OCEAN DRILLING PROGRAM

LEG 186 PRELIMINARY REPORT

WESTERN PACIFIC GEOPHYSICAL OBSERVATORIES

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SCIENTIFIC REPORT

ABSTRACT

Two borehole geophysical observatories were installed ~1100 m below the seafloor on the deep-sea terrace of the Japan Trench during Ocean Drilling Program Leg 186. Site 1150 (39°11′N, 143°20′E) and Site 1151 (38°45′N, 143°20′E) are located in areas with contrasting seismic characteristics. The northern site is within a seismically active zone where microearthquakes are frequent and M7 earthquakes recur. The southern site is within an aseismic zone where no earthquakes are observed. These features coexist within the seismogenic zone of the Japan Trench plate subduction zone, where the >100-Ma portion of the Pacific plate is subducting at a fast rate (~8 cm/yr) beneath northern Japan causing major earthquakes along the trench. Such a dynamic nature of the subduction seismogenic zone remains unexplained because no geodetic and few seismic stations exist on the seafloor that give us hard evidence in the vicinity of the fault (décollement) zone. Leg 186 is the first scientific venture to succeed in installing state-of-the-art strain, tilt, and seismic sensors for long-term operation in seafloor boreholes. The borehole instruments were installed only 10 km above the gently dipping (< 5°) plate boundary. The systems will start collecting data in September 1999 and will be serviced by a remotely operated vehicle (ROV) at least once a year to recover continuous high sampling rate and wide dynamic range data. These stations will make invaluable additions to the existing geophysical network over the western Pacific. This type of multiple-sensor seismo-geodetic observatory can now be emplaced by the *JOIDES Resolution* at many other areas where active processes await to be monitored.

Previous drilling in the area took place during Deep Sea Drilling Project (DSDP) Legs 56, 57, and 87, which transected the Japan Trench at ~39.8°N–40.7°N. These legs established the concept of tectonic erosion along a subduction zone. The Neogene subsidence history of the forearc was documented and numerous ash records were obtained that span the past 9 m.y. The coring and logging data obtained from Sites 1150 (2681-m water depth) and 1151 (2182-m water depth) provide additional observations to further our understanding of the tectonics of this area with better recovery and higher resolution than was available from previous drilling along the Japan Trench. The ages of the recovered sediments are 10–0 Ma at Site 1150 and 16–0 Ma at Site 1151. The sedimentation rates significantly differ before ~7 Ma between the two sites, but are similar since then, and are similar to the rates at DSDP Leg 57 Site 438 and Leg 87 Site 584.

Estimations on the deformational history from observed microfractures and microfaults and logging data are consistent with a general east-west extensional stress field in which normal faulting dominates. It will be of great interest to compare these structural data and additional mechanical properties measurements to be made on whole-round core samples with data from the observatories, where the current tectonic stress field is actually east-west compressional across the Japan arc to the Sea of Japan.

Recovering detailed ash records was one of the highlighted drilling objectives. As with previous drilling results, a general increase from ~9 Ma and a peak in the past 0.5–4 Ma are observed at the two sites. Postcruise studies will examine the details of the ash record, which was more completely recovered on Leg 186 than on previous cruises.

Inorganic geochemical analysis confirmed that a large decrease in chlorinity and salinity with depth exists in the Japan Trench region. This was first observed at DSDP Sites 438 and 439 but not at other sites of Legs 56 and 57. The character of the anomalies varies also between the two ODP Leg 186 sites. Overall, the magnitude of decrease seems much larger than other subduction environments such as at Nankai or Barbados.

To further our understanding of the plate subduction dynamics, near-site multiple disciplinary investigations are clearly needed. In particular, geological "hysteresis" concealed in present-day dynamics needs to be better understood to construct physical models by linking geological/geochemical and geophysical studies. Leg 186 is one such investigative attempt to link current and past dynamics by establishing borehole observatories and by obtaining core and logging data at the seismogenic zone of the Japan Trench.

INTRODUCTION

The scientific importance of establishing long-term geophysical stations in deep oceans has been acknowledged by earth sciences and Ocean Drilling Program (ODP) communities and is expressed in various articles (COSOD II, 1987; Purdy and Dziewonski, 1988; BOREHOLE, 1994; Montagner and Lancelot, 1995; Ocean Drilling Program, 1996). Indeed, more than a few important inferences on the dynamics of the Earth's deep interior have been inferred from seismic tomography images, such as existence of super plumes, deep continental roots, stagnation of subducting plates within the mantle, and variations in the thickness of the thermal boundary layer at the base of the mantle (e.g., Fukao, 1992). Detailed examination of active processes at plate boundaries have also brought about significant inferences on magma reservoirs at oceanic ridges and on the décollement structure of subducting plates.

In essence, we wish to understand active processes driving Earth's dynamics from a global to a regional scale. A major step forward will almost certainly be made by installing permanent observatories in the oceans, which constitute 71% of Earth's surface. Obtaining observations from oceanic areas is significant not only for global coverage, but because most of the plate boundaries exist beneath the oceans, particularly those boundaries where oceanic lithosphere is presently being generated and recycled.

The western Pacific area is ideal for addressing problems related to plate subduction. In particular, the Japan Trench area is where much effort has been made for monitoring seismic and geodetic motions on land for many years. Together with marine geological and geophysical investigations on both sides of the Japan island arc, this area probably is the best studied subduction area. The area can be characterized as having a fast subduction rate and being a seismically active and well-coupled area. We also have knowledge of the sedimentary and tectonic environment from previous drilling, which found the forearc area to be subsiding as a result of tectonic erosion with little accretionary prism development.

To monitor strain and seismic activity continuously and ultimately to understand how plate motion is accommodated across a subduction zone, we have installed two geophysical observatories on the landward side of the Japan Trench (Fig. 1). Coring and logging data collected during the cruise are also expected to provide a tectonic history that can be linked to the present dynamics, which will be inferred from the observatories.

Although not always the case, normal coring objectives and observatory objectives often overlap and are interrelated as in this leg or recent Circulation Obviation Retrofit Kit (CORK) legs. Once an observatory is established, ways and means to recover the data and to keep the station running become necessary. Such tasks are not easily undertaken even if a site only needs servicing once a year. A new fiber-optic cable owned by the University of Tokyo already exists and currently terminates near Site 1150. Once Site 1150 proves to be functioning, connections will be made to supply power, send commands, and retrieve data in real time on land. Furthermore, a 50-km cable extension is planned to connect Site 1151 as well. These stations will make invaluable additions to the existing geophysical network over the western Pacific. The data will eventually become accessible worldwide through the Internet.

PREVIOUS DRILLING ALONG THE JAPAN TRENCH

Previous deep-sea drilling sites along the Japan Trench are shown in Figure 2. During DSDP Legs 56 and 57, Sites 436 (Leg 56), 434 (Leg 56), 441, 440, and 435 (Leg 56) were drilled along seismic Line JNOC-2 across the trench at 39°45′N. Sites 438 and 439 were drilled along seismic Line JNOC-1 across the trench at 40°40′N (Scientific Party, 1980). During DSDP Leg 87, Site 584 was also drilled in the area (Kagami, Karig, Coulbourn, et al., 1986). These legs were focused to study the mechanism and dynamics of plate convergence and their effects on sedimentation. It is presently widely accepted that little tectonic accretion is occurring. Instead, a massive subsidence has been taking place along the Japan Trench. This was a surprising finding substantiated by past drilling. Another surprise was the unexpected discovery of andesitic volcanic rocks from Site 439, 90 km from the trench axis, which indicated that there is an offset of ~200 km between the present arc and where Oligocene volcanism occurred.

The Cretaceous unconformity widely recognized on land was observed at Site 439 and could be further extrapolated seaward by the aid of seismic records suggesting that a pre-Oligocene forearc once extended at least to the present midslope terrace where Site 440 is located. The objective at Site 584 was to further confirm and detail the findings of Legs 56 and 57. Site 584, at the outer slope, reached sediment of middle Miocene age, confirming persistent subsidence during the Miocene. It was suggested that extensional tectonics continued from the middle Miocene until the early Pliocene. Numerous ash layer records from all the sites suggest that onshore volcanic activity increased near the end of the late Miocene and continued through the early Pliocene.

Leg 186 was planned to establish borehole geophysical observatories that could monitor the ongoing tectonic processes and confirm and detail previous findings at two sites (Sites 1150 and 1151) ~25 km north and south of 39°N, corresponding to slightly seaward of Site 439 in longitude.

TECTONIC AND SEISMIC SETTING

Tectonic Setting

The convergent margin off northern Honshu has developed where lower Cretaceous Pacific ocean crust underthrusts the Eurasian plate in a westerly direction. A 10.5 cm/yr convergence rate between these two plates has been estimated (e.g., Wesnousky et al., 1982). The topographic features of the Japan Trench system consist of deep-sea terrace, inner trench slope, midslope terrace, trench lower slope, Japan Trench, and outer trench slope (Fig. 3). A forearc basin develops in the deep-sea terrace and trench upper slope, which extends from the northwest coast of Hokkaido more than 600 km to the south and is filled with Neogene sediments as much as 5 km thick. Sites 1150 and 1151 on the deep-sea terrace, located ~100 km west of the Japan Trench, are on the eastern edge of the forearc basin, where the Neogene section is ~1.5 km thick.

In multichannel seismic profiles, the reflective sequence above a major diffracting horizon represents a seaward transgressive sequence across an extensive angular unconformity (Fig. 4). Landward-dipping reflectors below the unconformity may represent formerly accreted sediments or folded and tilted older sedimentary rocks; they are dated by drilling as Upper Cretaceous at Site 439. The Neogene sequence is cut by landward-dipping normal faults spaced ~10 to 15 km apart (Nasu et al., 1980). Seismic refraction measurements indicate a continental crustal velocity structure beneath the deep-sea terrace (Murauchi and Ludwig, 1980; Suyehiro and Nishizawa, 1994).

Tectonic history in the convergent margin near the Japan Trench is characterized by tectonic subsidence and erosion. Regional subsidence during the latest period of plate convergence was established during DSDP drilling along the Japan Trench margin (von Huene, Nasu, et al., 1978) by coring through a subaerial erosion surface many kilometers below sea level (Fig. 5). That erosion surface corresponds to an angular unconformity that cuts across tilted beds and is buried beneath subhorizontal strata of the outer shelf and slope. The unconformity extends throughout a 150-km-long area (Nasu et al., 1980; von Huene et al., 1982) and shows no sign of ending beyond the published seismic coverage. Across the unconformity, seismic velocity increases abruptly from ~1.9 to 4.2 km/s (Murauchi and Ludwig, 1980; Suyehiro and Nishizawa, 1994), consistent with the contact between unconsolidated Oligocene to Quaternary strata and well-consolidated Cretaceous rock as drilled at DSDP Site 439. The sedimentary strata above the unconformity consist of a 48-m-thick breccia and conglomerate of dacite and rhyolite boulders, covered by 50 m of medium-grained sand containing abundant little-transported macrofossils, which was in turn buried by silt and sand turbidites (Scientific Party, 1980) with a probable seaward source (von Huene et al., 1982). The upper 800 m of the section consists of Miocene diatomaceous mud. The regional extent of rock types and erosion was explained by subsidence of a landmass during the past 22 m.y. (Scientific Party, 1980; von Huene et al., 1982). Benthic microfossils from the sediments indicate a succession of water depth consistent with such a history (Arthur et al., 1980; Keller, 1980).

Seismic Setting

In the Japan Trench area, seven large (magnitude [M] = >7) interplate events have occurred in the last 30 yr between 38°N and 41°N. Recent large events are the 1968 Tokachi-Oki earthquake (~41°N; moment magnitude [Mw] = 7.9) and the 28 December 1994 Far-off Sanriku earthquake (~40°N; Mw = 7.7) (Fig. 6). These events, however, are not sufficient to account for the subducting rate of ~8–10 cm/yr. Thus, the seismic coupling seems much smaller along the Japan Trench (35°N–41°N) as compared with the Kurile Trench or Nankai Trough regions, which have a higher seismic energy release rate. Subduction at the Japan Trench may be proceeding by stable sliding either only with relatively small (surface-wave magnitude [Ms] = <8) events or with occasional large events.

There is a third important category whereby the subduction rate is accommodated by episodic aseismic events of time constants on the order of 10 min to several days (slow earthquakes). Such events, if they exist, are presently extremely difficult to detect. Kawasaki et al. (1995) reported that an ultra-slow earthquake estimated to be Mw 7.3–7.7 accompanied the 1992 Off-Sanriku (39.42°N, 143.33°E; Mw = 6.9) earthquake, based on strain records observed ~120–170 km away from the source. A postseismic strain change of 10^{-7} to 10^{-8} with a time constant of about a day were observed by quartz-tube extensometers (devices that measure absolute strain). Historically, in the same area, the 1896 Sanriku tsunami earthquake (Mw = ~8.5 but body-wave magnitude [Mb] = ~7) killed ~22,000 people. Tsunami earthquakes rupture in a much longer time constant of minutes compared to normal type (Tanioka and Satake, 1996).

More recently, the Japanese global positioning system network revealed a postseismic motion of northern Japan after the 1995 Far-off Sanriku earthquake (M = 7.2) that can be explained by a stress diffusion model assuming slow slip on the earthquake fault (Heki et al., 1997). A different, but previously more prevalent interpretation is that the postseismic deformation is a result of aseismic slip at a depth extending below the seismogenic zone.

The above-mentioned large episodic events are responsible for the plate motion. There are numerous microearthquakes, which contribute little to tectonics, but delineate the characteristics of seismogenic zone (Fig. 7). Microearthquake activity in this area shows spatially clustered occurrence over at least a few tens of years. The plate geometry from microearthquakes suggests that a large bend occurs at ~20 km depth. The seismic activity seems to have a gap above and below this depth along the plate boundary. The shallower activity is conspicuously high between 39°N–41°N.

The seismic velocity structure of this area is characterized by a small accretionary wedge (Fig. 3). High velocity (> 6 km/s) material reaches beneath the inner trench slope. Either an extension of the island arc lower crust or the mantle wedge seems to meet the plate boundary where it plunges. Large thrust earthquakes in this area often initiate from the updip end of the seismogenic zone and reach beneath the coastline. It can be seen that from detailed velocity structure models that there is no obvious correlation with the updip and downdip ends. This suggests that the key factors in controlling the seismic activity are not in bulk properties, but rather in the localized properties at the well-developed décollement.

OPERATIONS STRATEGY

Previous drilling in the Japan Trench region was in the DSDP era before the advent of advanced hydraulic piston corer/extended core barrel (APC/XCB) technology (Legs 56 and 57 in 1977 and Leg 87 in 1982). Previous ODP drilling at plate subduction zones were at Izu-Marianas, Barbados, Costa Rica, Cascadia, Nankai, and Peru margins, which span quite different subduction types. Both Sites 1150 and 1151 are located at the deep-sea terrace at 2681- and 2182-m water depths, respectively.

A unique aspect of Leg 186 was the installation of two permanent borehole geophysical observatories. The installation required a complex operation that has never before been done. At this environment, a clear deep-seismic reflector is the Cretaceous unconformity, below which the physical properties such as *P*-wave velocities and densities become more favorable for the sensors. However, it did not seem realistic to drill to depths of more than 1.5 s in two-way traveltime at the two sites to penetrate the Cretaceous unconformity. Such an operation would have required an interim supply of casing joints during the leg and considerably more time than available on a standard leg. Therefore, a provisional depth of 1000 m was targeted for RCB coring and to check if the physical properties values were acceptable for the instruments. Logging data and observations from cores allowed us to monitor physical properties and decide on a suitable depth.

For initial coring objectives, one site with a fast sedimentation rate was to be double APC/XCB cored to ensure complete recovery in the Pliocene and younger section. Because of large uncertainties in installation time requirements, double APC coring was postponed until Site 1151.

Each site was equipped with a reentry cone and was cased through unstable sections leaving a 50- to 100-m open-hole section at the bottom. Because the sensor package diameter cannot run through the drill string as do logging tools, it had to be connected at the bottom of the drill string. To cement in the sensors, which is essential for the strain measurements, the drillship was required.

At Site 1150, the original plan for XCB coring to 450 mbsf level was deepened to 723 mbsf. Hole 1150B was thus drilled to 703 mbsf and cored to 1182 mbsf. Below ~1100 mbsf, the physical properties seemed to be adequate for the instrument. Logging data further confirmed and pinpointed where the instrument depth should be. The unfortunate abandonment of reentry Hole 1150C because of probable defects in the reentry cone caused a major change of planning. We had to go back to the port of Yokohama to obtain another reentry cone, at which time we also loaded the remaining 4½-in casing pipes purchased for hanging the instrument package in the drilled and cased holes. At this point, we focused the use of time on accomplishing the primary objectives for the leg, which meant that many other objectives might have to be temporarily abandoned.

The Site 1150 installation was successfully completed at 1900 hr on July 28, with only 18 days left for operations at the second site. It was then that we decided to skip APC/XCB coring and logging and instead aim for the shortest pathway to complete the observatory installation. Thus, Hole 1151A was RCB cored all the way to 1114 mbsf. The operations at Hole 1151B proceeded rapidly, and we successfully completed the instrument installation on August 9, just 12 days after arriving on site. After the installation, we proceeded to complete the remaining objectives for the hole, which included double APC coring this site to ~100 mbsf, and then logging to 870 mbsf.

SCIENTIFIC OBJECTIVES

The Leg 186 Scientific Party sailed out to investigate the dynamic properties of one of the world's most active plate subduction zones, the Japan Trench, where the oldest oceanic plate (>100 Ma) is subducting at a high rate (~100 km/m.y.). The drill sites were located about midway within the Japan Trench zone, which is ~650 km long.

The prime objective of this leg was to establish two geophysical observatories that monitor strain, tilt, and seismic waves to further our understanding of subduction dynamics. Coring and logging were aimed at gathering information about past and present tectonic and paleoceanographic conditions.

Dynamic Sliding of the Subducting Plate and Earthquake Process

The seismic coupling efficiency of the subduction zone off Tohoku appears to be as low as 25%. This means that of the total Pacific plate motion expected, only one-quarter is seen as stick-slip motion leading to thrust-type earthquakes. One possibility is that three-quarters of the motion is released as slow earthquakes, which are not recorded on normal seismographs. In the past, sparse observations suggest that the slow strain release may consist of multiple episodes in which each event is rather small. For this reason, installation of an instrument of the highest achievable sensitivity is required. Any data leading to better understanding of the partitioning of strain release into damaging “fast” events and slower events will be extremely valuable and may lend further insight into the whole earthquake process.

The plate boundary off northeast Japan fulfills three important conditions for a long-term geophysical observatory:

1. Dense geophysical networks to which our proposed observatories can be optimally linked already exist on land.
2. Moderately large (M = ~7) seismic events occur frequently, and aseismic slips (slow earthquakes) with comparable or larger magnitude are expected to occur even more frequently.
3. Crustal and uppermost mantle structures have been well studied by reflection-refraction seismic surveys (Suyehiro et al., 1985a, 1985b, 1990; Suyehiro and Nishizawa, 1994).

Earthquake Source Studies

Generally, interplate thrust earthquakes occur within a zone termed the seismogenic zone. The definition and controlling factors of this zone, however, are unclear. Temperature, material, or pore pressure that affect the frictional state of the fault are consequences of geological processes. But their relationship is unclear. We clearly need to define what a seismogenic zone is, if we are to relate to physical properties of the interacting plates. It is critically important to know where exactly earthquakes of various sizes are occurring. At present, it is not possible to locate earthquake faults using seismic techniques with less than several hundred meters’ accuracy relative to where the faults and velocity heterogeneities are. Where a local seismic network does not exist, the accuracy is often much worse and can be more than several kilometers in error.

The borehole geophysical observatories at Sites 1150 and 1151 will greatly improve source location (particularly depth), and focal mechanism and rupture process determinations of the earthquakes near the Japan Trench (Nishizawa et al., 1990, 1992; Suyehiro and Nishizawa, 1994; Hino et al., 1996). Near-field data, obtained from these observatories with the aid of ocean bottom seismographs, will particularly improve the resolution of source mechanisms of very slow rupture events such as tsunami earthquakes. These earthquakes may occur seaward of the updip end of normal thrust earthquakes (e.g., Tanioka and Satake, 1996).

High-Resolution Geometry of the Plate Boundary

The two stations at Sites 1150 and 1151 will be linked to the network of broadband and/or very broadband seismometers on the main Japanese islands and will make a dense seismic network that is 50 km in scale. The observations of various phases of body waves from the many shallow to deep earthquakes within the network will provide sufficient data to improve the structural image of the plate boundary—in particular, the changes in physical properties associated with tectonic erosion and seismogenesis.

Miocene and Younger Volcanic Ash Stratigraphy in the Western Pacific

The cores will represent an important reference section near Japan to compare with the remote ash deposits already cored to the east. They will also provide important information about eruptive processes, volcanic hazards, and aspects of climate such as response to wind, sand, and volcanogenic input of greenhouse and related gases (J. Natland, pers. comm., 1997).

During Leg 132, a number of rhyolitic to dacitic volcanic ash beds were recovered on Shatsky Rise, east of Japan. Comparison with ash stratigraphy at DSDP Sites 578–580, about halfway between Shatsky Rise and Japan, indicates that the Shatsky ash beds were derived either from Japan or the Kurile-Kamchatka arc systems and that they were carried far to the east on the high-speed polar and sub-tropical jet streams (Natland, 1993). A summary appraisal is that 25–40 eruptions in each of the past 3 m.y. produced ash that reached one or more of those sites, with ~10% of these reaching Shatsky Rise in the form of discrete ash beds or pumice. Some of the eruptions were extremely large, resulting in deposits 5 to 15 cm thick, even on Shatsky Rise. The last drilling in this region was during DSDP Legs 56 and 57, before the advent of hydraulic piston coring. An important, although seriously incomplete and at times highly disturbed, ash record was recovered in Holes 438A and 440B (e.g., Cadet and Fujioka, 1980).

Subsidence History Across the Continental Slope to Constrain the Processes of Tectonic Erosion

Quantitative estimates of the tectonic erosion process were made for the Neogene history of the Japan Trench region based on drilling and seismic records (von Huene and Lallemand, 1990; von Huene et al., 1994). Key evidence came from DSDP Site 439. Evidence collected from additional coring at ODP Sites 1150 and 1151, which are ~200 km south of Site 439, will further constrain the timing and erosion volumes in relation to backarc opening and the style of convergence. The comparison of results between 38°N and 41°N will delineate relative changes along the axis.

SUMMARY

Site 1150

Site 1150 is located in the deep-sea terrace on the landward side of the Japan Trench. The primary objective was to establish a borehole geophysical observatory to monitor seismo-geodetic signals immediately above the active portion of the seismogenic zone where large interplate thrust earthquakes recur. The first successful emplacement of a borehole geophysical observatory (NEREID-1) with a three-component strainmeter, a two-component tiltmeter, and two three-component broadband seismometers was completed on July 28. The sensing sections are less than 11 m in length bottoming at 1120 mbsf and were cemented in the 105-m-long open hole at Hole 1150D. Because the instrument string and battery frame could not be installed simultaneously, the electrical connection to the downhole instruments is yet to be made. The observatory sites will be visited by the ROV *Dolphin 3K* of the Japanese Marine Science and Technology Center (JAMSTEC) between 2 and 10 September to start the systems, check the status, and collect initial data. The observatories are designed to be serviced at least once a year.

All of the cores from 0 to 722.6 mbsf from Hole 1150A are dominated by diatomaceous silty clay. The upper 200 m of sediment consist of interbedded diatomaceous ooze and clay, with siliceous biogenic grains, diatoms, radiolarians, and sponge spicules occurring commonly, and foraminifers and nannofossils rarely. Volcanic glass and siliciclastic grains are also observed in smear slides, though they compose less than 10% of the total sediment. From 260 to ~620 mbsf, the sediments gradually become firmer and more hemipelagic with increasing depth. Compared with cores from the upper 200 m, volcanic ash, reworked ash layers, volcanic pebbles, thin turbiditic sand, and silt layers are rare but present in the lower section. Below ~620 mbsf, cores from both Hole 1150A (620–722 mbsf) and Hole 1150B (703–1181.6 mbsf) consist mainly of well-lithified diatomaceous silty claystone. Authigenic glauconitic sand is interbedded with the dominant clayey lithology below 430 mbsf in Hole 1150A and from the start of the cored interval (703 mbsf) at Hole 1150B. Local occurrences of detrital glauconite in minor amounts are rare within both holes. Bioturbation (*Chondrites, Zoophycos,* and *Planolites*) is abundant in Hole 1150B. A few carbonaceous layers and nodule-type accumulations are also found interbedded in the largely homogeneous diatomaceous silty claystone in Hole 1150B. Volcanic ash layers are rare in this hole.

Twelve diatom zonations were identified from core-catcher samples from Holes 1150A and 1150B. The age of the lowermost sediment is interpreted to be younger than 9.9 Ma, because the first occurrence of *Denticulopsis dimorpha* was not observed in the studied interval. The average sedimentation rate is 119 m/m.y., with higher sedimentation rates (>200 m/m.y.) occurring between 6.65–3.74 Ma and between 0.3 and 0.0 Ma. The lowest sedimentation rate occurs between 2.0 and ~1.24 Ma (18 m/m.y.). The Pliocene/Pleistocene boundary lies at ~110 mbsf and Pliocene/Miocene boundary at ~500 mbsf. Datums of calcareous nannofossils were difficult to determine accurately because of poor preservation and low abundance of these fossils. Of the 11 nannofossil datums identified, seven gave ages younger than those indicated by the diatom datums.

Chemical analyses of pore waters from Hole 1150A cores show that chlorinity gradually decreases with depth from ~550 mM at the top of the hole to 500 mM at ~200 mbsf. Chlorinity concentrations remain at about this value for 350 m downhole. From ~550 mbsf, values abruptly decrease with depth to reach a minimum of 350 mM at ~700 mbsf. A similar trend is observed in the magnesium, potassium, and alkalinity profiles. Values gradually decrease in the upper 200 m (from ~50 to 28 mM for magnesium; from ~11 to 8 mM for potassium; and from ~50 to 26 mM for alkalinity). Values remain fairly constant from ~200 to 500 mbsf, and drastically decrease with depth to reach minimum values of 11 mM for magnesium, 6 mM for potassium, and 11 mM for alkalinity. Calcium concentrations increase from ~2 to 8 mM in the upper 200 m, remain fairly constant to a depth of 400 mbsf, and then increase to 10 mM at 600 mbsf.

Bulk-elemental analyses for the upper 350 m of samples from Hole 1150A show relatively high concentrations of organic carbon. Values fluctuate with depth between 1.8 and 0.5 wt%. Typical values are ~1 wt%. Sulfur abundances also are relatively high in this interval. Typical values are ~0.9 wt%, fluctuating between 1.3 and 0.5 wt%. Nitrogen abundances are typically ~0.13 wt%, fluctuating between 0.6 and 0.1 wt%.

Gas analyses for Hole 1150B indicate that methane concentrations are between 2% and 8% as measured from headspace gas analysis. Ethane concentrations are typically ~6 ppm from 700 to 900 mbsf. Values then slightly increase with depth to typical values of ~14 ppm. Methane/ethane ratios tend to decrease gradually with depth from ~5000 at 700 mbsf to 2800 at the final depth of ~1200 mbsf. Other hydrocarbon gases are below the detection limit.

Physical properties data show several systematic trends that correlate with downhole chemical and lithologic changes, appearing to indicate variations in hydrological and mechanical conditions. Gas expansion and drilling disturbance (formation of drilling biscuits) affects the physical properties of most cores from Hole 1150A. The interval from 80 to 200 mbsf consists of pelagic ooze and clay, and inverse trends in index properties are observed, such as the bulk density decreases from ~1.5 to 1.4 g/cm^3 and porosity increases from ~65% to 75%. Constant and uniform values of index properties are observed from ~200 to 620 mbsf. The top of this interval coincides with a small change in lithologic composition, whereas the bottom corresponds to the change from firm sediments to sedimentary rocks. Bulk density and porosity range from ~1.35 to 1.55 g/cm^3 and 65% to 76%, respectively.

P-wave velocity gradually increases downhole from 1.55 at 300 mbsf to 1.60 km/s at 620 mbsf. There may be a bias in index properties and *P*-wave velocity measurements in this interval because only coherent and undisturbed pieces were sampled. Measurements in sedimentary rocks show a wide scatter in porosity, bulk density, and *P*-wave velocity, but suggest generally decreasing porosity and increasing bulk density and *P*-wave velocity trends. Preliminary analyses of sonic anisotropy combined with paleomagnetic declination data indicate that the sedimentary rock from 730 to 1180 mbsf is anisotropic, with maximum, intermediate, and minimum principal axes along the west-northwest to east-southeast, north-northwest to south-southwest, and vertical orientations, respectively. In the interval where the borehole instruments were installed, the porosity, bulk density, and *P*-wave velocity are 55%, 1.65 g/cm^3, and 2.0 km/s, respectively.

The magnetization of the first eight cores has an unambiguous normal polarity direction, with a steep downward inclination and a northward declination after applying the Tensor-tool orientation correction. The Brunhes/Matuyama boundary is most likely located in Core 186-1150A-10H at ~84–88 mbsf, though coring disturbance makes interpretation tenuous in this interval. Above 850 mbsf, the position of several reversals are evident following alternating-field demagnetization. These should be useful in establishing a few magnetostratigraphic tie points in the Pliocene–Miocene section at this site. The magnetization of the RCB cores from Hole 1150B is fairly stable, and polarity is dominantly normal below 850 mbsf. The declinations from the Hole 1150B cores have proved useful for reconstructing structural orientations of the numerous microfaults and fractures observed in the core. For example, after reorienting fracture and fault planes into geographic coordinates, we find that most in the depth range from 703 to 940 have north-south strikes and dips of 45° to 80°, with a clear preference for eastward-dipping planes. Normal offset is observed on most of the fault planes, suggesting an east-west extensional stress field is responsible for the deformation observed in this interval. The extensional stress direction changes downhole, so that below 1080 mbsf the dominant direction is west-northwest to east-southeast.

Equilibrium temperatures obtained from the APC temperature tool (Adara) and the Davis-Villinger temperature probe (DVTP) in the interval from 0 to 154.8 mbsf give a geothermal gradient of 28.9°C/km. The calculated heat flow is 20.1 mW/m^2, which, though low relative to global values, is typical for the tectonic environment.

Three logging tool combinations were used in Hole 1150B: the triple combination tool string, the Formation MicroScanner (FMS)-Digital Sonic tool string, and the borehole televiewer (BHTV) tool string.

Although operational difficulties prevented logging at ~650 mbsf, three strings were deployed down to ~1170 mbsf after a wiper trip operation. Data quality is good throughout the logged intervals. The whole logged section can be divided into six units using the resistivity log in conjunction with other logs. These units are consistent with core descriptions and core measurements. The FMS data show borehole geometries to be oval below ~750 mbsf with east-west elongation (20 cm in north-south and 30–35 cm in east-west). The in situ physical properties in the lowermost 100 m (i.e., in the interval where the borehole instruments were installed) are ~1.95 km/s for *P*-wave velocity, ~1.7 g/cm^3 for bulk density, 55%–60% for porosity, 1.2 Ωm for resistivity, and ~50 cps for spectral natural gamma ray.

Site 1151

Site 1151 is located 48 km south of Site 1150, in the deep-sea terrace of the Japan Trench, a similar geological setting as at Site 1150. The main objective at this site was to establish another borehole geophysical observatory to monitor active processes in a plate subduction zone with strain, tilt, and seismic sensors. A key difference is that this area is above an aseismic portion of the seismogenic zone. The strainmeter at this site measures volumetric strain changes. This second seafloor borehole geophysical observatory (NEREID-2) was successfully installed in Hole 1151B with much less downtime than for the first one. The sensor string was set in a section with a density of ~1.9 g/cm^3 and *P*-wave velocity of ~2000 m/s. The target depth is slightly shallower at 1095 mbsf for the sensor string bottom, but the physical properties suggest a more competent rock environment than at Site 1151. The bottom of the open hole was filled with cement up to ~50 m into the cased hole section. The observatory sites will be visited by the ROV *Dolphin 3K* of JAMSTEC between 2 and 10 September with a mission to start and check the system.

At Site 1151, the sedimentary section from 0 to 1113 mbsf was cored with APC (Holes 1151C and D) and RCB (Hole 1151A) coring systems. The recovered sequence ranges from Holocene to middle Miocene age. The average recovery was 68% for Hole 1151A and ~100% for Holes 1151C and 1151D. The common major lithology at this site is diatomaceous silty clay with intercalations of minor lithologies such as volcaniclastic ash, pumice, silt, and sand. Brittle deformational structures dominate below 400 mbsf. Bioturbation can be seen in most cores below 300 mbsf. Detrital glauconite occurs as sand-sized grains distributed throughout the section. Authigenic glauconite, found in both the major and minor lithologies, is of fine silt size. The detrital glauconite is always found in association with the finer-grained authigenic glauconite, but the latter may occur in the absence of the former. Alteration to limonite locally occurs. The following lithostratigraphic units were identified:

Unit I (0–295 mbsf; 0–4.5 Ma) consists of diatomaceous silty clay. Minor lithologies (sand, silt, ash, and pumice) occur frequently except in the range 78–106 mbsf. The biogenic components increase to their peak value.

Unit II (295–411 mbsf; 4.5–5.5 Ma) consists of diatomaceous spicule-bearing silty clay. Ash and pumice are rare throughout the unit.

Unit III (411–817 mbsf; 5.5–7.5 Ma) consists of various combinations of diatom-, glass- and spicule-bearing silty clay. Brittle deformational structures occur first and reach their peak within this unit. Siliciclastic components compose >50% of the sediments.

Unit IV (817–1007 mbsf; 7.5–11.5 Ma) consists of diatom- and spicule-bearing claystone. Minor lithologies only occur rarely.

Unit V (1007–1113 mbsf; 11.5–16 Ma) consists of combinations of glassy or glass-bearing silty claystone, locally spicule-bearing. The diatoms compose <10% of the sediment. Minor lithologies are rare.

At Site 1151, 24 diatom datum levels were identified from core-catcher samples, the lowest being in middle Miocene (< 16.3 Ma). Calcareous nannofossils are generally barren to abundant throughout, with variable preservation. As at Site 1150, of the 11 nannofossil datums identified, seven gave ages younger than those indicated by the diatom datums. Except for some ash layers and dolomite layers, the sequence contains few to abundant diatoms throughout. Diatom assemblages from all samples consist almost entirely of oceanic species, mainly from the subarctic North Pacific Ocean.

Sedimentation rates at Site 1151 were estimated using a combination of biostratigraphy and magnetostratigraphy. The upper 200 m has a relatively low rate (20 to 152 m/m.y.). It increases between 200 and 450 mbsf, reaching ~240 m/m.y., and remains at that level down to 800 mbsf, below which the rate gradually decreases. At 1027 mbsf, there is a hiatus of more than 0.2 m.y., and the rate then gradually increases downhole to 43 m/m.y. Site 1151 had high rates in the latest Miocene and low rates before and after this, a pattern similar to that at Site 1150. The intervals of low rate correspond to the early late Miocene (before 8.5 Ma) and the early to middle Pleistocene (2.0–0.78 Ma).

Gas analyses at Site 1151 indicate that methane concentrations are between 0.4% to 5% with an average concentration of ~2%. Ethane concentrations fluctuate between 1 and 12 ppmv and typically are of ~4 ppmv. Methane/ethane ratios are ~4400 throughout. Other hydrocarbon gases are below the detection limit.

No trend is present in the distribution of carbonate abundances with depth. Abundances range from 0.08 to 79 wt%, with an average value of 3.3 wt%. Most values, however fall between 2 and 4 wt% with excursions having peak values up to 15 wt%. Low carbonate abundances are in agreement with low occurrences of calcareous fossils in the sediments.

Sediments exhibit relatively high abundances of organic matter (OM) with characteristic low (<10) C/N ratios. Abundance of organic carbon (C_{org}) fluctuates between 0.2 and 1.4 wt%, with an average value of ~0.9 wt%. Total sulfur abundances irregularly fluctuate between 0.35 to 1.5 wt% with an average value of 0.85 wt%.

Several geochemical parameters exhibit similar distributions with depth. K^+, Na^+, Mg^{2+}, chlorinity, and salinity show a characteristic decreasing trend with depth. Salinity gradually decreases with depth from a value of ~32 at the top of the borehole to a value of 18 at ~900 mbsf. Below this depth, salinity remains constant at 18 to the final depth. Chlorinity concentrations remain constant at ~500 mM in the upper 200 m of the borehole and then steadily decrease to 320 mM at the final depth.

Alkalinity values gradually decrease downhole in the upper 200 m from 31 to 17 mM and then increase to 25 mM at ~450 mbsf. Below this depth, values decrease steadily downhole to 2 mM at the bottom. Dissolved sulfate concentrations exhibit values lower than 2 mM throughout.

Concentrations of dissolved calcium (Ca^{2+}) in pore waters slightly increase downhole from ~3 mM at the top to 18 mM at the bottom. Concentrations of dissolved strontium (Sr^{2+}) fluctuate between 100 and 130 µM down to 550 mbsf and then increase to reach a maximum value of 232 µM at the bottom. Concentrations of dissolved lithium (Li^+) gradually increase from 20 to 480 µM in the upper 850 m and then decrease to ~280 µM at the bottom.

The gamma-ray attenuation porosity evaluator density in Hole 1151A ranges from ~1.3 to 2.0 g/cm^3. Lithostratigraphic Unit II is characterized by rather constant values, averaging ~1.4 g/cm^3. Density varies from 1.3 to 1.7 g/cm^3 along an oscillating trend in Unit III. Similar oscillating trends increase in magnitude in Units IV (1.3–1.8 g/cm^3) and V (1.4–2.0 g/cm^3). Such an oscillating trend is also observed in natural gamma-ray activity. The average thermal gradient, which was obtained from three measurements, is 35.9°C/km.

In Hole 1151A, *P*-wave velocity (horizontal) ranges from 1540 to 5290 m/s, with most values being less than 2150 m/s. The highest velocities were measured in thin beds of carbonate-rich sediments (i.e., dolomite layers or dolomite concretions). The maximum velocity in Hole 1151A of 5290 m/s was measured on a dolomite concretion at 1108 mbsf.

The ranges of porosity, bulk density, and grain density in Hole 1151A are 10%–77%, 1.32 to 2.42 g/cm^3, and 2.09 to 3.91 g/cm^3, respectively. The section from 78 to 295 mbsf (Unit I) has scattered, but slightly inverse trends of porosity and bulk density: porosity and bulk density generally range from 57% to 77%, and 1.32 to 1.59 g/cm^3, respectively. The top of Unit IV (825 mbsf) coincides with a shift to higher porosity, and lower bulk density values. Yet another significant shift to higher porosity, by ~13%, occurs from 963 to 977 mbsf. The corresponding decrease in bulk density is ~0.22 g/cm^3. Apart from these two shifts, index properties show normal trends across Units IV and V. At the base of Hole 1151A, porosity, bulk density and grain density are 49%, 1.75 g/cm^3, and 2.46 g/cm^3, respectively.

The remanent magnetization at Site 1151 is very similar in behavior to that at Site 1150. The upper 78 m has an unambiguous normal polarity direction, with a steep downward inclination. The location of the Brunhes/Matuyama reversal appears to be well resolved by the abrupt downhole change to negative inclinations at ~78.2 mbsf in Hole 1151C, 80.1 mbsf in Hole 1151D, and at 82–84 mbsf (between Cores 186-1151A-2R and 3R) in Hole 1151A. However, the reversals lower in the section are not easily correlated with the geomagnetic polarity time scale. Below 700 m, virtually the entire section has very stable positive inclinations that average ~60°. We interpret this interval to be partially or totally overprinted by a recent normal polarity field direction. The stable declinations from these cores have proved useful for reconstructing structural orientations of the microfractures and bedding planes. We have found that the orientation of fracture planes changes downhole with dip azimuths dominantly to the west-northeast and east-southeast in the upper domain, but dominantly east and west in the middle and lower domains. Below 900 mbsf, the dip angles of bedding planes are more than 10° and preferentially dip toward the east.

Three logging runs (one triple combo and two FMS/Sonic runs down to 850 mbsf) were achieved in Hole 1151D by extending the second APC/XCB hole (1151D). The hole condition (caliper log) was much more stable at Site 1151, and logging was accomplished without difficulty.

ACCOMPLISHMENTS AND INTERESTING OBSERVATIONS

The principal objective of Leg 186 was to install two permanent borehole observatories with several seismic and deformation-measuring sensors. A strainmeter, tiltmeter, and two broad-frequency range seismometers were grouted in at the bottom of boreholes drilled deep enough to penetrate higher velocity, indurated rock. This objective was successfully achieved. Figures 8 and 9 show the seafloor installation as well as the arrangement of sensors in the borehole. Actual vibration-isolated television camera views of the seafloor unit are shown in Figure 10. In addition, both sites were cored to instrument depth and have yielded scientific results of considerable interest. In all, we recovered 1742 m of core from the two sites, despite the major emphasis on instrument installation. The dominant lithology was diatomaceous silty clay or claystone with many ash and some dolomite layers (Fig. 11).

Compared with results from earlier drilling along the Japan trench, the salinity and chlorinity variations with depth exhibit both similar behavior and significant differences. Sites along the deep-sea terrace—Sites 1150, 1151, 438, and 439—have chlorinity of 550–550 mM just below the seafloor, decreasing to ~300 mM at a depth of 1000 m. In contrast, sites far from the subducting slab, such as the ODP Leg 126 Sea of Japan Sites 798 and 799, and sites near the trench (Site 536) have chlorinity that does not decrease as much. Figure 12 shows a comparison of the deep-sea terrace data from Sites 1150, 1151, and 438, and data from the Sea of Japan Site 799. Site 1150 has a notable deviation from the monotonic behavior of other sites. Down to 600 m the chlorinity does not drop below 500 mM, but below 650 m, the values drop to those of the other terrace sites. One tentative explanation is that in the terrace sites, there is a supply of freshwater from depth that mixes (possibly continuously) with the saline sea bottom–derived water. In Site 1150, a less permeable layer interrupts this mixing, so that the upper part is isolated from freshwater. In other areas such as the Sea of Japan sites or the near trench sites, this freshwater supply is not available. A possible source of the freshwater is dehydration of slab interface components at depth where earthquakes occur (i.e., deeper than 10 km).

The age of the sediments of Sites 1150 and 1151, as well as those from Sites 438 and 584 farther to the north, are shown in Figure 13. The sedimentation rates derived from these data are shown in Figure 14. Aside from the generally lower rate of sedimentation from 0.5–3 Ma or so, a notable feature is the fairly widespread increase at 6–8 Ma. Many factors can be responsible for this increase and one of the important contributions of Leg 186 is to provide the samples and data that can be used postcruise to constrain these possibilities. The tantalizing range of causes include change in wind direction or increase in the rate of mountain building because of increased tectonic compression.

There have been major changes in the tectonics of Japan. Until 14 m.y. ago, the islands were subjected to east-west tension, and the Sea of Japan was opening. Today, there is strong east-west compression. It is possible that some of the change in sediment flux as well as volcanic output is affected by the changes in the force system at the subduction interface. From Figure 15 it is apparent that there was a major increase in volcanic deposits at Site 1150 ~3 Ma and a decrease in the most recent half a million years or so. At Site 1151, the increase starts at ~4 Ma. Further north (40.6°N) in Hole 438A, the volcanism increased from ~5 Ma until ~2 Ma. The cores collected during 186 will enable us to identify, quantify, and date the ash layers derived from great volcanic eruptions.

Whereas a major goal of Leg 186 is measuring the current deformation resulting from the subduction forces, the fractures and hole deformation data also bear on that problem. The logging of Hole 1150B indicates significant enlargement of the hole by 40% in the east-west direction. This means that the north-south compressive stresses are greater. This is not surprising because the bending of the upper plate caused by the subduction drag would indeed result in east-west tension in the upper layer. The faults observed in the cores from Hole 1150B are consistent with such an east-west tensional stress field (Fig. 16A). Hole 1151D was logged to depths less than 870 m. To that depth there were negligible breakouts, indicating that either stresses are much lower or the rock was much stronger. It is known that the rock at Site 1151 was more stable during drilling than that at Site 1150, but it is not clear what effect is dominant in governing the hole elongation. In addition, Figure 16B shows that the fracture directions are less well organized than those of Site 1150. Figure 17 shows a comparison of the dominantly normal faults in the two holes. The fault density is rather similar, though Site 1150 does have more fractures. Overall, the long-term deformation, as determined by number, orientation, and offset of faults, indicates that the two sites are broadly comparable (Figs. 16, 17). Normal faulting dominates in both holes with the extension direction being west-northwest–east-southeast in both cases. Interpreting the differences will be aided by postcruise analysis of the mechanical properties of the cores. In all the above fields and others not mentioned, postcruise analysis of the data and samples provided by Leg 186 will improve our understanding of the processes in this subduction zone.

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TABLE CAPTION

Table 1. Leg 186 operational summary.

FIGURE CAPTIONS

Figure 1. Location of Leg 186 sites. Contours shown at 1000-m intervals. Sites 1150 and 1151 are situated at the deep-sea terrace landward of the Japan Trench.

Figure 2. Map of the Japan Trench area off northeast Japan showing t ODP Leg 186 Sites 1150 and 1151 plus previous drilling sites from DSDP Legs 56 , 57, and 87 and seismic lines.

Figure 3. Schematic cross section of the Japan trench-arc system (from Suyehiro and Nishizawa, 1994).

Figure 4. An example of seismic record section across the Japan Trench showing characteristic features of this area.

Figure 5. A model of tectonic subsidence history (from von Huene and Lallemand, 1990).

Figure 6. Epicenters of large thrust earthquakes. An M 7 class earthquake can rupture an area on the order of 1000 km^2 dislocating ~1 m.

Figure 7. Map of Japan Trench area with seismicity (R. Hino, pers. comm., 1998). The locations of proposed Sites 1150 and 1151 are shown. Focal depth symbols: open circle = 0–10 km, open square = 10–20 km, open triangle = 20–30 km, closed circle = 30–40 km, closed square = 40–50 km, closed triangle = 50+ km.

Figure 8. Schematic of the seafloor and borehole installation for Hole 1150D. The reentry cone is installed and the casing cemented in. The instrument string is coupled to 4½-in casing pipe and to the hanger/riser. This is inserted into the hole using the drill string. Cement is pumped through the instrument string and up into the cased part of the hole. The battery frame is then lowered onto the reentry cone, and the hanger/riser is then decoupled from the drill string. mbrf = meters below rig floor, TD = total depth.

Figure 9. Schematic of the seafloor and borehole installation for Hole 1151B. Layout and abbreviations as for Hole 1150D in Figure 8. The open hole is half the length of that in Hole 1150D.

Figure 10. The principal aspects of the sensor installation. The cement is pumped through the strainmeter and out the stinger extension, forming a solid base below and around the strainmeter and other sensors.

Figure 11. Lithostratigraphic summary for Sites 1150 and 1151.

Figure 12. Chlorinity change in interstitial water. Data from this leg are compared with the ODP Leg 126 Sea of Japan (Site 799) and DSDP Leg 57 Japan Trench (Site 438) results.

Figure 13. Age-depth curves for Leg 186 Sites and other Japan Trench sites. Geomagnetic polarity time scale is also shown.

Figure 14. Smoothed curve presentation of sedimentation rates along the Japan Trench.

Figure 15. Ash records from Leg 186 compared with other Japan Trench sites.

Figure 16. Fault orientations. **A.** Hole 1150. **B.** Hole 1151.

Figure 17. Fault occurrence frequency at Sites 1150 and 1151.

Table 1. Leg 186 operational summary.

ID	Latitude	Longitude	Water depth (m)	Number of cores	Interval cored (m)	Core recovered (m)	Recovery (%)	Interval drilled (m)	Maximum penentration (m)
Hole 1150A	39°10.9148'N	143°19.9155'E	2680.8	76	722.6	566.40	78.38	0.0	722.6
Hole 1150B	39°10.9145'N	143°19.9470'E	2680.8	50	478.3	269.39	56.32	703.3	1181.6
Hole 1150C	39°10.9172'N	143°19.8942'E	2680.7	0	0.0	0.00	0.00	1050.0	1050.0
Hole 1150D	39°10.9172'N	143°19.8942'E	2680.7	0	0.0	0.00	0.00	1139.8	1139.8
Site 1150 Totals	39°10.9159'N	143°19.9127'E	2680.7	126	1200.9	835.79	69.60	2893.1	1181.6
Hole 1151A*	38°45.1195'N	143°20.0642'E	2182.2	108	1035.6	707.57	68.32	78.0	1113.6
Hole 1151B	38°45.1244'N	143°20.0147'E	2181.6	0	0.0	0.00	0.00	1113.0	1113.0
Hole 1151C	38°45.0202'N	143°20.0425'E	2174.2	11	97.2	101.75	104.68	0.0	97.2
Hole 1151D	38°45.0138'N	143°20.0441'E	2171.9	10	93.0	96.19	103.43	781.0	874.0
Site 1151 Totals	38°45.0695'N	143°20.0414'E	2177.5	129	1225.8	905.51	73.87	1972.0	1113.6
Leg 186 Totals				255	2426.7	1741.30	71.76	4865.1	1181.6

ID	Arrival date and time (local)	Departure date and time (local)	Time on hole (hr)	Number of APC cores	Number of XCB cores	Number of RCB cores	Seafloor depth (mbrf)	Total drill string length (mbrf) (mbrf)
Hole 1150A	6/22/99 18:30	26-Jun-99	99.75	12	64	0	2692.2	3414.8
Hole 1150B	6/26/99 22:15	3-Jul-99	159.25	0	0	50	2692.2	3873.8
Hole 1150C	7/23/99 15:30	23-Jul-99	7.00	0	0	0	2692.2	3742.2
Hole 1150D	7/23/99 22:30	28-Jul-99	116.50	0	0	0	2692.2	3832.0
Site 1150 Totals			382.50	12	64	50	2692.2	3715.7
Hole 1151A*	7/28/99 22:00	2-Aug-99	115.75	0	0	108	2193.7	3307.3
Hole 1151B	8/2/99 17:45	9-Aug-99	168.00	0	0	0	2193.7	3306.7
Hole 1151C	8/9/99 17:45	10-Aug-99	16.00	11	0	0	2186.3	2283.5
Hole 1151D	8/10/99 9:45	12-Aug-99	61.75	10	0	0	2184.0	3058.0
Site 1151 Totals			361.50	21	0	108	2189.4	2988.9
Leg 186 Totals			744.00	33	64	158	2440.8	3352.3

Note: * = totals do not include a wash core (186-1151A-1W) collected at the top of Hole 1151A.

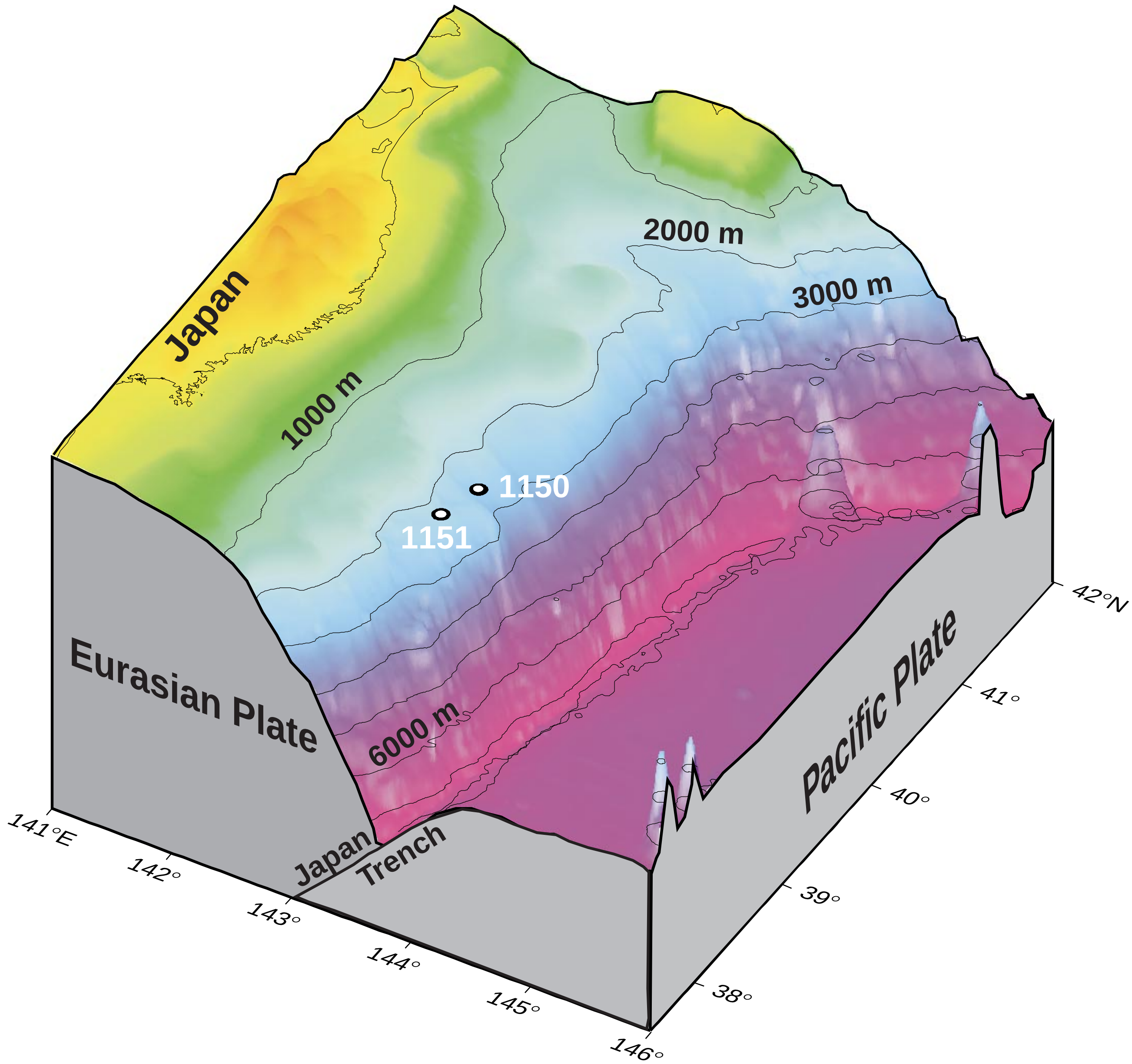

Japan
1000 m
2000 m
3000 m
6000 m
1150
1151
Eurasian Plate
Pacific Plate
Japan Trench
141°E
142°
143°
144°
145°
146°
38°
39°
40°
41°
42°N

Figure 1

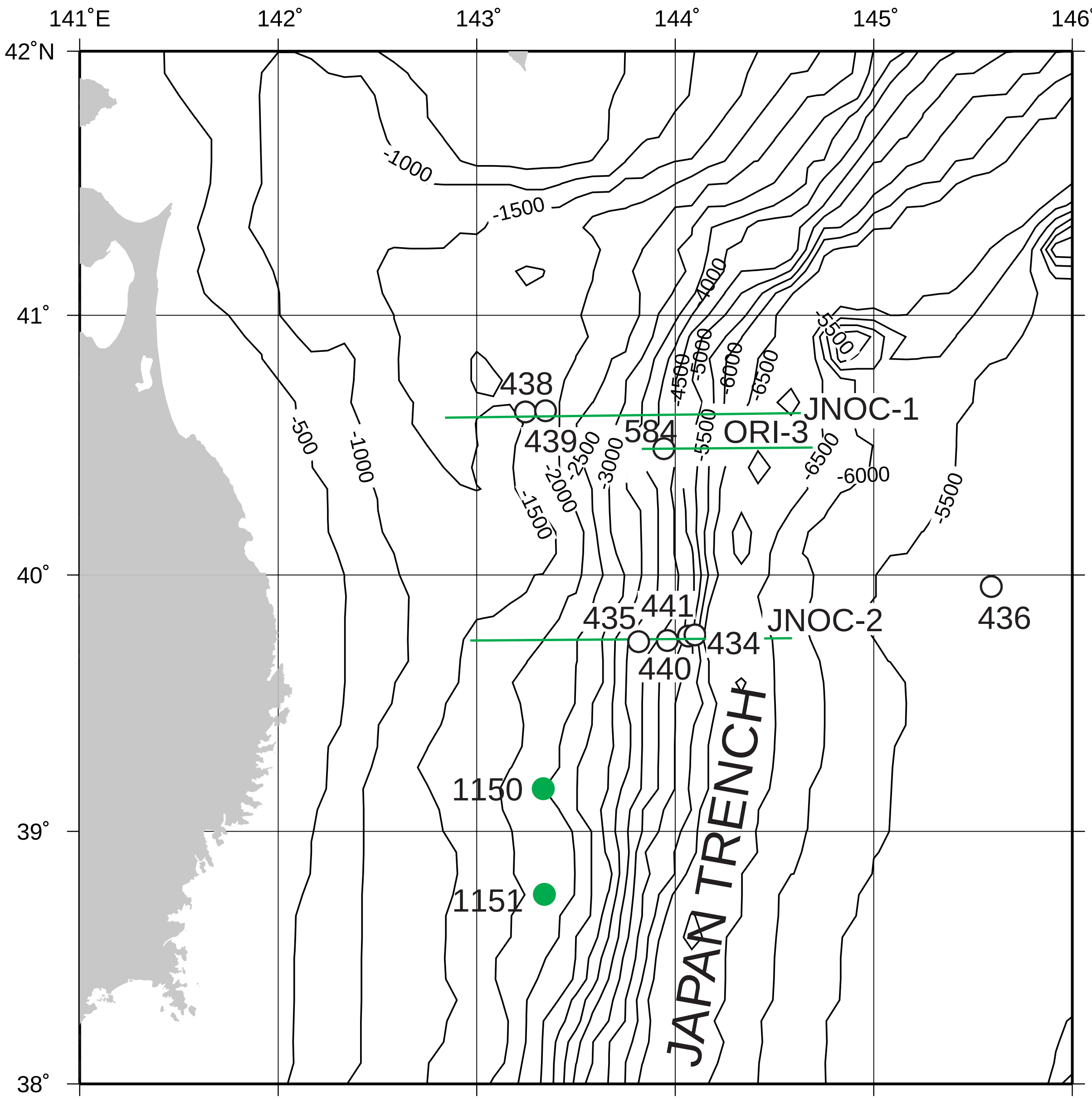

141°E
142°
143°
144°
145°
146°
42°N
41°
40°
39°
38°
-500
-1000
-1500
-2000
-2500
-3000
4000
-4500
-5000
-5500
-6000
-6500
438
439
584
ORI-3
JNOC-1
JNOC-2
435
441
434
440
436
1150
1151
JAPAN TRENCH

Figure 2

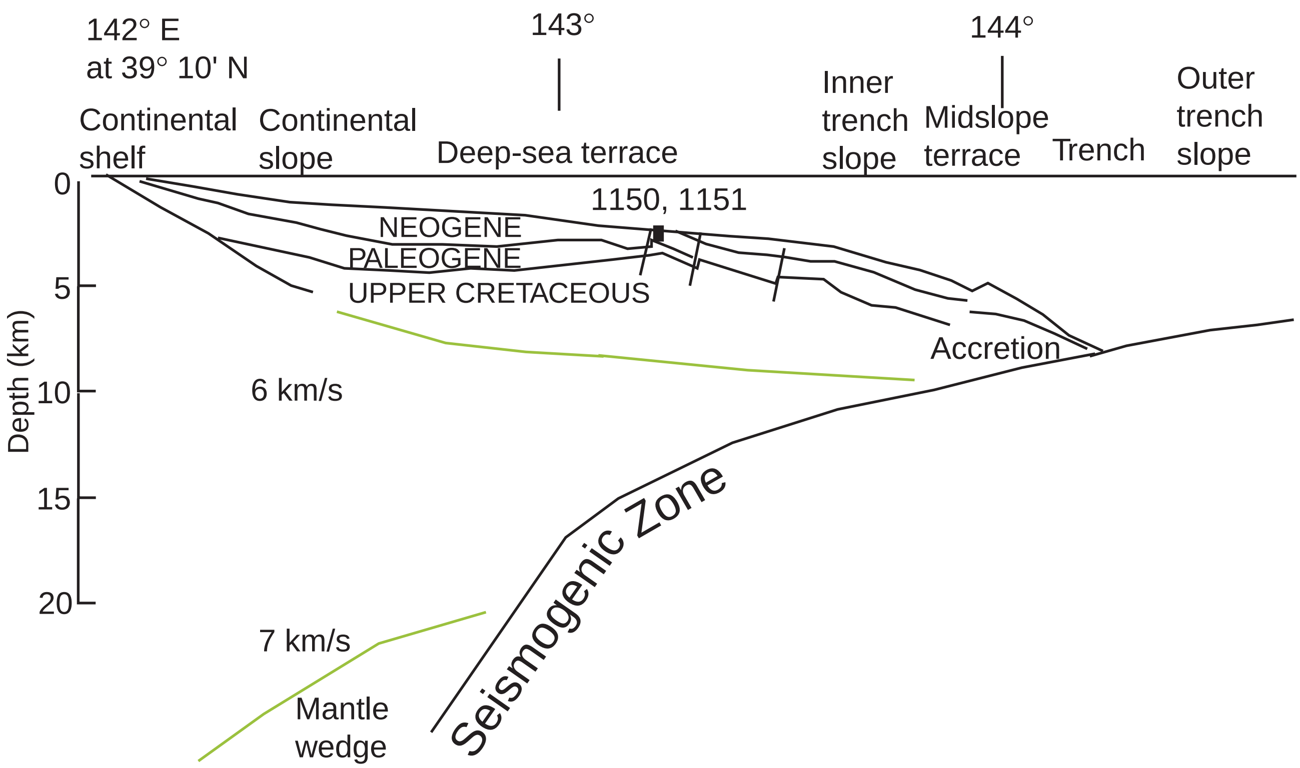

142° E
at 39° 10' N
143°
144°
Continental shelf
Continental slope
Deep-sea terrace
Inner trench slope
Midslope terrace
Trench
Outer trench slope
1150, 1151
NEOGENE
PALEOGENE
UPPER CRETACEOUS
Accretion
6 km/s
7 km/s
Mantle wedge
Seismogenic Zone
Depth (km)
0
5
10
15
20

Figure 3

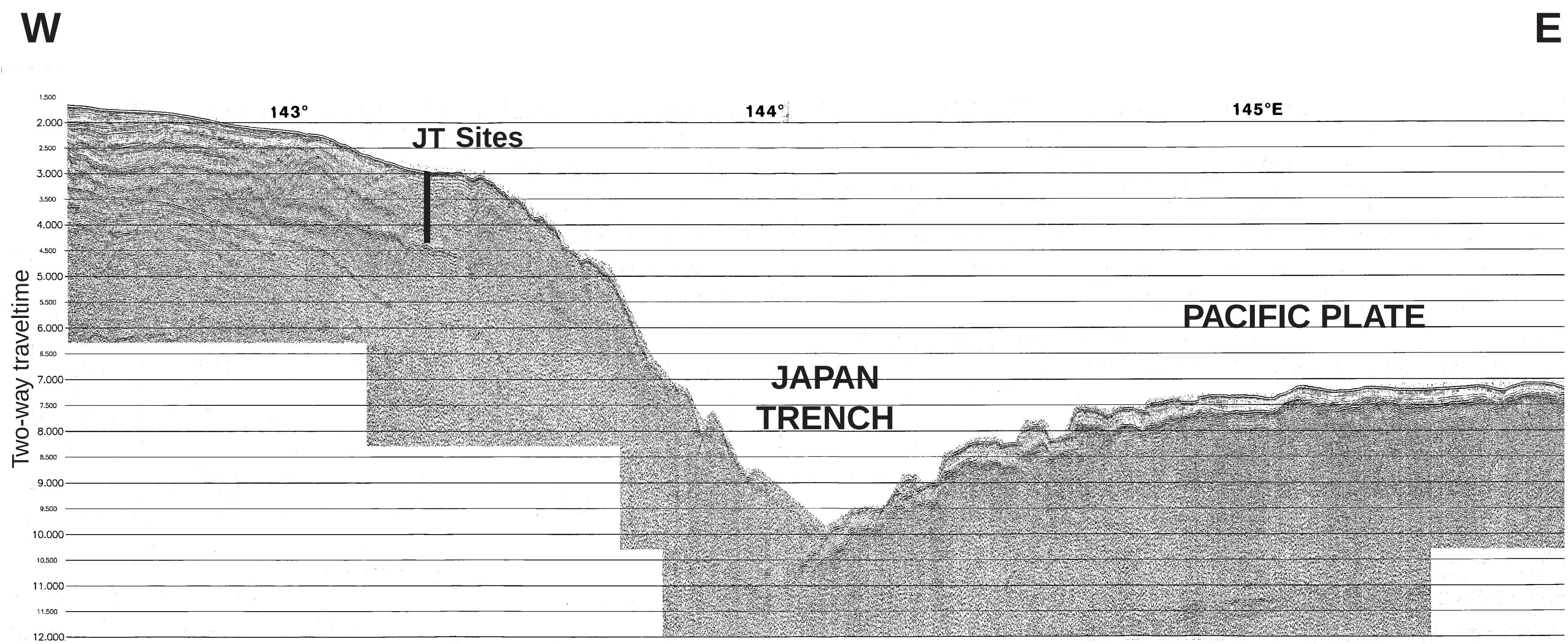
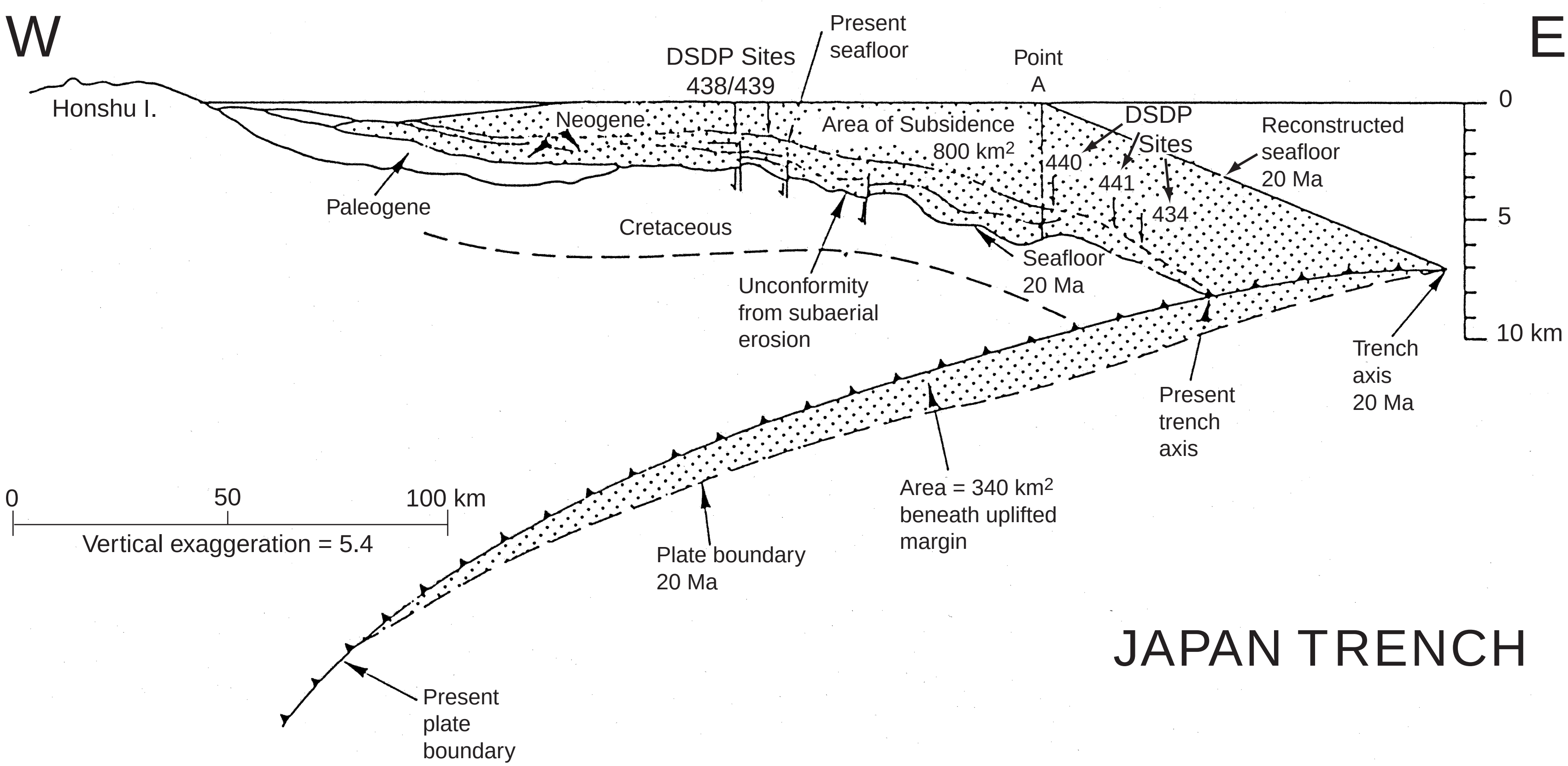

W
E
143°
144°
145°E
JT Sites
JAPAN
TRENCH
PACIFIC PLATE
Two-way traveltime
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000
6.500
7.000
7.500
8.000
8.500
9.000
9.500
10.000
10.500
11.000
11.500
12.000

Figure 4

Figure 5


W
E
Present
seafloor
DSDP Sites
438/439
Point
A
Honshu I.
0
Neogene
DSDP
Sites
Reconstructed
seafloor
20 Ma
Area of Subsidence
800 km2
440
441
434
5
Paleogene
Cretaceous
Seafloor
20 Ma
Unconformity
from subaerial
erosion
10 km
Trench
axis
20 Ma
Present
trench
axis
0
50
100 km
Vertical exaggeration = 5.4
Area = 340 km2
beneath uplifted
margin
Plate boundary
20 Ma
JAPAN TRENCH
Present
plate
boundary

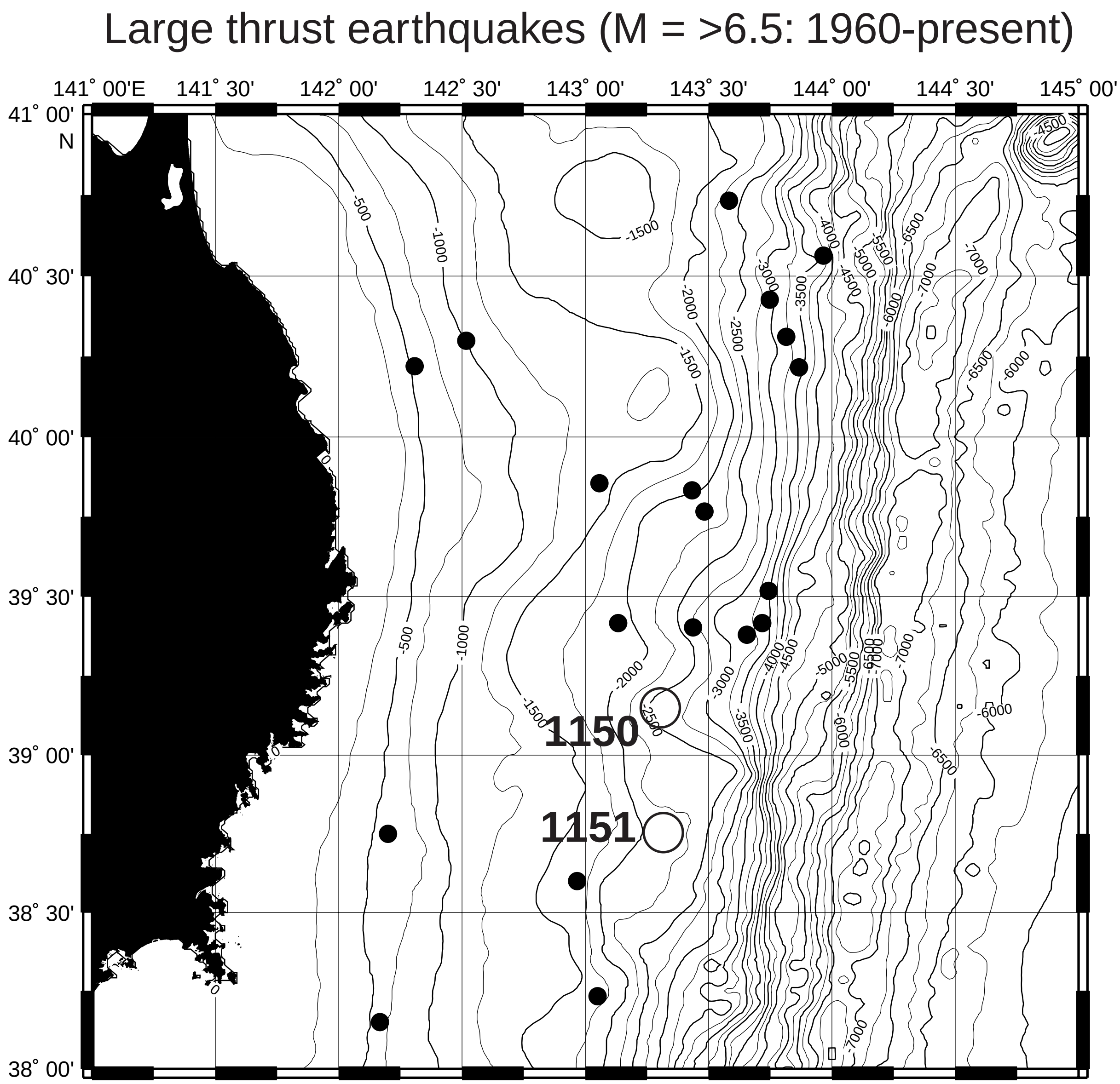

Large thrust earthquakes (M = >6.5: 1960-present)
141° 00'E
141° 30'
142° 00'
142° 30'
143° 00'
143° 30'
144° 00'
144° 30'
145° 00'
41° 00' N
40° 30'
40° 00'
39° 30'
39° 00'
38° 30'
38° 00'
1150
1151

Figure 6

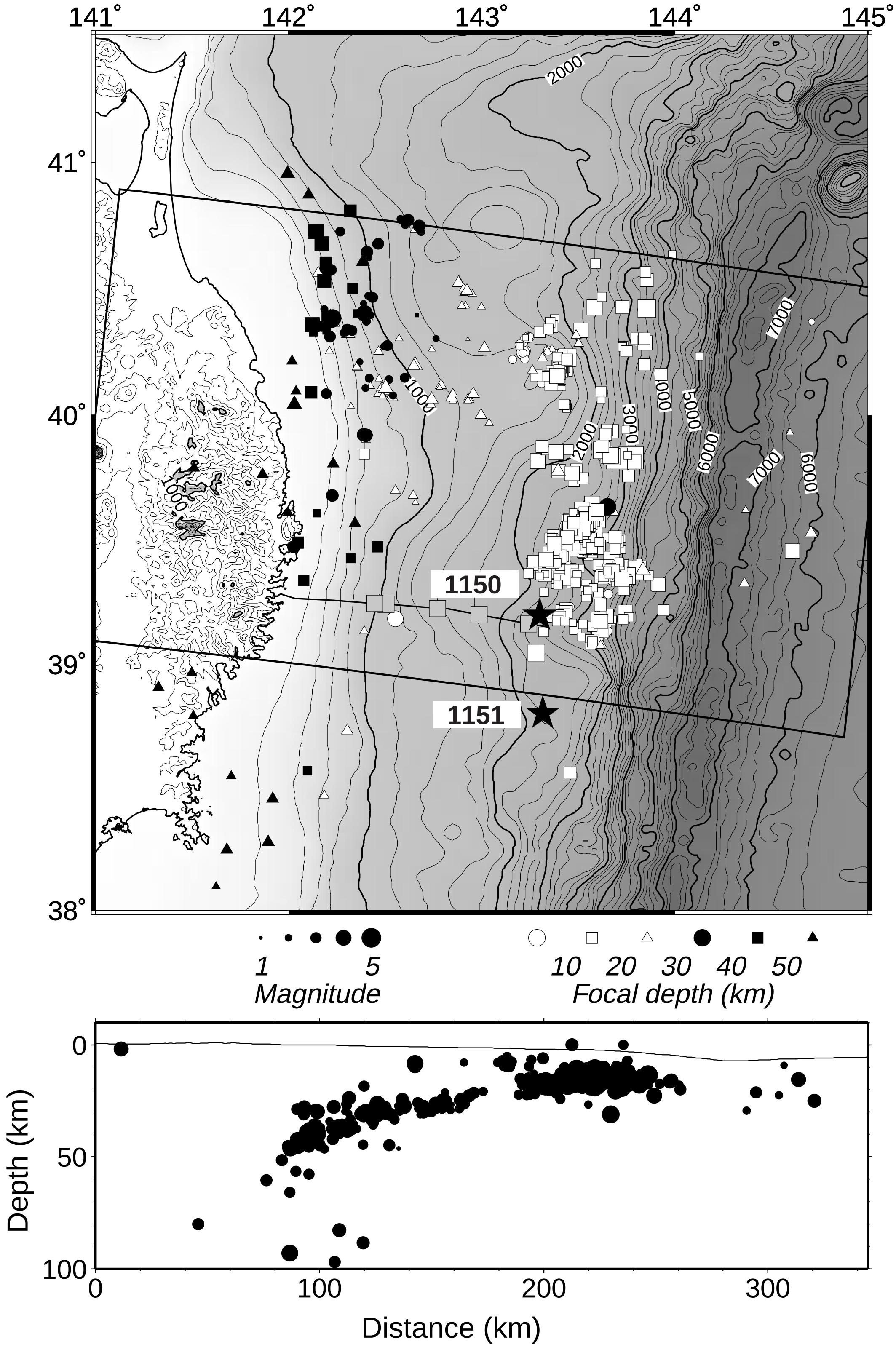

141°
142°
143°
144°
145°
41°
40°
39°
38°
2000
1000
3000
4000
5000
6000
7000
1150
1151
1
5
Magnitude
10
20
30
40
50
Focal depth (km)
0
50
100
Depth (km)
200
300
Distance (km)

Figure 7

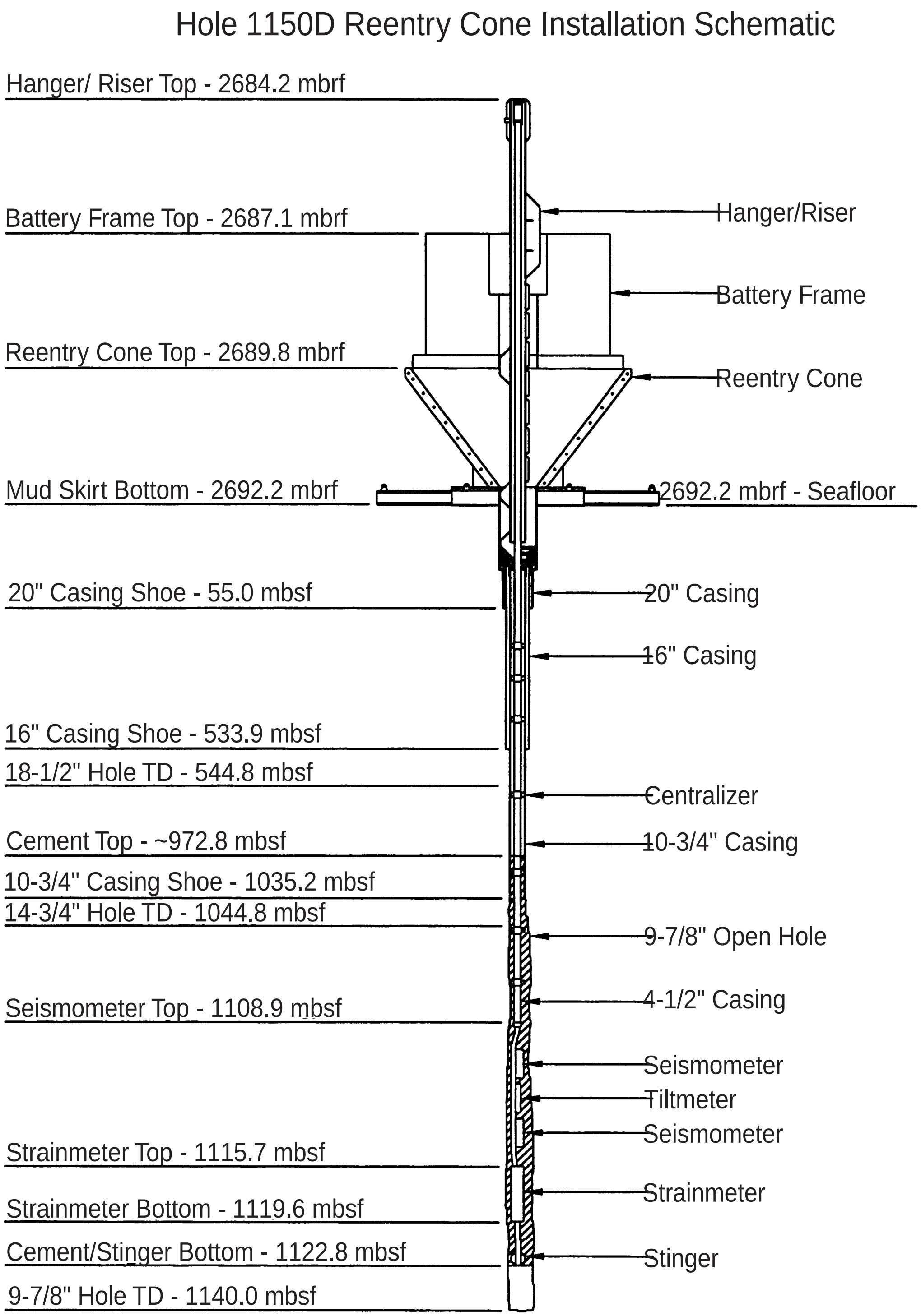

Hole 1150D Reentry Cone Installation Schematic
Hanger/ Riser Top - 2684.2 mbrf
Battery Frame Top - 2687.1 mbrf
Reentry Cone Top - 2689.8 mbrf
Mud Skirt Bottom - 2692.2 mbrf
20" Casing Shoe - 55.0 mbsf
16" Casing Shoe - 533.9 mbsf
18-1/2" Hole TD - 544.8 mbsf
Cement Top - ~972.8 mbsf
10-3/4" Casing Shoe - 1035.2 mbsf
14-3/4" Hole TD - 1044.8 mbsf
Seismometer Top - 1108.9 mbsf
Strainmeter Top - 1115.7 mbsf
Strainmeter Bottom - 1119.6 mbsf
Cement/Stinger Bottom - 1122.8 mbsf
9-7/8" Hole TD - 1140.0 mbsf
Hanger/Riser
Battery Frame
Reentry Cone
2692.2 mbrf - Seafloor
20" Casing
16" Casing
Centralizer
10-3/4" Casing
9-7/8" Open Hole
4-1/2" Casing
Seismometer
Tiltmeter
Seismometer
Strainmeter
Stinger

Figure 8

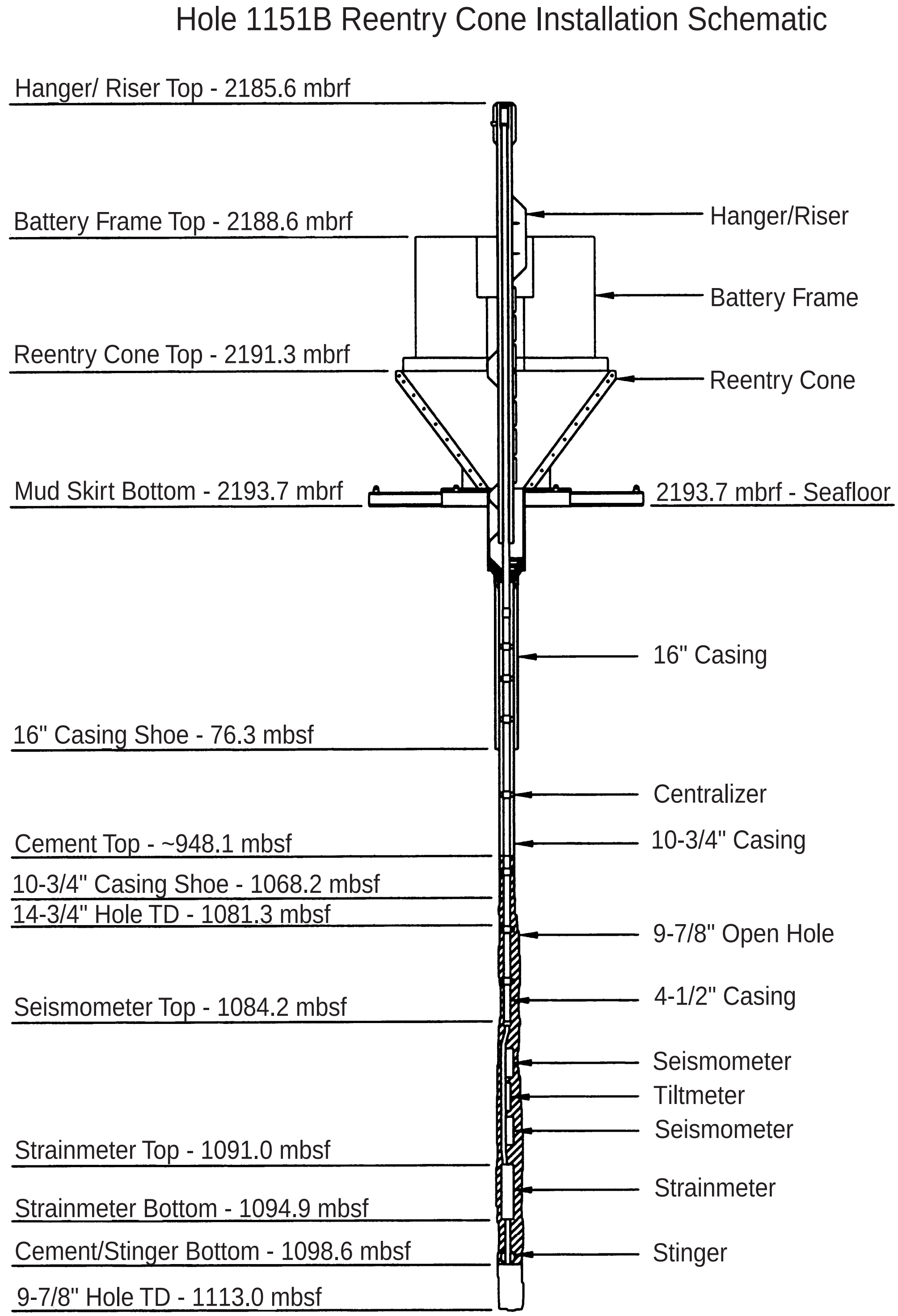

Hole 1151B Reentry Cone Installation Schematic
Hanger/ Riser Top - 2185.6 mbrf
Battery Frame Top - 2188.6 mbrf
Reentry Cone Top - 2191.3 mbrf
Mud Skirt Bottom - 2193.7 mbrf
16" Casing Shoe - 76.3 mbsf
Cement Top - ~948.1 mbsf
10-3/4" Casing Shoe - 1068.2 mbsf
14-3/4" Hole TD - 1081.3 mbsf
Seismometer Top - 1084.2 mbsf
Strainmeter Top - 1091.0 mbsf
Strainmeter Bottom - 1094.9 mbsf
Cement/Stinger Bottom - 1098.6 mbsf
9-7/8" Hole TD - 1113.0 mbsf
Hanger/Riser
Battery Frame
Reentry Cone
2193.7 mbrf - Seafloor
16" Casing
Centralizer
10-3/4" Casing
9-7/8" Open Hole
4-1/2" Casing
Seismometer
Tiltmeter
Seismometer
Strainmeter
Stinger

Figure 9

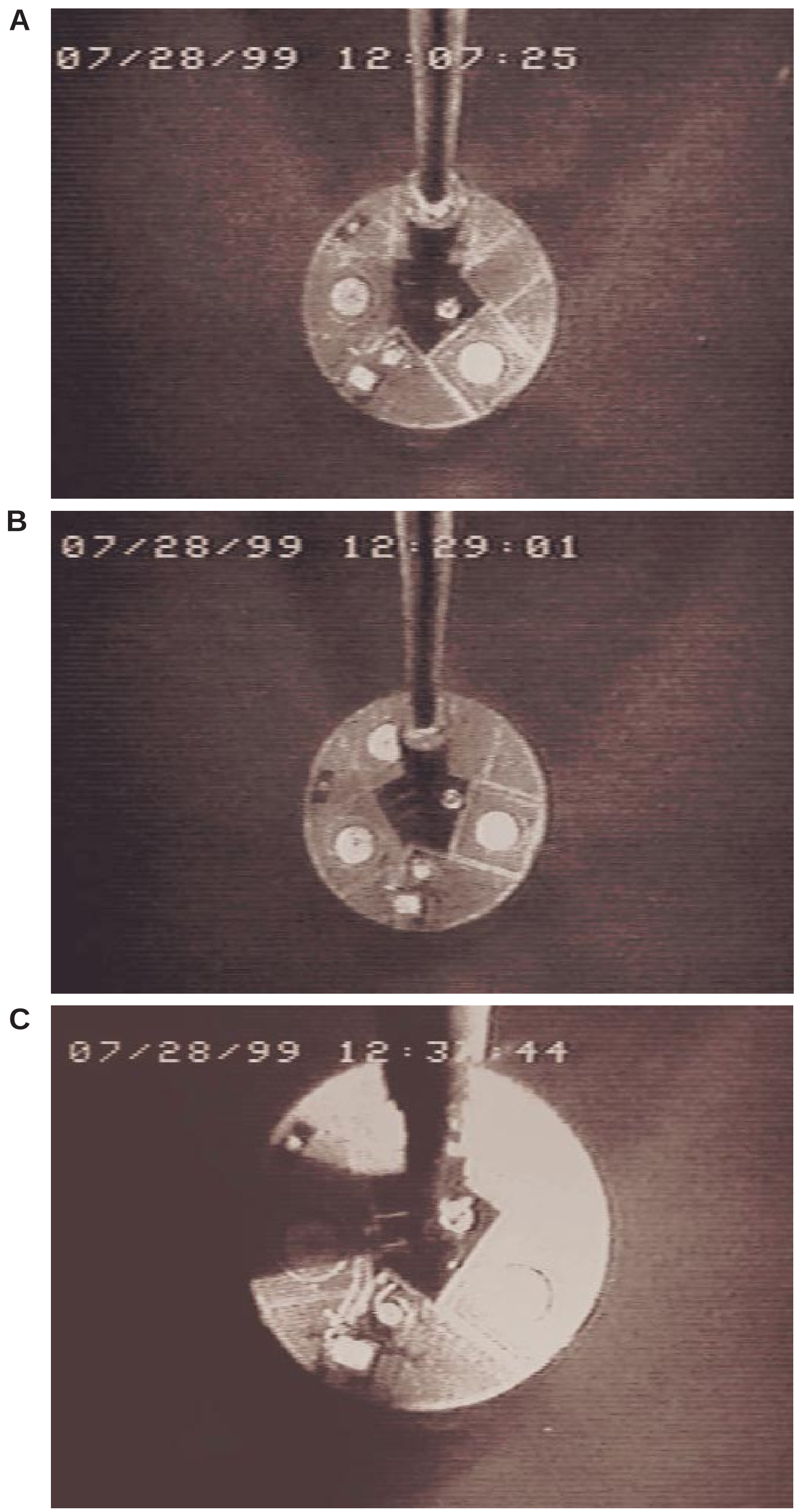


Figure 10

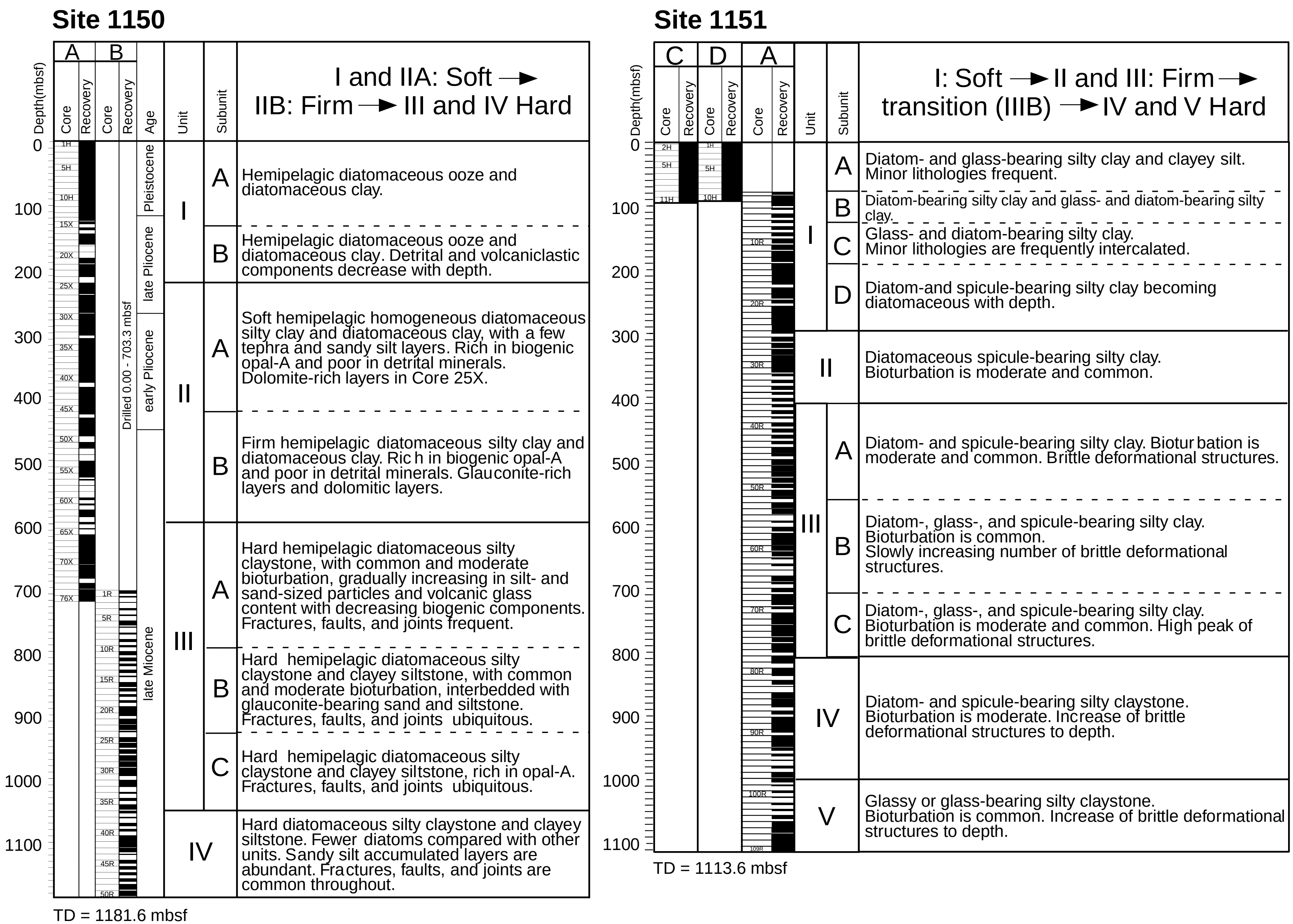

Site 1150
Depth(mbsf)
A
B
Core
Recovery
Core
Recovery
Age
Unit
Subunit
I and IIA: Soft → IIB: Firm → III and IV Hard
Pleistocene
late Pliocene
early Pliocene
late Miocene
Drilled 0.00 - 703.3 mbsf
I
A
Hemipelagic diatomaceous ooze and diatomaceous clay.
B
Hemipelagic diatomaceous ooze and diatomaceous clay. Detrital and volcaniclastic components decrease with depth.
II
A
Soft hemipelagic homogeneous diatomaceous silty clay and diatomaceous clay, with a few tephra and sandy silt layers. Rich in biogenic opal-A and poor in detrital minerals. Dolomite-rich layers in Core 25X.
B
Firm hemipelagic diatomaceous silty clay and diatomaceous clay. Rich in biogenic opal-A and poor in detrital minerals. Glauconite-rich layers and dolomitic layers.
III
A
Hard hemipelagic diatomaceous silty claystone, with common and moderate bioturbation, gradually increasing in silt- and sand-sized particles and volcanic glass content with decreasing biogenic components. Fractures, faults, and joints frequent.
B
Hard hemipelagic diatomaceous silty claystone and clayey siltstone, with common and moderate bioturbation, interbedded with glauconite-bearing sand and siltstone. Fractures, faults, and joints ubiquitous.
C
Hard hemipelagic diatomaceous silty claystone and clayey siltstone, rich in opal-A. Fractures, faults, and joints ubiquitous.
IV
Hard diatomaceous silty claystone and clayey siltstone. Fewer diatoms compared with other units. Sandy silt accumulated layers are abundant. Fractures, faults, and joints are common throughout.
TD = 1181.6 mbsf
Site 1151
C
D
A
Core
Recovery
Unit
Subunit
I: Soft → II and III: Firm → transition (IIIB) → IV and V Hard
I
A
Diatom- and glass-bearing silty clay and clayey silt. Minor lithologies frequent.
B
Diatom-bearing silty clay and glass- and diatom-bearing silty clay.
C
Glass- and diatom-bearing silty clay. Minor lithologies are frequently intercalated.
D
Diatom-and spicule-bearing silty clay becoming diatomaceous with depth.
II
Diatomaceous spicule-bearing silty clay. Bioturbation is moderate and common.
III
A
Diatom- and spicule-bearing silty clay. Bioturbation is moderate and common. Brittle deformational structures.
B
Diatom-, glass-, and spicule-bearing silty clay. Bioturbation is common. Slowly increasing number of brittle deformational structures.
C
Diatom-, glass-, and spicule-bearing silty clay. Bioturbation is moderate and common. High peak of brittle deformational structures.
IV
Diatom- and spicule-bearing silty claystone. Bioturbation is moderate. Increase of brittle deformational structures to depth.
V
Glassy or glass-bearing silty claystone. Bioturbation is common. Increase of brittle deformational structures to depth.
TD = 1113.6 mbsf

Figure 11

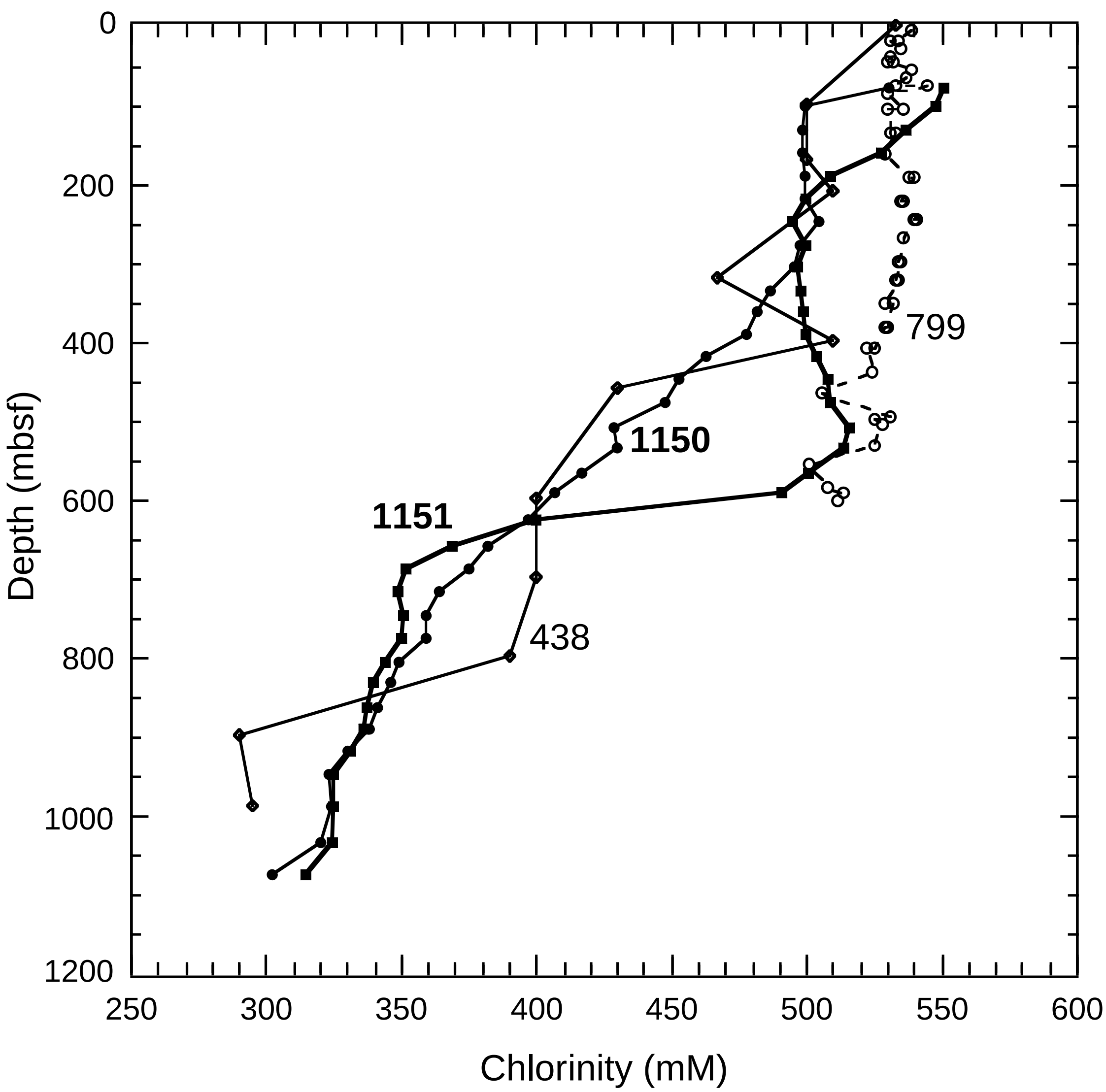

0
200
400
600
800
1000
1200
Depth (mbsf)
250
300
350
400
450
500
550
600
Chlorinity (mM)
799
1150
1151
438

Figure 12

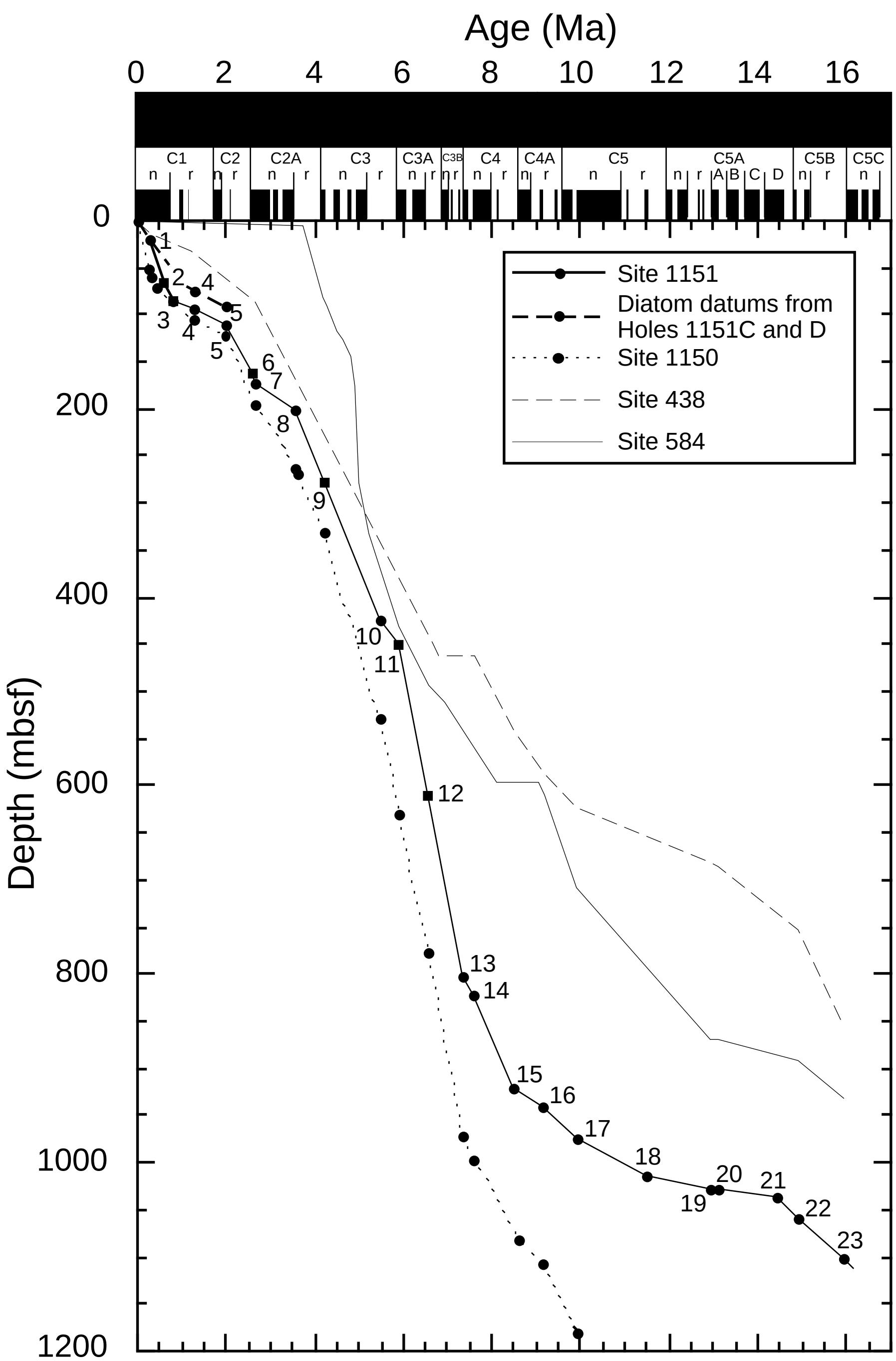

Age (Ma)
0 2 4 6 8 10 12 14 16
C1 C2 C2A C3 C3A C3B C4 C4A C5 C5A C5B C5C
Depth (mbsf)
0 200 400 600 800 1000 1200
Site 1151
Diatom datums from Holes 1151C and D
Site 1150
Site 438
Site 584

Figure 13

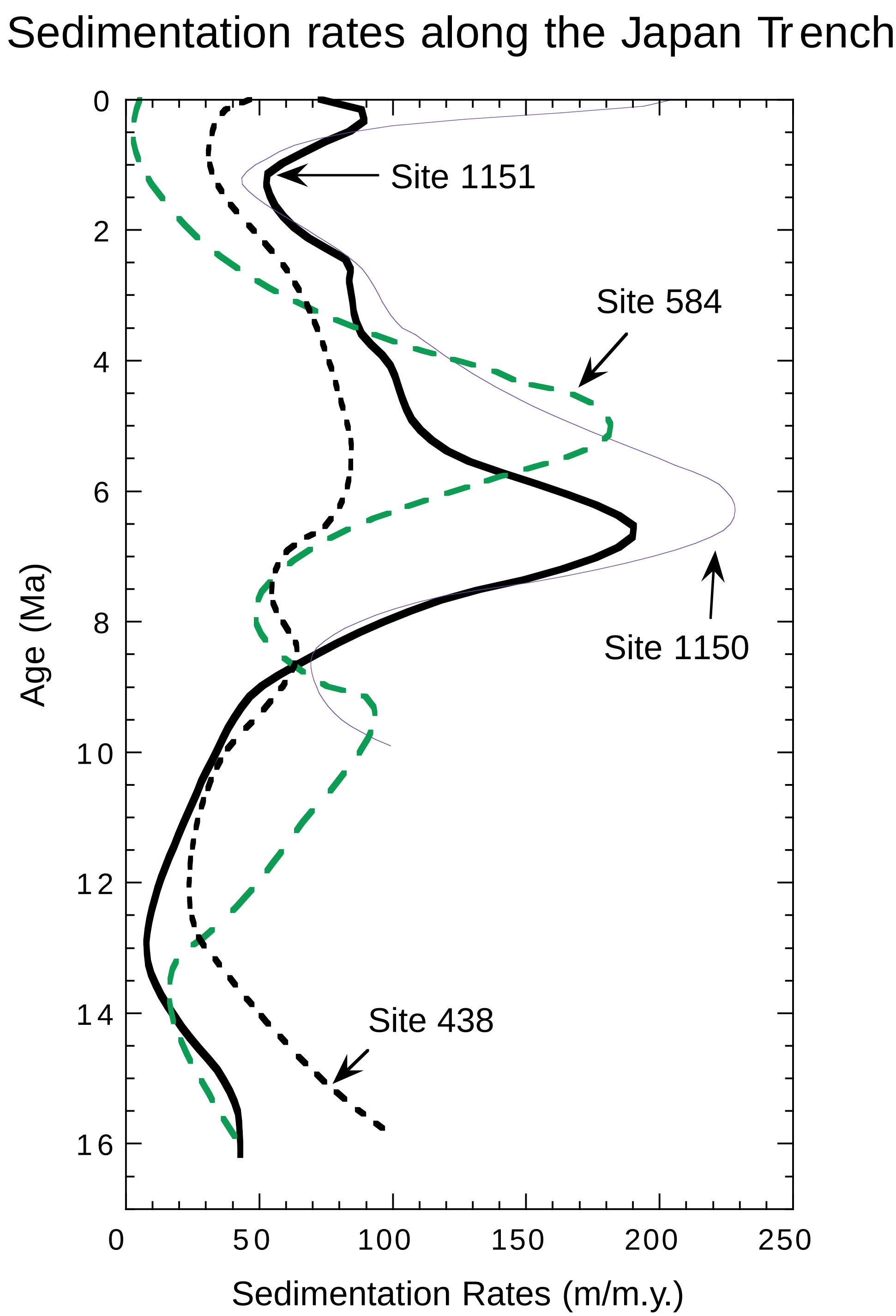

Sedimentation rates along the Japan Trench
Site 1151
Site 584
Site 1150
Site 438
Age (Ma)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
250
Sedimentation Rates (m/m.y.)

Figure 14

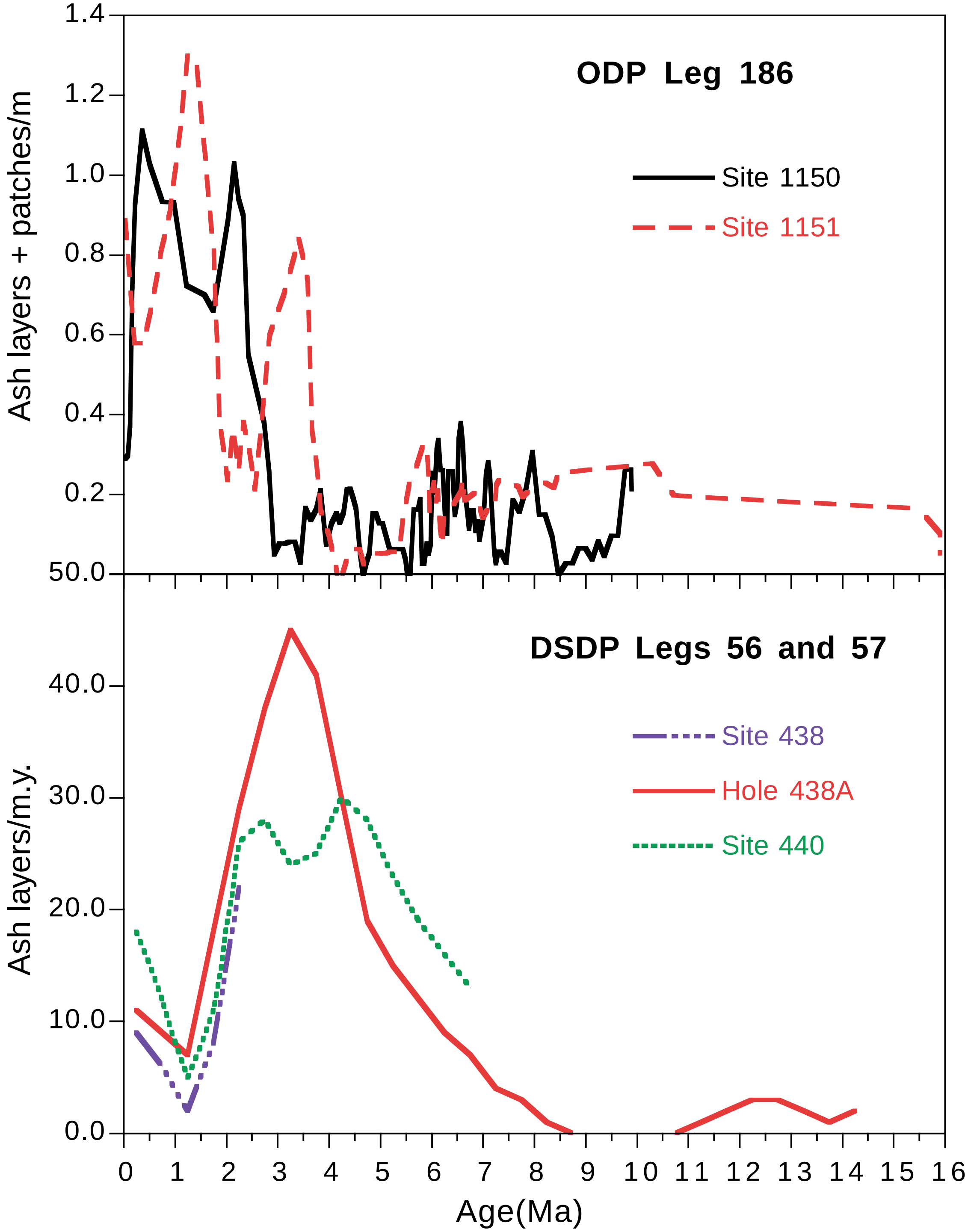
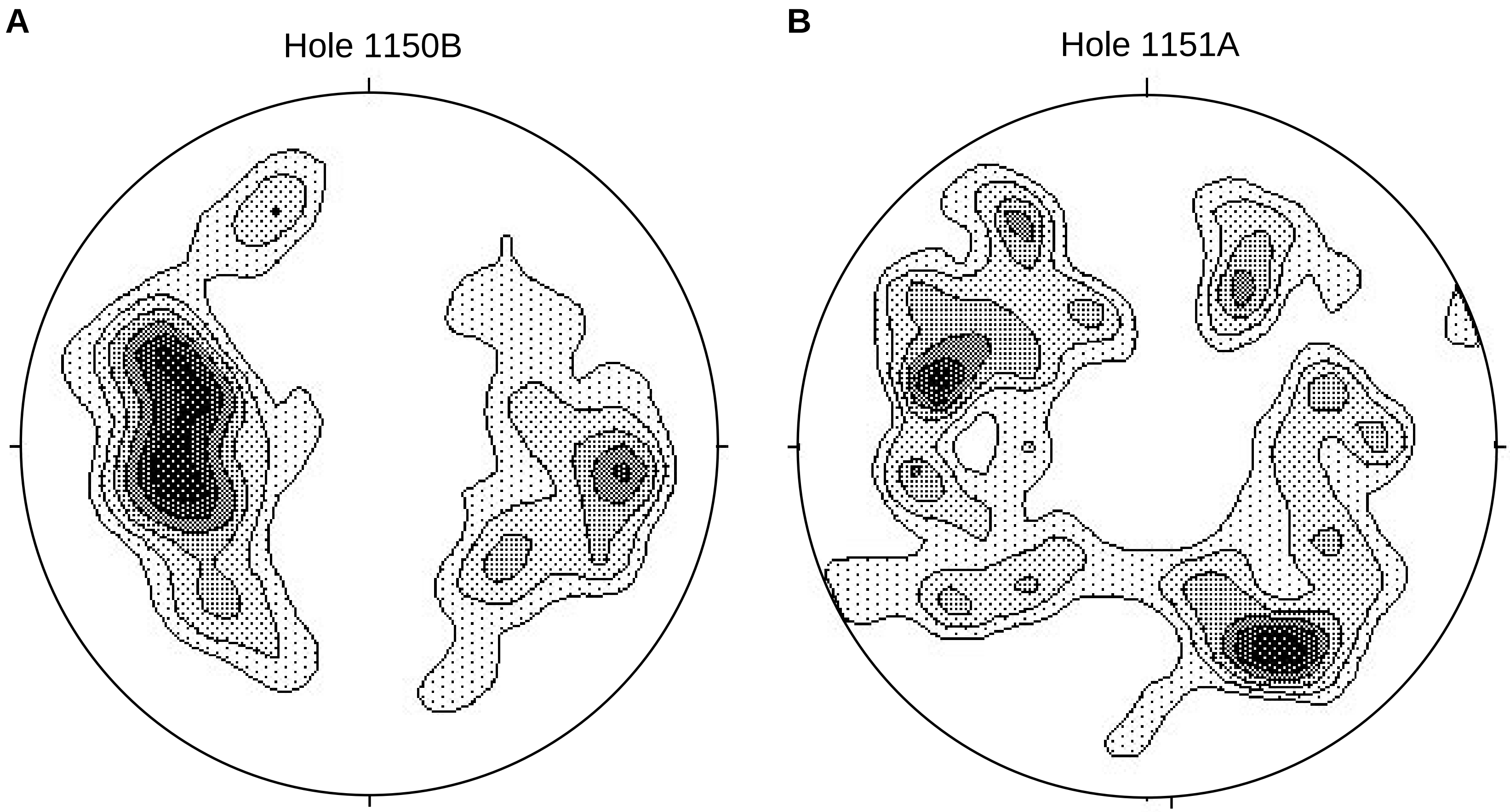
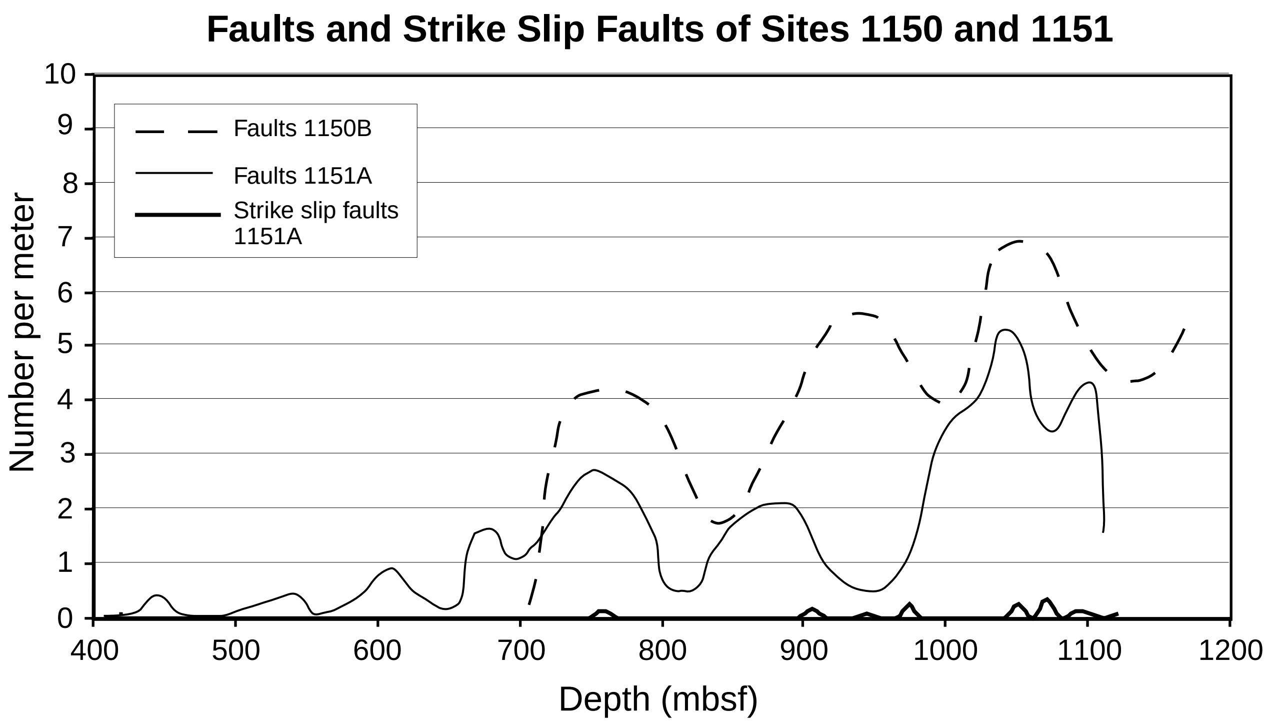

ODP Leg 186
Site 1150
Site 1151
Ash layers + patches/m
1.4
1.2
1.0
0.8
0.6
0.4
0.2
50.0
DSDP Legs 56 and 57
Site 438
Hole 438A
Site 440
Ash layers/m.y.
40.0
30.0
20.0
10.0
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Age(Ma)

Figure 15

Figure 16





Faults and Strike Slip Faults of Sites 1150 and 1151
Faults 1150B
Faults 1151A
Strike slip faults 1151A
Number per meter
Depth (mbsf)
0
1
2
3
4
5
6
7
8
9
10
400
500
600
700
800
900
1000
1100
1200

Figure 17

OPERATIONS SYNOPSIS

Port Call

Leg 185 ended and Leg 186 officially began with the first line ashore at 2018 hr on Monday 14 June 1999 in Yokohama, Japan (all times are reported are in local ship time, which is UTC + 9 hr). Because of the large amount of casing to be used during Leg 186, the riser (casing) hold had to be emptied and rearranged. The following casing was loaded: eight joints of 20-in (94 lb/ft; ~13.86 m/joint; total length = ~111 m), 83 joints of 16-in (75 lb/ft; ~12.70 m/joint; total length = ~1054 m), 156 joints of 10¾-in (40.5 lb/ft; ~12.98 m/joint; total length = ~2024 m), and 179 joints of 4½-in (10.5 lb/ft; ~11.64 m/joint; total length = ~2084 m) casing.

Port call activities included a number of tours, which were managed by the Japanese Marine Science and Technology Center (JAMSTEC), and a reception hosted the evening of 16 June by the Ocean Research Institute (ORI). All Ocean Drilling Program/Texas A&M University (ODP/TAMU) and Sedco employees plus scientists from Legs 185 and 186 were invited. The reception was attended by many dignitaries including consulate personnel from various member countries and many Japanese scientists involved with the future of ocean drilling, particularly through the OD21 initiative. In the end, port call extended a day longer than anticipated owing in part to a strike by the Yokohama dock workers that fortunately only extended through the weekend. The extra time during the weekend was used to assemble the battery packs for the borehole instruments and to replace the aft crane boom on the port side of the ship.

Transit to Site 1150

The *JOIDES Resolution* departed Yokohama at 1145 hr on Monday 21 June. Traveling the 363-nmi transit at an average speed of 11.9 kt, we arrived at Site 1150 (JT-1C) at 1830 hr on 22 June and began drilling operations. The initial beacon deployed was released and recovered because it was not as close to the desired site location as we would have liked. A second beacon was released at 2047 hr and, because we would be spending a significant number of days at this site, a back-up beacon was deployed at 2145 hr.

Hole 1150A

Hole 1150A was spudded at 0530 hr on 23 June using the advanced hydraulic piston corer/extended core barrel (APC/XCB) coring system in a water depth of 2680.8 m (2692.2 mbrf). Cores 3H through 12H were oriented using the Tensor tool. Three successful Adara temperature measurements were taken on Cores 3H at 26.7 mbsf, 6H at 55.2 mbsf, and 9H at 83.7 mbsf. An overpull of 60,000 lb after the third Adara run led us to cancel any further Adara measurements.

Biogenic methane was present throughout the APC-cored interval, which led us to cease APC coring. The gas content coupled with the tendency of the APC to pack material fully in the core liners resulted in the explosive ruptures of the core liners for Cores 10H and 11H. It was felt that rotary type coring would alleviate some of the propensity of the liners to explode even if the gas remained present in the cores. APC coring was therefore terminated before reaching any typical refusal point. Overpull at that point was running a mere 15,000–20,000 lb for non-Adara deployments.

XCB coring began with Core 13X and continued through Core 76X to a depth of 3414.8 m (722.6 mbsf). Methane gas continued to be present in the cores at the same level; however, there was only a single exploding core liner incident with the XCB and this occurred before removing the liner from the core barrel. The Davis-Villinger Temperature Probe (DVTP) was successfully run twice during the XCB-cored interval: once after Core 13X at 116.4 mbsf and again after Core 18X at 164.4 mbsf. The three Adara data points, two DVTP data points, and the single Adara mudline temperature measurement combined to define a very linear temperature gradient of 33.9°C/km. There were no hydrocarbon safety issues while drilling this hole. Biogenic methane was present for the entire section cored with head space data averaging around 3% methane and 1–2 ppm ethane.

Hole 1150A was cored to a total depth of 722.6 mbsf. The maximum drill string deployed was 3414.8 mbrf. A total of 566.40 m of core was recovered for an average of 78.4% of the section cored. Penetration rates varied from 99 m/hr in the surface sediments to just under 20 m/hr at total hole depth (TD). The entire XCB cored section of 610.4 m was cored at an average rate of penetration (ROP) of 35.1 m/hr. Of the 112.2 m penetration with the APC system, 118.25 m of core was recovered (105.4% recovery), and, of the 610.4 m penetrated with the XCB, 448.15 m (73.4%) of core was recovered (Table 1). The APC/XCB drilling assembly was pulled clear of the mudline at 1415 hr on Saturday 26 June 1999.

Jet-In Test

The ship was offset ~20 m west of Hole 1150A and a jet-in test was conducted for the future emplacement of the reentry cone and 20-in casing string. The jet-in test was completed in 2.5 hr after washing without rotation to a depth of 67.0 mbsf. A hard layer was detected at 56.0 mbsf, though increased weight on the bit (WOB) and circulation kept the drill bit advancing without any problem. The jet-in test was concluded at 1830 hr 26 June when the bit cleared the seafloor.

Hole 1150B

The APC/XCB core bit reached the rig floor at 2215 hr 26 June 1999 ending Hole 1150A and beginning Hole 1150B. The bit was found to be in excellent condition after accumulating a total of 23.2 rotating hr and 913.8 m of penetration.

Hole 1150B was spudded about 44 m east of Hole 1150A at 0415 hr on Sunday 27 June with the RCB coring system in a water depth of 2680.8 m (2692.2 mbrf). The hole was drilled down to 703.3 mbsf before coring began. Drilling was briefly halted during this interval when a hydraulic line in the top drive umbilical ruptured. Extremely heavy rain and high wind hampered the repair effort, which took 1.5 hr. Overall, drilling and connection time was 19.75 hr, with an average ROP of 35.6 m/hr.

RCB coring was initiated about two cores above the XCB termination depth of 722.6 mbsf. We had originally planned to core to 1000 mbsf but continued deeper in search of more indurated sedimentary rock, which would be better suited for the borehole instruments planned for installation in Hole 1150C. In addition, we wanted to get deep enough to log through the rock units directly below and at the depth at which the borehole instruments were to reside. Coring ceased at 1181.6 mbsf on 1 July, when it was deemed that the lithification and depth was sufficient to accomplish our goals. In all, we cored 478.3 m and recovered 269.4 m of sediment and sedimentary rock from 50 RCB cores, for an average recovery of 56.3% (Table 1).

No hydrocarbon problems were experienced in this hole. Methane gas continued to be present in the cores at an average of about 3%, slightly higher than the average of 1.5% seen in Hole 1150A. Ethane was present at ~10 ppm, and no higher hydrocarbons were identified.

In preparation for logging, we completed a wiper trip, circulated a 30-bbl sepiolite pill, released the bit, displaced the hole with 330 bbl of sepiolite logging mud, and pulled the bottom of the drill pipe up to ~114 mbsf. Though we encountered no apparent restrictions during the wiper trip, the first logging run encountered a tight interval at ~643 mbsf, which we were unable to get through. Logging with the triple combo tool string proceeded upward from 646 mbsf. The second logging run, using the Formation MicroScanner (FMS) tool string, encountered a second obstruction, this time at ~473 mbsf, and the hole was logged upward from this depth. After completing the first two logging runs, we lowered the drill string to 742 mbsf. No resistance was identified by the driller. This allowed three logging runs—the triple combo, FMS, and borehole televiewer runs—to reach to within 7 to 11 m of the bottom of the hole. Formation MicroScanner data indicated an elliptical hole with one axis diameter measuring 10 in, the other measuring 14 in.

The wireline logging tools and sheaves were rigged down by 0600 hr 3 July, and the drill string was pulled to a depth of ~3292 m (~600 mbsf). A 30-bbl cement plug (~96 m long) was set at that point to ensure that there would be no communication of seawater downhole and through a fracture network to the reentry installation. The drill string was pulled clear of the seafloor at 0900 hr 3 July, and the drill string was flushed with seawater to remove any remnant cement.

Hole 1150C

While recovering the drill string the drillship was offset ~80 m west, which was ~40 m west of the original APC/XCB Hole 1150A. The end of the drill string reached the rig floor at 1330 hr on 3 July 1999, ending Hole 1150B and beginning Hole 1150C.

Reentry Cone and 20-in Casing String Installation

The upper guide horn was removed to assemble the 20-in casing string and reentry cone ensemble. Assembly of the 20-in casing went exceptionally well, taking only 2.5 hr to join the shoe joint, three additional joints of casing, and the Dril-Quip running tool.

With the reentry cone positioned beneath the rotary table on the moonpool doors, we attempted to lower and latch the 20-in casing hanger into the reentry cone. The first sign of trouble occurred when the hanger landed at the base of the reentry cone panels rather than proceeding smoothly into the bore of the transition pipe. Even after jostling the cone around the hanger, the hanger continued to hang up sporadically in the transition pipe and would not move freely down to the landing shoulder. We decided that there must be a significant interference between the 20-in casing hanger body and the weld attaching the latch ring body extension. To save time, the top joint of 20-in casing was laid out with the hanger attached. The next joint of 20-in casing was also laid out. The third and fourth joints of casing plus casing shoe were raised up into the derrick, allowing access to the reentry cone. The cone was then repositioned onto its side to allow a more detailed inspection. After inspecting the transition areas of both reentry cones aboard it was apparent that the axial weld on the transition pipe and the weld attaching the transition pipe to the latch ring body extension protruded far enough to prevent the casing hanger from traveling freely to the landing shoulder. Also, it appears from field measurements that the uppermost ~1-in of the latch ring body extension was incorrectly machined. Once the welds and the incorrectly machined portion of the latch ring were ground flush on the inside diameter, the casing string was once again assembled, and this time the casing hanger latched into the proper position as designed. This incident resulted in 8.5 hr of lost time.

The casing string and reentry cone were lowered to a depth of 2654 m, and the subsea camera on the vibration-isolated televison (VIT) frame (referred to as VIT camera herein) was deployed during the pipe trip. Hole 1150D was spudded at 0930 hr on 4 July by jetting the casing into the seafloor. It took 4.25 hr to jet-in the casing to a depth of 58.13 mbsf and land the reentry cone at the seafloor at a depth of 2692.2 m.

The pipe was tripped back to the rig floor, where the nozzles on the bit were replaced and the bottom-hole assembly (BHA) was assembled in preparation for drilling the 18.5-in diameter hole. The first reentry into the cone was made at 0245 hr on 5 July. By 0145 hr on 6 July we had drilled the 18.5-in hole down to a depth of 539.8 mbsf, for an average drilling rate of 27.5 m/hr. The hole was swept clean with two 50-bbl sepiolite pills and a wiper trip, displaced with 550 bbl of sepiolite, and the drill string pulled out of the hole, reaching the rig floor at 1245 hr.

Supply Boat Rendezvous

The 30-m-long sea-going tug *Fumi Maru #26* came alongside to discharge cargo and seven passengers at 0600 hr on 6 July. Arriving personnel included Masanao Shinohara from the Earthquake Research Institute at Tokyo University (shipboard participant), Kevin Sharp (cable-connector technician from Ocean Design), Andrew Green and Murry McGowan (seismometer technicians from Guralp Systems Ltd., United Kingdom), and Michael Acierno (computer specialist from Carnegie Institution). In addition, a two-man film crew (Satoru Ninomiya and Daisuke Yamada), hired by ORI, came aboard. The film crew and the two Guralp technicians departed the ship the following day at 1200 hr after their work was completed.

The 16-in Casing String

The rig crew ran the 42 joints (525.87 m) of 16-in casing, assembled the casing hanger, and engaged the Dril-Quip running tool in only 5.5 hr. The 16-in casing string was lowered to the seafloor, and the second reentry occurred at 0130 hr on 7 July. The casing began to show resistance almost immediately upon entry into the 20-in conductor pipe. The circulating head had to be installed and the casing circulated down to 137.8 mbsf. While running the casing into the bore hole, weights of 20–30 kilopounds (kips) were used to advance the casing string. By 0845 hr on 7 July, the casing hanger was landed. The casing was cemented using 30 bbl of cement, which should have resulted in cement reaching ~100 m up the exterior of the 16-in casing. The cementing dart was launched and at 1015 hr the plug was landed at the cementing shoe and confirmed with 500 psi pump pressure. Within 15 min, the running tool was released and the drill string was then flushed with seawater to remove any residual cement in the drill string. The pipe was pulled out of the hole clearing the rotary table at 1600 hr that same day.

After attaching a new 14¾-in drill bit, the drill string was lowered and the cone reentered at 2315 hr on 7 July. Because the bit was hanging up and not sliding smoothly into the transition pipe, the bit was pulled clear of the reentry cone at 2345 hr and the top drive was picked up to allow the pipe to be rotated. The reentry cone was reentered once again at 0030 hr on 8 July. The bit was “rolled” gently into the transition area. The 16-in cementing shoe was contacted at a depth of 527 mbsf and we began drilling out the cementing shoe, wiper plug, and dart assembly.

Drilling had been in progress for 2.5 hr when at 0640 hr, 60,000 lb of string weight was suddenly lost along with 300 psi of pump pressure. Calculations indicated that the drill string had parted at or near the seafloor. The VIT camera was deployed to verify the position of the fish (the part of the drill string in the hole) in relation to the reentry cone. The top of the fish was not visible. The camera showed, however, that the 5-in drill pipe had parted about 1 m below a tool joint in the area where the tube of the pipe had been rubbing the casing hanger during the cement-shoe drilling operation. Once the drill string was at the surface it was verified that the string did part in the 5-in drill pipe, 0.98 m below a box tool joint. The pipe showed signs of rubbing against the hanger or the transition pipe of the reentry cone during rotation, but still measured a full 5-in in diameter. The pipe coating was worn away, but no deep cuts or gouges were noted. The failure was a clean break with no metal extending over the diameter of the pipe.

To retrieve the fish, we used fishing tools consisting of a 8-7/8-in diameter overshot with a 5-in basket grapple and an 8-7/8-in diameter wall hook guide. The fish consisted of the BHA assembly plus 13-2/3 stands of 5-in drill pipe for a total length of 526.5 m. The top of the fish was calculated to be at 2693.3 m, which put it near the top of the 16-in casing hanger. The fishing assembly was made up and run into the top of the reentry cone. On the first two attempts to engage the fish, the overshot slid down beside the fish in the 15-1/8-in inside diameter casing. On the third attempt the guide passed over the top of the fish and the grapple engaged the 5-in drill pipe tube. The fish was pulled to the surface and the broken joint removed.

At 1045 hr on 8 July Hole 1150C was reentered. As on the previous reentry, the bit once again hung on the lip of the reentry cone at the entrance to the transition pipe. This time, chain tongs were used to rotate the pipe and it eventually slipped into the throat of the reentry cone. The pipe was run to bottom and at 1245 hr we once again began drilling operations. At 1400 hr on 10 July, we finished drilling the 14.75-in hole for emplacement of the 10.75-in casing string. It took 24.25 hr to drill the 510 m of 14.75-in hole down to a depth of 1050.0 mbsf, an average rate of 21 m/hr. Sepiolite mud sweeps of 30 bbl every 40 m were pumped during the drilling process and the hole was circulated with a 50-bbl sepiolite pill. The pipe was tripped to the rig floor at 0245 hr on 11 July.

The 10¾-in Casing String

The 10¾-in casing string, consisting of 82 joints of 10¾-in casing plus the casing hanger, was assembled just 8.75 hr. The casing string was lowered to the seafloor, and Hole 1150C was reentered Hole 1150C at 1735 hr on 11 July.

An hour was spent attempting to advance the casing shoe through the throat of the reentry cone without success. The bit was pulled clear of the reentry cone at 1630 hr and the top drive was picked up. The cone was reentered after 35 min of ship maneuvering but the problem persisted. As the casing string was lowered, the casing shoe would catch and cause the casing string to bend or bow with as little as 5000–8000 lb of weight. We observed the deflection of the casing string with the subsea camera, which moved off center of the hole when weight was applied to the shoe. On previous reentries the same problem had occurred entering the transition pipe/casing hanger area but had been solved with rotation that allowed the bits to pass. Because the Dril-Quip running tool released with right-hand rotation, left-hand rotation was planned to work the casing shoe through the transition pipe/casing hanger area. The top drive torque limit was set at 150 A (~2000 ft-lb) to prevent overtorquing the running tool and to keep the reverse torque well below the make-up torque of the casing (4200 ft-lb). Very slow reverse rotation was initiated, and the pipe was worked in an attempt to pass. Because of the low torque limit setting, rotation stopped as soon as the casing shoe took weight and never approached the make-up torque of the casing. Rotation at the reentry cone matched the rotation at the surface. The casing string was worked with and without rotation with weights reaching 12,000 lb during vessel heaves. The vessel was also offset 20 m forward at this time to try to reposition the casing in relation to the cone.

At 1750 hr on 11 July the string parted in a casing coupling 17 joints (~205 m) above the casing shoe. Part of the casing was observed falling down through the previously impassable transition pipe and into the hole. The VIT camera was recovered and the remaining 67 joints of casing were pulled to the rig floor. Several days later when we returned to Hole 1150C to plug it with cement, we observed many of the lost joints lying on the seafloor. Thus, only a few joints may have fallen into the hole.

After reviewing the operation, the failure of the casing coupling was attributed to the flexing and bending of the casing string. This may have been caused by flaws in the reentry cone. As noted earlier in the leg, when trying to land the 20-in casing hanger in the reentry base used on Hole 1150C, the landing ring body extension welded to the transition pipe was observed to be machined improperly and the welds inside the pipe were not dressed to specifications. When the same machined area on the reentry cone for Hole 1150D was ground flush, it was noticed that the body extension was not welded properly, creating a serious weakness to the structure. If the same welding techniques were used on the base of the reentry cone for Hole 1150C, the weld could have failed, creating an opening between the casing hangers and the transition pipe welded to the bottom of the base. This could have been the cause of the difficulties getting the bits and casing shoes to pass through the transition pipe/hanger area. This also could have been the problem that led to the drill pipe failure that occurred while drilling out the 16-in casing shoe.

Considering the rapid rate at which the casing string dropped into the hole, there would have been a slim chance of removing the pile of metal that would have crashed at the base of the hole. There was also concern that even if we were able to fish the casing, we might not have been able to pull it through the flawed reentry cone. Thus, we abandoned operations on Hole 1150C and started over in Hole 1150D.

Hole 1150D

Operations at Hole 1150D began with a great deal of welding and grinding to bring the reentry cone up to required tolerance and strength specifications. A total of 14 hr were required before the reentry cone could be positioned in the center of the moonpool doors. In the meantime, the ship was offset 60 m south of Hole 1050A.

Reentry Cone and 20-in Casing String Installation

Four joints of 20-in casing (including the shoe joint) were assembled and attached to the 20-in casing hanger. The hanger was lowered into the reentry cone and engaged the reentry cone as designed without incident. Hole 1150D was spudded at 0545 hr on 13 July at a seafloor depth of 2692.2 m. The cone landed at the seafloor 11 hr later positioning the 20-in casing shoe at a depth of 55.0 mbsf.

The drill string was pulled back to the ship and we changed out the No. 16 jets with No. 24 jets in the 18½-in drill bit. The BHA was assembled and the drill string was run back to bottom. The first reentry was made into Hole 1150D at 0345 hr on 14 July after maneuvering the vessel for 45 min. This time the bit slid smoothly into the throat of the reentry cone and continued to the casing shoe without any resistance. We drilled the hole to a depth of 544.8 mbsf at an average penetration rate of 35.7 m/hr. Following bentonite mud sweeps, a wiper trip, and a hole displacement with sepiolite mud, we tripped the drill string to the rig floor.

The 16-in Casing String

By 1230 hr on 15 July, the drill crew had assembled 41 joints of 16-in casing. Reentry was made at 1700 hr on 15 July without requiring any time to reposition the vessel. The 16-in casing shoe went through the reentry cone transition without any problem and the string was advanced to a depth of 278 m before the top drive was picked up. The remaining portion of the casing string was “washed” to bottom in the relatively tight hole. The 16-in casing shoe was landed at 533.9 mbsf at 0100 hr on 16 July and cemented into place with 30 bbl of cement 15.8 lb/gal (~1.92 g/cm^3). The drill string was recovered to the rig floor by 0745 hr on 16 July.

After positioning the ship for 30 min, Hole 1150D was reentered at 1315 hr on 16 July with the 14¾-in drill bit. As before, the bit went straight through the reentry cone transition area and advanced to bottom where the cementing shoe was tagged at a depth of 532.8 mbsf. By 0830 hr on 17 July, the hole was drilled to a depth of 1044.8 mbsf. Only 16 hr was required to drill the 500 m of hole at an average rate of penetration of 31.3 m/hr. As before, the hole was circulated with a 50-bbl bentonite mud sweep, and a wiper trip was conducted up to the 16-in casing shoe.

The 10¾-in Casing String

It took ~7.5 hr to assemble 80 joints of 10¾-in and the casing hanger. The casing string was lowered, the VIT camera was deployed, and at 0800 hr on 18 July, after positioning the ship for 30 min, Hole 1150D was reentered for the fourth time. Unlike the difficulties we had at Hole 1150C, this time the 10¾-in casing shoe slipped through the throat of the reentry cone without resistance and the string was run to 1044.8 mbsf and then cemented with 50 bbl of 15.8 lb/gal cement.

During this operation, we had been monitoring a storm system that was heading in our direction. To avoid the possibility of being caught in a storm while deploying the borehole instruments, we decided to delay the deployment and instead head to Yokohama to get additional casing and a reentry cone, which were needed for Site 1151 operations. The drill pipe was tripped to the surface, the rig floor was secured for transit, and the ship got under way at 2130 hr on 18 July.

Yokohama Port Call for Resupply

The 370-nmi distance to Yokohama was covered in 36.8 hr at an average rate of 10.3 kt. The pilot came aboard at 0750 hr and we proceeded dockside with the first line ashore at 1000 hr on 20 July. Even though it was a Japanese holiday called “Day of the Oceans,” the resupply went exceptionally well. The shipping agent, Kiyoaki Chiba of Sea Trade & Agency Inc., was able to arrange for a forklift and foreman to remain on duty to assist the ship’s crew with continued loading activities after normal holiday working hours had ended. In addition, loading was expedited by having the cargo predelivered dockside before our arrival. Cargo taken aboard included one reentry cone, six joints of 16-in casing, 48 joints of 10¾-in casing, and 32 joints of 4½-in casing. In addition, Michael Acierno (Carnegie computer specialist) and Kevin Sharp

(Ocean Design connector technician) both departed the vessel since their work was completed. Dan Malone, Overseas Drilling Ltd. warehouseman replacement for the retiring Mick Malone (on the other crew), came aboard to spend the rest of the leg coordinating with Mike Cole, the warehouseman on the Leg 186 crew. All loading was completed by 1800 hr, although we were unable to depart right away because of harbor congestion associated with the holiday fireworks display. The delayed provided a chance for all on the *JOIDES Resolution* to enjoy nearly 2 hr of fireworks and some much-needed entertainment along the dock. We eventually secured both pilots required for transit out of the port area and departed at 2145 hr on 20 July.

Return to Hole 1150D

The 364-nmi transit back to Site 1150 took 31 hr at an average rate of 11.7 kt. We acquired the positioning beacon at 0700 hr the morning of 22 July.

In exceptionally calm seas, we reentered Hole 1150D. Using a 9-7/8-in tricone drill bit, we drilled through the cementing shoe at a depth of 1031.8 mbsf and began drilling the 9-7/8-in diameter hole. Drilling in Hole 1150D was completed to a depth of 1140.0 mbsf. The final 95.2 m of hole took 5.5 hr to drill at a rate of 17.3 m/hr. The hole was circulated with a 50-bbl bentonite gel mud sweep and the wiper trip commenced back to the 10¾-in casing shoe. We completed the trip back to the casing shoe without incident, though on the return back down experienced 20–30 kips of drag almost from the start. Torquing and elevated pump pressure was also apparent. After reaming the hole to bottom twice and circulating two additional sepiolite pills, the hole seemed to be clean.

Cementing Hole 1150C

At 1315 hr on 23 July, we began pulling out of the hole to the seafloor. We cleared the reentry cone at 1530 hr and offset the ship back to Hole 1150C to plug the open hole with cement. During the move between holes we identified a long string of 10¾-in casing resting on the seafloor near Hole 1150C. As discussed above, the 10¾-in casing string at Hole 1150C apparently failed in more than one place, which allowed some casing to fall into the reentry cone and the rest to fall outside onto the seafloor. We were not able to accurately determine the quantity of casing outside the reentry cone; however, it is possible that only one or two joints actually fell into the hole.

At 1630 hr, we reentered Hole 1150C and, as anticipated, we had to rotate the drill bit with the top drive to pass through the cone transition area. Because we had made five flawless reentries into Hole 1150D, we can now definitively rule out environmental causes for the reentry problems experienced in Hole 1150C. Therefore, there must be a major structural problem or failure in the transition area of the Hole 1150C reentry cone. The pipe was advanced to a depth of 263.0 mbsf and a 15-bbl plug of cement was pumped into the 16-in casing. This was to prevent flow between Hole 1150C and Hole 1150D, where the instrument string was to be emplaced. At 1845 hr, after displacing the cement plug, the pipe was pulled clear of the Hole 1150C reentry cone. The pipe cleared the rotary table at 2230 hr, and preparations began for deployment of the instrument package in Hole 1150D.

Installation of the Borehole Instruments at 1150D

The ship was offset back to Hole 1150D as the rig floor was prepared for handling the instruments. The instrument string was assembled by its various parts, of which the lowest is a stinger pipe, a tube that allows cement to be pumped below the instruments (Fig. 8). The stinger is bolted to a overlying strain meter. Above this is a deployment frame with two seismometers and a tilt meter. This part of the instrument package was lowered into the moonpool area below the rig floor where the four ¾-in diameter instrument cables were connected to the respective instruments. The rest of the instrument string consisted of 4½-in casing, a circulating sub, and a riser/casing hanger. Ninety-five joints (~1107.1 m) of 4½-in casing were run while strapping and taping the instrument cables with tie wraps and duct tape. In addition, casing centralizers were installed ~7.0 m apart along the casing. After deploying 40 joints of casing, the circulating sub, which allows the drill string to be flushed after the instruments are cemented in place, was installed. Then the other 55 joints of 4½-in casing were assembled with cables being attached in the same manner. The last 2 joints were not taped because this portion of cable was to be removed later to allow the watertight connectors to be installed in the subsea shop.

After running all of the 4½-in casing, the J-slot running tool was assembled, and the riser and casing hanger were picked up and connected to the top joint of 4½-in casing. It was then lowered into the moonpool area, where the instrument cables were measured and cut to length. The riser was pulled back up to the rig floor while the cable ends were fed into the subsea shop for installation of the watertight connectors, a process referred to as cable termination.

The cable termination began at 1945 hr on 24 July and extended until 1030 hr on 25 July. By 1200 hr, MEG had been installed into the specially designed riser carrier, and the four cables and their new connectors were plugged into the MEG. (MEG is composed of combiner/repeater module, analog-digital converter modules, strainmeter interface module, and power conditioning/distribution module, all of which acquire signals from the sensors, convert analog signals to digital data, and send out all the converted digital data to recorders via a single serial link.) By 1300 hr the final instrument checks had been completed. Once the riser/hanger was lowered beneath the ship, the VIT camera was deployed over the running tool/riser/casing hanger assembly to ensure that there was no interference. The VIT was recovered after the successful test and we commenced tripping the drill string to seafloor.

After positioning the ship for 1 hr, we reentered Hole 1150D at 1730 hr on 25 July. The reentry drill string was spaced out so as to allow the entire 16-m instrument package to be inserted completely into the throat of the reentry cone with the top of the instruments below the 10¾-in casing hanger. The bottom of the instrument string was then lowered to a depth of 1032 mbsf where the top drive was picked up in preparation for inserting the instrument package into the borehole. Slow circulation was maintained as the package was lowered into the open 9-7/8-in hole so we would know immediately if the end of the stinger began to plug. Resistance was met almost immediately after entering the open hole. Washing continued for 3½ hr as the package was advanced to a depth of 1101.8 mbsf or 23.4 m short of landing the riser/casing hanger in the reentry cone. Throughout the insertion period we experienced 10–20 kips overpull or drag and pressures of up to 1500 psi. When making connections with each new pipe joint, the hole would close around (pack off) the stinger or the stinger would become plugged. Casing advance proved impossible until pump pressures returned to normal. Several times the casing had to be picked up and worked back down again. This frequently failed to lower the pressure, indicating the stinger pipe was probably still plugged. Our efforts to emplace the instrument package were further aggravated by a leak path that was apparently coming from the J-type running tool. This made it difficult to determine how much circulation was going out the stinger and how much was leaking past the running tool. Mud sweeps did not improve the situation. At 2400 hr on 25 July we elected to pull the instrument string back inside the casing shoe. At this point, the stinger was completely plugged, and increasing the pump pressure did not unplug it.

It was obvious to all that we needed to reenter the hole with a drilling assembly and ream out the ~100 m of open hole before we had any chance of successfully inserting the instrument package. Fortunately the stinger unplugged itself during the pipe trip eliminating another potentially serious problem. The final step was to check the status of the instruments once the riser was pulled into the moonpool area. To our relief, all of the instruments were functioning. Given their multiple trips up and down the tight part of the open hole and their trip through the casing and reentry cone, the instruments and cables proved to be quite robust.

We decided to attempt hang off the intact instrument string from the ceiling above the moonpool rather than undertake the enormous job of re-spooling the cables, removing the tape, tie wraps, and centralizers, breaking down the 4½-in casing string, and disassembling the stinger/strain meter/seismometer/tilt meter instrument package. We were able to attempt this nonstandard operation because of very calm weather and sea conditions and because the hang-off loads were relatively low at ~20 tons. To allow hanging off the instrument string we had to make some modifications to the riser/hanger stabilizer fins. These were cut back ~18 cm (~7-in) to install the 10¾-in casing elevators with the 10¾-in casing slips installed below. We then disengaged the running tool and set it aside for inspection and repair. Four 1-1/8-in diameter wire slings were attached to the 10¾-in elevators and connected to the blocks. As the blocks were lowered, the load was slowly transferred from the lowering slings to the hang-off slings. This allowed the ~1130-m-long instrument string to swing slightly forward in the moonpool where it was secured with a tugger line. The transfer was completed in 5 hr (including riser/hanger modifications), and the rig floor was then clear for pipe handling/drilling operations to continue. In addition to the hang-off activities, the wash pipe in the running tool was welded at the top end to eliminate a circulation leak path within the J-type running tool.

A 9-7/8-in tricone drill bit was assembled with two stands of drill collars and the normal 5½-in transition pipe. We lowered the pipe to bottom and reentered Hole 1150D at 1730 hr on 26

July. We reamed out the hole making several passes through tight spots and circulated several 30-bbl sepiolite mud sweeps. This was followed by a wiper trip, circulating 5 m of fill from the hole, and then displacing the hole with 40 bbl of sepiolite mud.

We pulled out of the hole clearing the reentry cone at 0515 hr on 27 July and proceeded pulling pipe until clearing the rotary table at 0900 hr. Within 2 hr, the instrument string was transferred back to the running tool and a final instrument check was again performed. The pipe was once again run to bottom, and Hole 1150D was reentered for the eighth and final time at 1630 hr on 27 July.

This time the string entered the open hole with little resistance; however, after three pipe joint connections the drag and elevated pump pressure once again became our nemesis. As before, when a connection was made the string would pack off and high pump pressure was required to initiate circulation. Despite the repairs made to the running tool, we were once again faced with a circulation leak. The pipe was worked, the stinger unplugged multiple times, and after 3 hr we successfully landed the riser and casing hanger in the reentry cone placing the end of the instrument string stinger at 1125.2 mbsf.

We pumped 80 bbl of 15.8 lb/gal cement, displacing it with the rig pumps. The cementing dart landed in the circulating sub located ~455 m above the instrument package and the sleeve sheared as designed at ~1500 psi. This opened up circulation ports to the annulus and allowed the drill string to be thoroughly circulated (two times capacity) to remove any remaining cement. The VIT camera was recovered, and at 0045 hr on 28 July we began to rig up for assembling the battery frame halves on the moonpool doors.

Battery Pack Installation

The battery frame halves were bolted together around the pipe on the moonpool doors. Final deployment rigging and release bridles with dual acoustic release systems were attached. We waited until daylight to deploy the assembly through the moonpool because of the intricate rigging required and the poor visibility at night within the moonpool. We did not want to risk snagging a deployment cable on the guide horn. After waiting until 0430 hr (~45 min) we began to lower the platform through the moonpool. This intricate operation was completed quite well, partly because of the relatively calm sea state, although there was some surge within the moonpool.

The battery platform was lowered at ~3500 ft/hr using the logging line, and, at 0830 hr, the assembly landed in the reentry cone. Within 10 min, a portable command unit was used to send a 10-kHz acoustic signal to the release system. After recovering the logging line and the remaining deployment bridle equipped with acoustic releases, the VIT camera was deployed. At 1145 hr we verified that the battery platform had indeed been placed exactly in position as planned. All cables and surface gear appeared to be in good condition, undamaged by the deployment process.

It took about 1 hr to actually release the J-type running tool from the riser, keeping the entire drill crew and science party on edge. At 1245 hr on 28 July, while working the tool through the neutral point and with ~200 A torque, the running tool abruptly released from the riser/hanger. This completed the instrument installation for Hole 1150D.

During the pipe trip to the rig floor, both positioning beacons were released and recovered aboard, the rig floor was secured for transit, and at 1900 hr on 28 July the ship got under way for Site 1151.

Weather

The weather was quite variable during operations in Hole 1150B. At no time was the operation halted because of weather, though conditions did deteriorate markedly during the passage of a low-pressure cell northwest of the drilling location. We began to experience the effects of one low-pressure cell on the afternoon of 30 June, which continued through midday on 1 July. At its worst this gale brought sustained winds of 42 kt gusting to 56 kt, 28-ft seas on 7-s periods, and 30-ft swells on 7- to 8-s periods. The maximum roll, pitch, and heave experienced was 5°, 4°, and 9 ft, respectively.

Weather while drilling Hole 1150C was moderate and did not influence operations. The climate was characterized by frequent fog, overcast skies, frequent rain showers, and cool temperatures.

Weather and sea state were both excellent during operations at Site 1150D. The concern that a tropical depression was going to cross the site before installation of the instrument string influenced us to head to port earlier than would have been ideal. The storm appeared to dissipate as it neared the site, though we have no idea what its final effect on the site was since we were in Yokohama then.

Transit to Site 1151

The 26-nmi distance between Site 1150 and Site 1151 (JT-2L) was covered in 2.8 hr at an average speed of 9.3 kt. The primary positioning beacon was deployed at 2200 hr on 28 July. The BHA was assembled, core barrels spaced out for RCB coring, and the pipe was tripped to the seafloor. The depth estimated from the precision depth recorder (PDR) for this site was 2202.4 m; however, we determined our actual rig floor adjusted seafloor depth by using the VIT subsea camera to visually observe the bit tag the seafloor.

Hole 1151A

Hole 1151A was spudded at 0445 hr on 29 June 1999 at a depth of 2182.2 m (2193.7 mbrf). Because this was to be a reentry site, we conducted a jet-in test to 78.0 mbsf as our first operation. Because the RCB coring system was unlikely to recover much quantity or quality core in the upper sediments, we decided to conserve valuable time by initiating continuous RCB coring at the base of the jet-in hole rather than pulling back to the seafloor and starting a new hole. The first barrel recovered was considered a wash barrel (1W) because of the extended interval of advance.

The wash barrel was checked with the handheld hydrogen sulfide (H_2S) monitor, and it registered 4 ppm H_2S gas. This core was left on the catwalk after splitting until it had degassed. H_2S gas was not detected in any of the subsequent cores. Methane varied from 3711 to 61,526 ppmv and ethane from 1.4 to 13.4 ppmv; both were similar to levels observed at Site 1150. The lowest C_1/C_2 ratio was 3374 and no higher hydrocarbons were detected.

RCB coring in Hole 1151A began with Core 2R at a depth of 78.0 mbsf and continued through Core 109R to a depth of 1113.6 mbsf. Of the 1035.6 m cored, 707.57 m, or 68.3%, was recovered (Table 1). Recovery was highly variable ranging from 0% to 102%. The average ROP for the cored interval was 61.3 m/hr, which is exceptionally high. Even at depth, the ROP was quite rapid with the last 48.3 m of hole advancing at a rate of 32.2 m/hr.

Coring was halted at that point because the formation was considered hard enough for a successful instrument emplacement, which was planned for Hole 1151B. Wireline logging was not conducted in this hole because all remaining time was to be used for the primary leg objective of installing the second instrument string

At 1130 hr on 2 August we began pulling the pipe to a depth of 600.0 mbsf and rigged the circulating head for setting a cement plug. The hole plugging operation was finished at 1345 hr on 2 August after displacing a 15-bbl plug of 15.8 lb/gal cement into the hole. With the cementing operation completed, we continued to pull out of the hole clearing the seafloor at 1430 hr. The bit was back at the rig floor by 1745 hr on 2 August, officially ending Hole 1151A.

Hole 1151B

Reentry Cone and 16-in Casing String Installation

Preparations began immediately for making up the 16-in casing string/reentry cone assembly. While this was happening, we offset the ship 60 m to the west. At 1900 hr, the reentry cone was moved onto the moonpool doors and preparations began for running the 6 joints (73.7 m) of 16-in casing. Within 4.75 hr, the entire casing operation was completed. This included welding all casing couplings, making up the 16-in casing hanger, engaging the Dril-Quip running tool, lowering the casing into the reentry cone and verifying latch-in, disengaging the running tool, making up the stinger assembly and remaining BHA components, and reengaging the running tool. At 2345 hr on 2 August, we began tripping the drill string to the seafloor with its 30,000-lb load.

At 0300 hr on 3 August, we spudded Hole 1151B as the casing shoe tagged the seafloor at 2181.6 m (2193.7 mbrf). The jetting process took 10.5 hr (at an average rate of 7.3 m/hr), and at 1330 hr that same day we landed the reentry cone at the seafloor with the casing shoe positioned at 76.3 mbsf.

While recovering the VIT camera, we began to trip the drill string back to the rig floor to change out the jet nozzles in preparation for drilling the 14¾-in hole. By 2045 hr on 3 August, the ship and drill string were positioned for reentry. After only 15 min of maneuvering time, Hole 1151B was reentered for the first time at 2100 hr.

It took 29.5 hr to drill the 14¾-in diameter hole to a depth of 1081.3 mbsf, completing the drilling at 0315 hr on 5 August. A 34.1 m/hr net ROP was achieved. There were no mud sweeps pumped while drilling the hole. At TD we circulated a 30-bbl sepiolite mud pill out of the hole and then made a wiper trip to 76.3 mbsf. The trip up and back did not identify any trouble spots in the hole. On bottom we found ~12 m of fill that was circulated out of the hole while pumping a 50-bbl sepiolite mud sweep. The hole was displaced with an additional 400 bbl of sepiolite, and the drill string was recovered back to the ship. The reentry cone was cleared at 1215 hr on 5 August and the bit was back at the rig floor by 1500 hr.

The 10¾-in Casing String

The casing shoe joint, 79 joints (1065.8 m) of 10¾-in casing, and casing hanger were assembled in just over 7 hr. We lowered the 10¾-in casing to just above the seafloor and after 30 min of positioning the ship Hole 1151B was reentered for the second time. The casing was run to 1023.3 m without resistance. The top drive was picked up and the remaining casing was lowered into the hole, placing the bottom of the casing string at 1068.2 mbsf. This is the longest casing string set in open hole (991.9 m of open hole) in the operation history of DSDP and ODP. Because of the excellent hole conditions, the casing slid into the hole with ease, making it also one of the fastest casing operations. After making up the cementing swivel we landed the 10¾-in casing hanger at 0615 hr on 6 August. Latch-in was verified with 15,000 lb of overpull.

We displaced 50 bbl of 15.8 lb/gal cement to bottom using the rig pumps, but there was no indication that the cement dart had properly landed or that the wiper plug sleeve had sheared. We overdisplaced the cement by a few barrels and then checked for back flow verifying that the check valve in the cementing shoe was holding. After releasing the running tool from the reentry cone, it was clear that the casing wiper plug was still attached to the launching sub. Further investigation of the cementing manifold verified that the dart had hung up in the sub and not released. We offset the ship 50 m and then pumped the cementing dart wiping the drill string and expelling the wiper plug assembly at the seafloor.The drill string was then tripped back to the drill ship clearing the rotary table by 1500 hr on 6 August

The 9-7/8-in drilling assembly was assembled and run to bottom. Within 45 min of positioning the ship, the third reentry of Hole 1151B was made at 1930 hr on 6 August. The bit was run to bottom, and we tagged the cementing shoe at 1068.3 mbsf. Without the rubber wiper plug and dart in the hole, it only took an hour to drill out the cementing shoe and cement. By 0145 hr on 7 August we had drilled the 9-7/8-in hole to a TD of 1113.0 mbsf. The hole was swept with 20 bbl of sepiolite mud and a wiper trip was made to the 10¾-in casing shoe and back. No problems were experienced with the wiper trip and, once back on bottom, another 20-bbl sepiolite mud sweep was circulated out of the hole. After displacing the hole with an additional 30 bbl of sepiolite, the drill string was recovered back to the ship. The reentry cone was cleared at 0715 hr, and at 1030 hr on 7 August the bit was back at the rig floor.

Installation of the Borehole Instruments

Deployment of the instrumentation string went smoothly and even more efficiently than in Hole 1150D. After having run the instrument package, strapping/taping the cables, making up 93 joints (1082.4 m) of 4½-in casing, making up the riser/hanger, and installing MEG, it was time to conduct the final instrument checks. Much to our dismay, only three of the four instruments responded correctly. One of the seismometers was not functioning properly. After removing MEG, we isolated the problem in MEG rather than the downhole instrument package or cabling. Within 3.75 hr the problem had been identified, corrected, and MEG mounted once again on the riser/hanger.

The trip to bottom was interrupted only to deploy the VIT sleeve and test it over the riser/hanger. The VIT camera was then positioned above the hanger and followed the drill string to bottom. By 2130 hr on 8 August, after maneuvering the ship for 30 min, Hole 1151B was reentered for the forth and final time. The hanger landed at 0100 hr on 9 August placing the end of the cementing stinger at a depth of 1098.6 mbsf and was cemented into the hole with 80 bbl of 15.8 lb/gal cement.

Battery Pack Installation

The battery frame halves were moved onto the moonpool doors, and preparations began on the assembly and rigging of the battery platform at 0315 hr on 9 August. At 0645 hr, the battery frame was deployed through the moonpool on the logging line and run to bottom at ~3500 ft/hr. The frame landed in the reentry cone at 0900 hr and was immediately released, using the same acoustic release system as was used at Site 1150. The logging line was recovered and the VIT deployed to inspect the installation. At 1145 hr, we determined that the battery frame was resting in the correct position around the riser/hanger. The J-type running tool was released and the drill string and VIT camera were both pulled out of the hole. The J-tool cleared the rig floor at 1745 hr on 9 August completing Hole 1151B and ending the second successful instrument emplacement operation.

Hole 1151C

The running tool and associated subs were disassembled and the APC/XCB coring BHA was assembled while the ship was offset 200 m to the south of Hole 1151A. Bathymetric data indicated the seafloor was about 10 m shallower than at Holes 1151A and 1151B, and a PDR reading that indicated the seafloor depth was about 6 m shallower. Based on this information, the bit was placed at a depth of 2179.0 m. Hole 1151C was spudded with the APC coring system at 0045 hr on 10 August, establishing a seafloor depth of 2174.2 m (2186.3 mbrf), about 8 m shallower than at Holes 1151A and 1151B.

APC coring continued through Core 11H to a depth of 97.2 mbsf. Nonmagnetic core barrels were run intermittently with the standard alloy steel barrels to evaluate the effectiveness of nonmagnetic components relative to the magnetic overprint seen in the cores. Coring was halted after experiencing an overpull of 70,000 lb on Core 11H. A single Adara temperature measurement was taken on Core 4H at a depth 30.7 mbsf. Because overpull on that core was 40,000 lb, we decided to abandon further Adara measurements so as not to risk possible loss of the hole or equipment. Core orientation was also begun with Core 4H. The drill string was pulled clear of the seafloor, and Hole 1151C was officially ended at 0945 hr. Of the 97.2 m penetrated with the APC, 101.75 m (104.7%) of core was recovered.

There were no hydrocarbon problems associated with this hole, though H_2S gas was measured in Core 4H at 20 ppm. Readings for all other cores never exceeded 4 ppm.

While coring operations were under way, a helicopter chartered through the Royal Japanese Helicopter Service landed at 0815 hr on 10 August. The following personnel came aboard for the day. Kim Cheh (U.S. congressional staff), James Henry Hall and Edward Kloth (American Embassy, Tokyo), Timothy Clancy (National Science Foundation), Michael Woods (Pittsburgh *Post Gazette*), and Jeff Fox (TAMU). The helicopter departed at 1500 hr with all passengers except for Michael Woods, who stayed aboard until the Yokohama port call.

Hole 1151D

With the drill string clear of the seafloor, the ship was offset 15 m further to the south, and Hole 1151D was spudded with the APC at 1030 hr on 10 August. We continued the nonmagnetic core barrel component evaluation on this hole. A calculated seafloor depth of 2179.9 m (2184.0 mbrf) was established with the first APC barrel which was shot 3 m lower to stagger the core breaks. APC coring continued through Core 10H to a depth of 93.0 mbsf. Cores 4H through 10H were oriented with the tensor tool. Overall, APC coring in this hole netted a recovery of 96.19 m, or 103.4%, of the formation cored.

Drilling resumed from 93.0 mbsf in Hole 1151D using an XCB center bit assembly. At 1800 hr on 11 August we terminated the drilling operation at a depth of 3058.4 m, or 874.4 mbsf. After circulating a 40-bbl bentonite gel mud sweep out of the hole, the top drive was set back and we pulled the drill string to a logging depth of 100.4 mbsf.

At 2100 hr on 11 August, we installed the logging sheaves and began rigging up for wireline logging. The first tool string consisted of the FMS and the Digital Sonic (FMS-DSI) tools. This string was deployed to TD of 874.0 mbsf. After logging up to the bit, a second pass with the FMS-sonic was made, again reaching TD. The second tool string consisted of the triple combo, which also reached TD. By 1515 hr, after 18.25 hr of logging, all tools were out of the hole and the sheaves were rigged down.

The drill string was lowered to TD and the hole was displaced with 260 bbl of barite-weighted (10.5 lb/gal) mud. The string was then recovered back to the drillship. The bit cleared the seafloor at 1830 hr, and the positioning beacon was released and recovered aboard at 1915 hr on 12 August. At 2330 hr on 12 August, the last thruster was secured, and we were under way for the transit to Yokohama, Japan.

Transit to Yokohama, Japan

Almost immediately after departing Site 1151, the transit propulsion motor overheated because of a water cooling problem. Because the propulsion motors are coupled, we had to take a second propulsion motor off line. An opposing current further slowed our overall speed for a good portion of the trip, though we still managed to maintain an average speed of 8.6 kt over the 346 nmi distance. The bay pilot came aboard at 1400 hr, the harbor pilot came aboard at 1540 hr, and the vessel was tied up with the first line ashore at 1615 hr on 14 August 1999. This officially ended Leg 186.

Weather

Weather on-site and during transits was exceptionally good. Calm seas, scattered clouds, and a gentle wind typified each day. A southerly swell generated some heave, but this rarely exceeded 0.6 m.