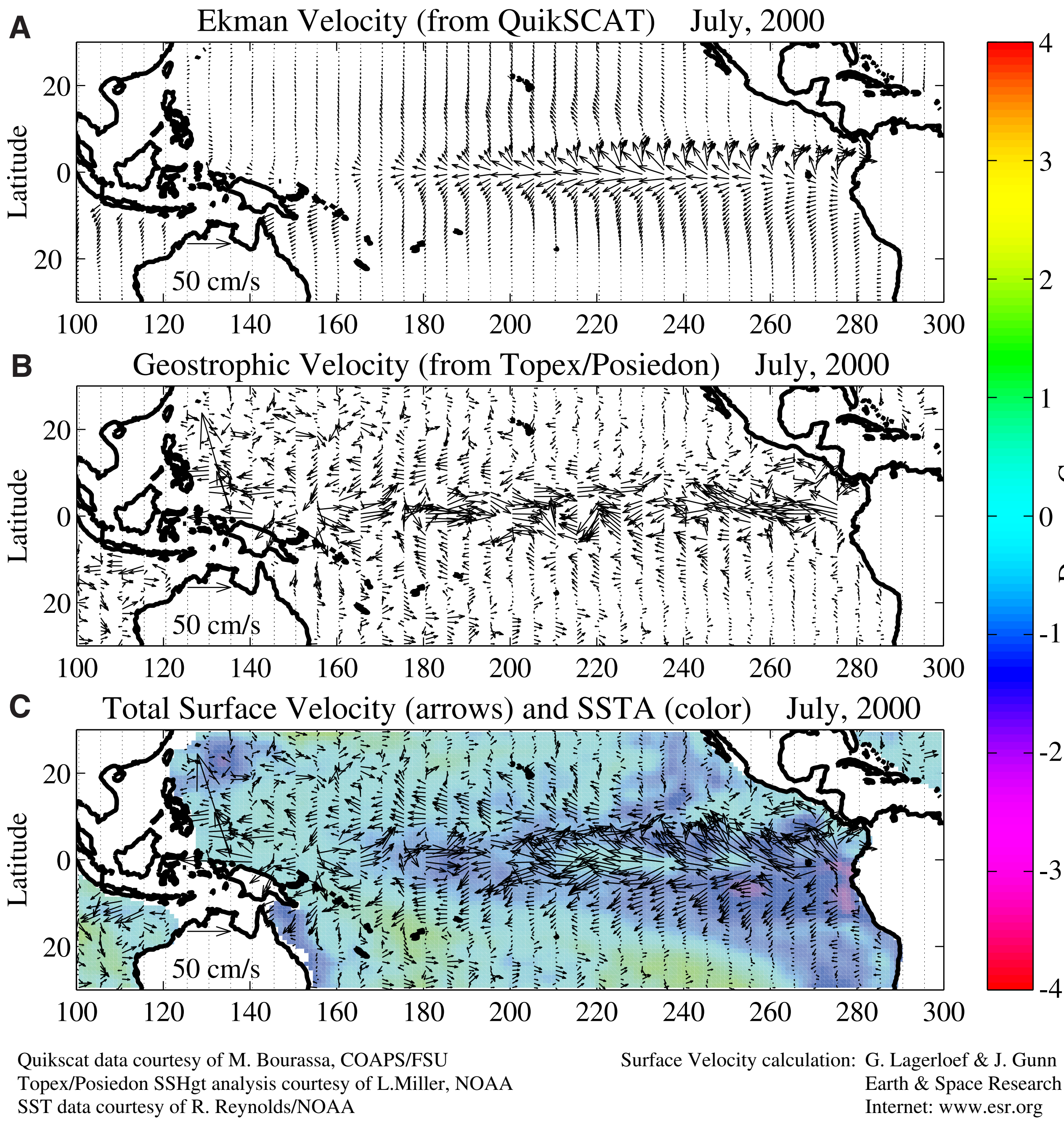
A
Ekman Velocity (from QuikSCAT) July, 2000
B
Geostrophic Velocity (from Topex/Posiedon) July, 2000
C
Total Surface Velocity (arrows) and SSTA (color) July, 2000
Latitude
20
0
20
50 cm/s
100 120 140 160 180 200 220 240 260 280 300
4
3
2
1
0
-1
-2
-3
-4
Degrees C
Quikscat data courtesy of M. Bourassa, COAPS/FSU
Topex/Posiedon SSHgt analysis courtesy of L.Miller, NOAA
SST data courtesy of R. Reynolds/NOAA
Surface Velocity calculation: G. Lagerloef & J. Gunn
Earth & Space Research
Internet: www.esr.org

Figure F11

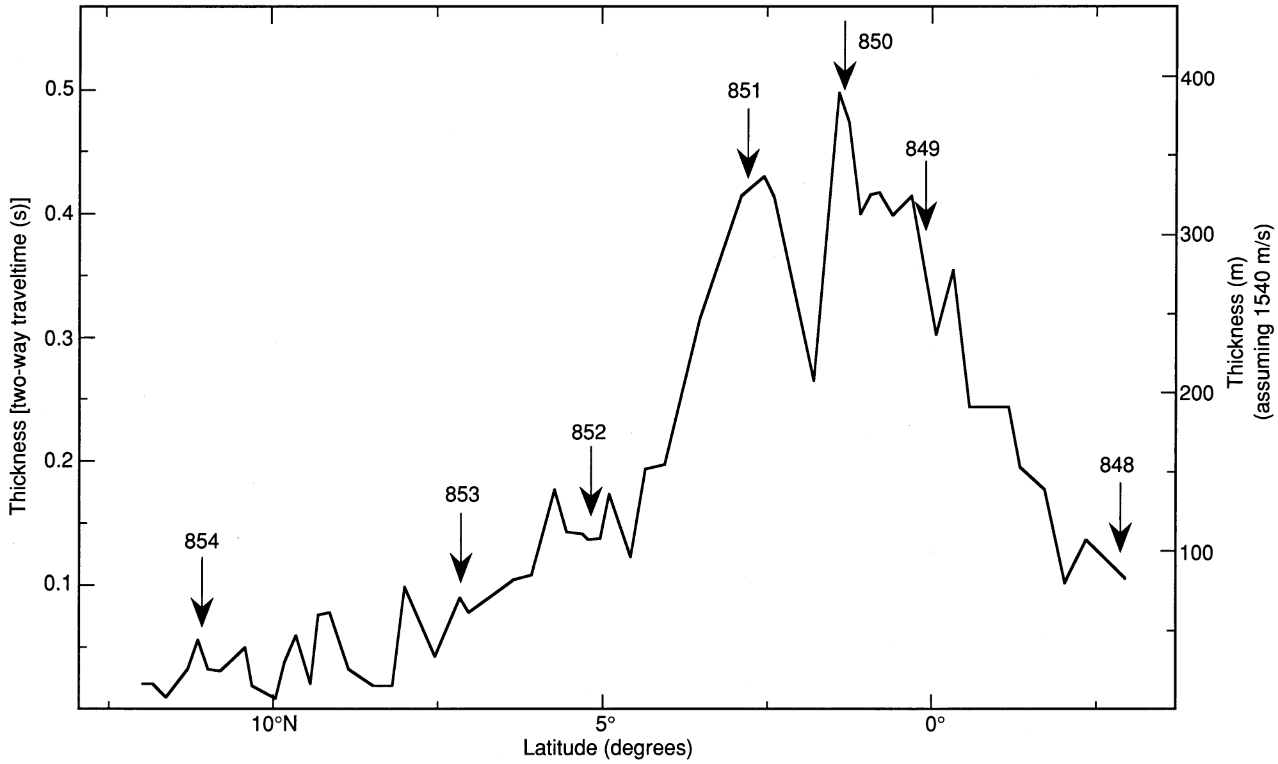
0.5
0.4
0.3
0.2
0.1
Thickness [two-way traveltime (s)]
400
300
200
100
Thickness (m)
(assuming 1540 m/s)
10°N
5°
0°
Latitude (degrees)
854
853
852
851
850
849
848

Figure F12

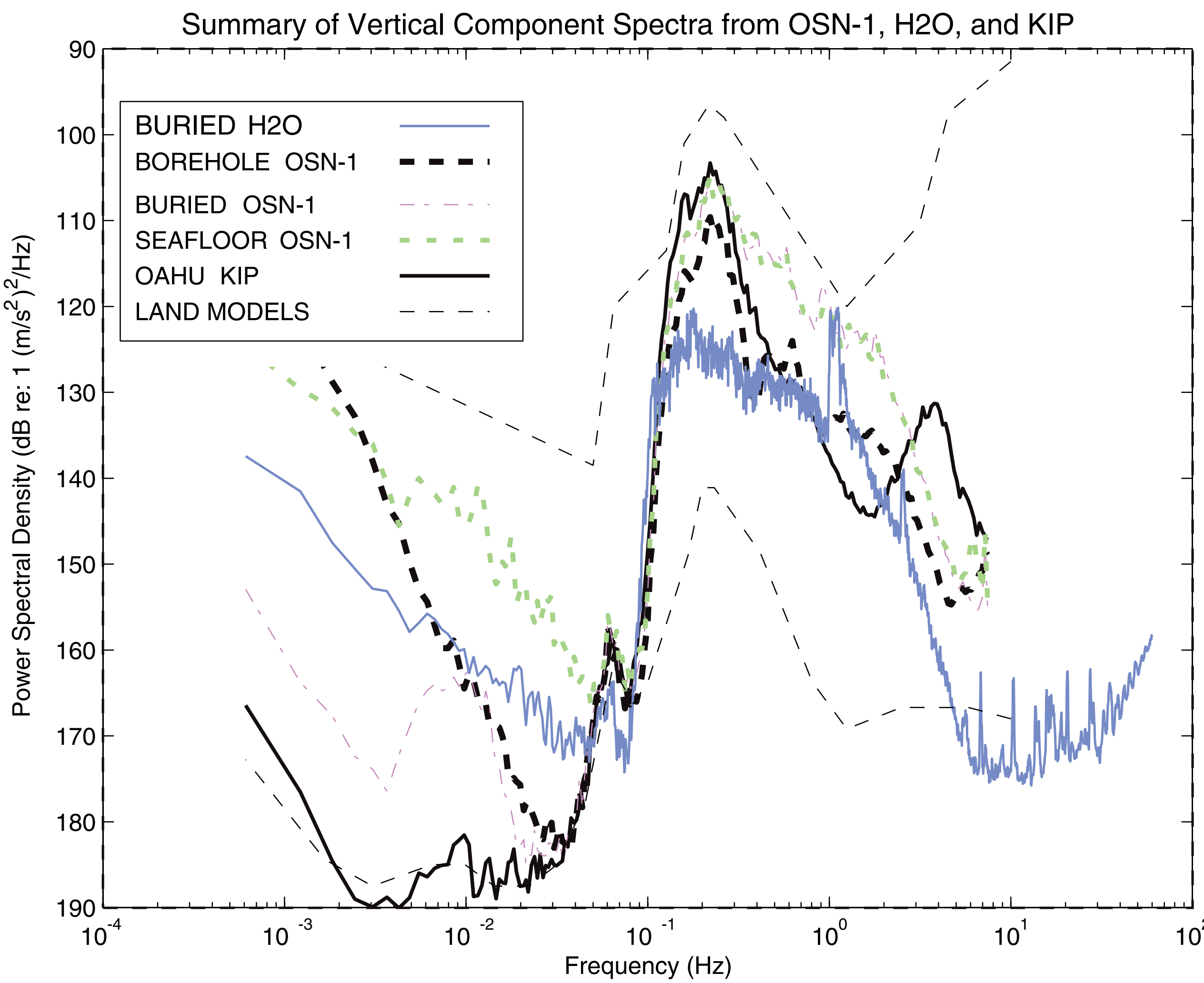
Summary of Vertical Component Spectra from OSN-1, H2O, and KIP
BURIED H2O
BOREHOLE OSN-1
BURIED OSN-1
SEAFLOOR OSN-1
OAHU KIP
LAND MODELS
Power Spectral Density (dB re: 1 (m/s^2)^2/Hz)
Frequency (Hz)
90
100
110
120
130
140
150
160
170
180
190
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

Figure F13

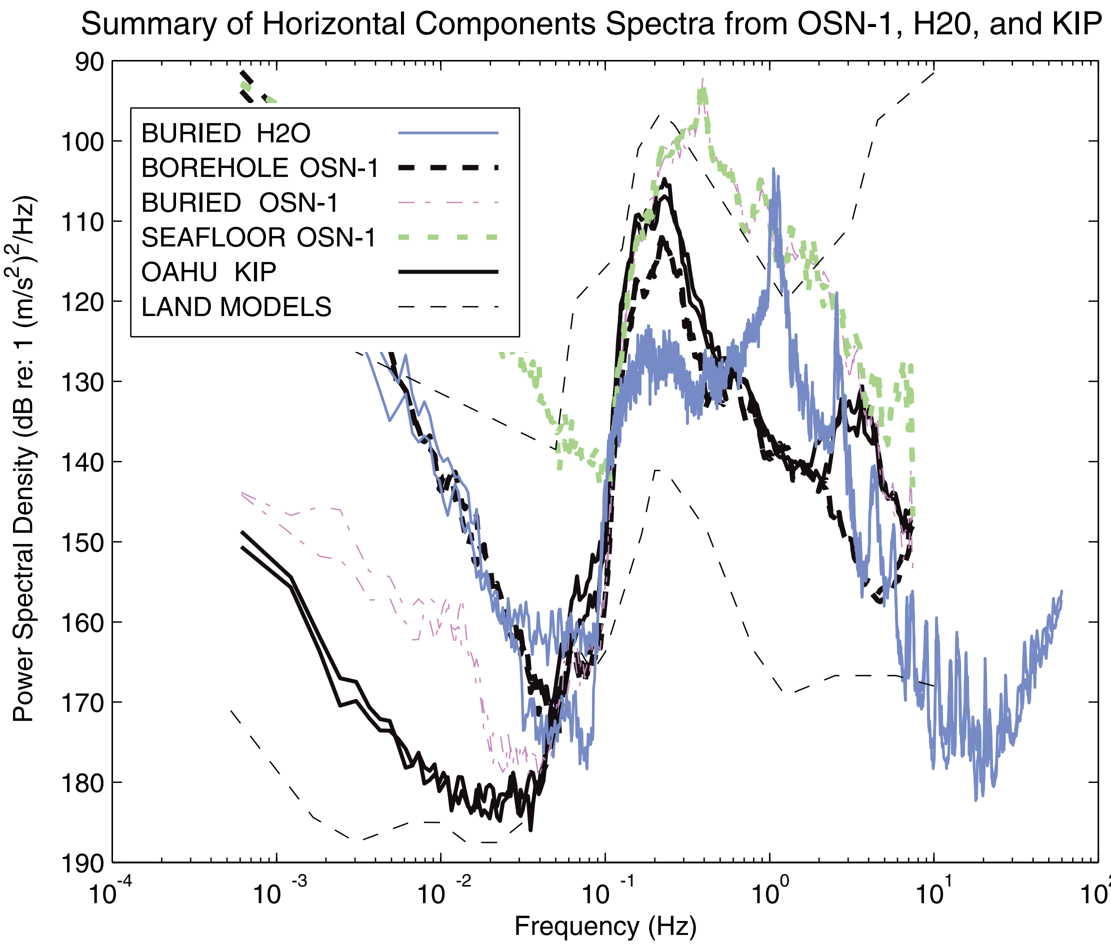
Summary of Horizontal Components Spectra from OSN-1, H20, and KIP
BURIED H2O
BOREHOLE OSN-1
BURIED OSN-1
SEAFLOOR OSN-1
OAHU KIP
LAND MODELS
Power Spectral Density (dB re: 1 (m/s^2)^2/Hz)
90
100
110
120
130
140
150
160
170
180
190
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
Frequency (Hz)

Figure F14

Table 1. Summary of holes drilled in "normal crust" on the Pacific plate with an age <100 Ma into basement >10 m.

Site/Hole	Leg	Age (Ma)	Location	Basement penetration	Sediment thickness
163	DSDP 16	72.0	11°N, 150°W	18 m	176 m
420	DSDP 54	3.4	09°N, 106°W	29 m	118 m
421	DSDP 54	3.4	09°N, 106°W	29 m	85 m
429A	DSDP 54	4.6	09°N, 107°W	21 m	31 m
469*	DSDP 63	17.0	33°N, 121°W	58 m	391 m
470A	DSDP 63	15.0	29°N, 118°W	48 m	167 m
471	DSDP 63	12.0	23°N, 112°W	82 m	741 m
472	DSDP 63	15.0	23°N, 114°W	25 m	112 m
597B**	DSDP 92	29.0	19°S, 130°W	25 m	48 m
597C†	DSDP 92	29.0	19°S, 130°W	91 m	53 m
599B	DSDP 92	8.0	19°S, 120°W	10 m	41 m
843B‡	ODP 136	95.0	19°N, 159°W	71 m	243 m

Notes: * = At the foot of Patton Escarpment. † = A reentry cone was emplaced at this site. Site OSN-1. ** = This hole is in crust generated by fast spreading (55 mm/yr half rate). Da the Leg 200 Scientific Prospectus.

Table 2. Operations plan and time estimates for Leg 203.

Site	Location & Depth	Operations Description	Transit (days)	Drilling (days)	Logging (days)	On-site (days)
Balboa	8.57°N, 79.33°W	Transit from Balboa to proposed Site OSN-2, ~1899 nmi @ 10.5 kt	7.54			
OSN-2	5°17.566'N, 110°04.579'W	**Hole A:** Cased reentry hole for multidisciplinary observatory				
	Water depth = 3860 m	1. Geophysical survey and jet-in test.		1.33		1.33
		2. Set reentry cone and jet-in ~60 m of 20-in casing.		1.41		1.41
		3. Drilling to ~140 mbsf with 18.5-in tricone bit and set 16-in casing to ~130 mbsf.		3.12		3.12
		4. Drill out cement and casing shoe and RCB core in basement from 140 to 216 mbsf.		2.33		2.33
		5. Wireline logging from 130 to 216 mbsf.			1.77	1.77
		6. Drill 14.75-in hole from 130 to 216 mbsf and set 10.75-in casing to ~211 mbsf.		4.21		5.98
		Hole B: RCB coring and logging if time permits (see Table 3)				
		Prepare for transit.		0.33		0.33
San Francisco	44.6°N, 125.1°W	Transit from proposed Site OSN-2 to San Francisco, ~2486 nmi @ 10.5 kt	9.87			
		SUBTOTAL:	**17.4**	**12.7**	**1.8**	**16.3**
		TOTAL REQUIRED OPERATING DAYS:	**31.9**			

Table 3. Time estimates for secondary operations that may be conducted if extra time is available.

Site	Location & Depth	Operations Description	Transit (days)	Drilling (days)	Logging (days)	On-site (days)
		PREFERRED OPTION				
OSN-2	5°17.566'N, 110°04.579'W	**Hole B:** RCB coring and logging if time permits				
	Water depth = 3860 m	1. RCB drill to ~80 mbsf and core from 80 to 140 mbsf.		1.15		1.15
		2. Release bit and wireline log with triple combo and FMS/sonic toolstrings.			1.59	1.59
		Subtotal	0.00	1.15	1.59	2.74
		OTHER SECONDARY OPTIONS				
	5°17.566'N, 110°04.579'W	**Hole A:** After completing casing, run cement bond				
OSN-2	Water depth = 3860 m	Log in 10.75-in casing from 140 to 211 mbsf.			1.30	1.30
	5°17.566'N, 110°04.579'W					
OSN-2	Water depth = 3860 m	**Holes C and D:** Double APC coring to 116 mbsf			2.48	2.48

SITE SUMMARY

Site: OSN-2

Priority: 1
Position: 5°17.566′N, 110°04.579′W
Water Depth: 3860 m
Sediment Thickness: 116 m
Target Drilling Depth: 216 mbsf
Approved Maximum Penetration: Unlimited (pending approval)
Seismic Coverage: North-south SCS line collected during ODP Leg 138. North-south analog seismic line collected during the *Thomas Washington* Venture 1 cruise. Proposed observatory site is at ODP Site 852 cored during Leg 138.

Objectives: The objectives at proposed Site OSN-2 are to:

1. Drill a reentry hole into basement for a permanent broadband borehole seismograph;
2. Provide a borehole for other long-term borehole measurements; and
3. Provide a "reference site" with in situ igneous samples in normal, fast-spreading, ~12-Ma ocean crust to constrain geochemical and hydrothermal models of crustal evolution.

Drilling Program: Jet-in a reentry cone with 20-in casing to 40–60 mbsf; drill to 140 mbsf, install 16-in casing to 130 mbsf, which is ~14 m into basement; RCB core from 140 to 216 mbsf or deeper if time permits, log with the triple-combo and FMS/sonic tool strings, open hole and set 10.75-in casing ~5 m above the total depth of the hole. If time permits, drill a second hole to ~80–90 mbsf, RCB core to ~140 mbsf, and log with the triple-combo and FMS/sonic tool strings.

Logging and Downhole: Triple-combo and FMS/sonic.

Nature of Rock Anticipated: Soft sediment and fractured pillow basalt. See Figures F5 and F7 for the seismic lines and Figures F4 and F6 for the track lines.

SCIENTIFIC PARTICIPANTS

Co-Chief
John Orcutt
Institute of Geophysics and Planetary Physics (0225)
Scripps Institution of Oceanography
La Jolla CA 92093-0225
USA
Internet: jorcutt@igpp.ucsd.edu
Work: (858) 534-2887
Fax: (858) 822-3372

Co-Chief
Adam Schultz
Department of Earth Sciences
Cardiff University
Cardiff CF10 3YE
United Kingdom
Internet: schultza@cf.ac.uk
Work: 44-(0)29 2087 4325
Fax: 44-(0)29 2087 4326

Staff Scientist
Gary D. Acton
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: acton@odpemail.tamu.edu
Work: (979) 845-2520
Fax: (979) 845-0876

Microbiologist
Chuanlun Zhang
Department of Geological Sciences
University of Missouri, Columbia
101 Geological Science Building
Columbia MO 65211
USA
Internet: zhangcl@missouri.edu
Work: (573) 884-2677
Fax: (573) 882-5458

Paleomagnetist
Julie Carlut
Laboratoire de Geologie
École Normale Supérieure
24 rue Lhomond
75231 Paris
France
Internet: carlut@ipgp.jussieu.fr
Fax: (33) 01-44-32-20-00

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

Logging Staff Scientist
Arno Buysch
Applied Geophysics
Aachen University of Technology (RWTH-Aachen)
Lochnerstrasse 4-20
52056 Aachen
Germany
Internet: a.buysch@geophysik.rwth-aachen.de
Work: (49) 241 809 4826
Fax: (49) 241 809 2132

Schlumberger Engineer
Kerry Swain
Schlumberger Offshore Services
369 Tristar Drive
Webster TX 77598
USA
internet: swaink@webster.oilfield.slb.com
Work: (281) 480-2000
Fax: (281) 480-9550

Operations Manager
W. Brian Jonasson
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: jonasson@odpemail.tamu.edu
Work: (979) 845-2024
Fax: (979) 845-2308

Assistant Laboratory Officer
Chieh Peng
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: peng@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Laboratory Specialist: Yeoperson
Michiko Hitchcox
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: hitchcox@odpemail.tamu.edu
Work: (979) 845-2483
Fax: (979) 845-0876

Marine Laboratory Specialist: Chemistry
Dennis Graham
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: graham@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Laboratory Specialist: Curator
Kim A. Bracchi
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: bracchi@odpemail.tamu.edu
Work: (979) 845-4822
Fax: (979) 845-0876

Marine Laboratory Specialist: Downhole Tools/Thin Sections
Ted Gustafson
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: gustafson@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Laboratory Specialist: Paleomagnetism
Charles A. Endris
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: endris@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Laboratory Specialist: Photographer
Cyndi J. Prince
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: prince@odpemail.tamu.edu
Work: (979) 845-2480
Fax: (979) 845-0876

Marine Laboratory Specialist: Underway Geophysics
Paula Weiss
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: pweiss@qwest.net
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Electronics Specialist
Michael Meiring
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: meiring@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Computer Specialist
Randy W. Gjesvold
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547-9547
USA
Internet: gjesvold@odpemail.tamu.edu
Work: (979) 845-3602
Fax: (979) 845-0876

Marine Computer Specialist
Margaret Hastedt
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: hastedt@odpemail.tamu.edu
Work: (979) 862-2315
Fax: (979) 458-1617

Marine Computer Specialist
Erik Moortgat
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: moortgat@odpemail.tamu.edu
Work: (979) 845-7716
Fax: (979) 845-0876

ODP/TAMU Programmer
Granville Wright
Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Internet: wright_g@odpemail.tamu.edu
Work: (979) 845-1918
Fax: (979) 458-1617