OCEAN DRILLING PROGRAM

LEG 191 SCIENTIFIC PROSPECTUS

NORTHWEST PACIFIC SEISMIC OBSERVATORY AND HAMMER DRILL ENGINEERING TESTS

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This Scientific Prospectus is based on precruise JOIDES panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Manager that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Science and Operations Committees (successors to the Planning Committee) and the Pollution Prevention and Safety Panel.

Technical Editors: Karen K. Graber and Susan Nessler

ABSTRACT

Ocean Drilling Program Leg 191 consists of two parts: (1) a science segment devoted to drilling and casing a hole on the northwest Pacific abyssal seafloor (Site WP-2) coupled with the installation of a broadband seismometer for a long-term sub-seafloor borehole observatory and (2) engineering tests of the hard rock reentry system (HRRS) and other equipment. The seismic observatory is an important component of the International Ocean Network seismometer net. By filling a large gap in the global station grid, it will help increase the resolution of global tomographic studies, which have revolutionized understanding of mantle dynamics and structure. Moreover, it will allow more precise studies of the seismic structure of old Pacific Ocean crust and lithosphere, as well as better resolution of earthquake locations and mechanisms in the northwest Pacific subduction zone. Approximately 400 m of sediments and 100 m of basalt will be cored at Site WP-2. Studies of these cores will add to existing knowledge of Cretaceous Pacific mid-ocean ridge basalt chemistry, construction of the ocean crust, paleolatitude, the age of magnetic lineations, basalt physical properties, and the deep biosphere. Engineering tests will be conducted to test the performance of hammers and bits for the HRRS that will eventually allow hard-rock spudding of holes at mid-ocean ridges and other locales where holes must be started on hard outcrops. The hammer tests are proposed for Site SR-1, a bare basalt outcrop atop Shatsky Rise. Engineering goals may also include testing of the Hydrate Autoclave Coring Equipment System.

INTRODUCTION

Tomographic studies using earthquake waves propagating through the Earth's interior have revolutionized our understanding of mantle structure and dynamics. The greatest problem in improving such tomographic models is the uneven distribution of seismic stations, especially the lack of stations in large expanses of ocean such as the Pacific. The International Ocean Network (ION) project, an international consortium of seismologists, has identified "gaps" in the global seismic observation network and is attempting to install digital seismometers in those locations. One of the highest ION priorities is to install a station beneath the deep seafloor of the northwest Pacific (Fig. 1).

Site WP-2, situated in the Northwestern Pacific Basin (Figs. 1, 2), is slated to become a long-term borehole seismic observatory, where it will be bounded by the Petropavlosk (PET) station (the station is beyond the boundaries of Fig. 1A but is located at 53.0235°N and 145.7430°E) to the north, by many Japanese stations to the west, by Minami-Torishima (MCSJ) Island station to the south (Fig. 1A), and by the proposed Midway Island station to the east. Owing to its location, this site will provide unique seismic observations from the seaward side of the Japan Trench (Fig. 2). Unlike other existing (Sites 1150 and 1151; Suyehiro, Sacks, Acton, et al., in press) and planned (Site WP-1) oceanic borehole observatories, there are no nearby coaxial transoceanic telephone cables to utilize for data recovery and power, so the Site WP-2 installation is designed as a stand-alone system with its own batteries and recorder. Thus, once instruments are installed in the hole, they must be serviced for data analyses, distribution, and archiving. This will be done under the auspices of an ongoing national program within Japan (Ocean Hemisphere Network Project). Initially, power will be supplied to the observatory by a battery pack, and data will be retrieved by a remotely operated vehicle (ROV; Fig. 3). The data will eventually become accessible worldwide through the Internet. Although this means data recovery will be costly and the data will not be available in real time, the scientific importance of the site to the ION concept makes this worthwhile.

Site WP-2 is also important because it will provide samples representative of the Cretaceous crust of the northwest Pacific. Results from this site will augment those from Leg 185, which characterized material being subducted into the Mariana and Izu-Bonin Trenches to better understand geochemical fluxes at convergent plate boundaries (Plank, Ludden, Escutia, et al., in press). Results from this site will also add to our knowledge of Pacific crustal structure, geochemistry, plate tectonics, magnetic lineations, sedimentation, and microbiology.

Site SR-1, atop the ocean plateau known as Shatsky Rise (Figs. 2, 4), was chosen for engineering tests because it offers a bare basalt outcrop at a relatively shallow depth in a convenient location. A basalt outcrop is needed because one of the main purposes of the hammer drill system is to emplace a casing string directly into such rocks. If the hard rock reenty system (HRRS) tests are successful, the Ocean Drilling Program (ODP) will be able to begin holes in geologic environments that have previously frustrated coring attempts. If basalts are recovered during the engineering tests from Shatsky Rise, they will provide valuable data about the age and composition of that large igneous province (LIP).

Tests of the technical feasibility and modes of operation of the HYACE (Hydrate Autoclave Coring Equipment) System are also scheduled at Shatsky Rise. The tests will be conducted at Site SR-3, tenatively located near (~15-20 km) Site SR-1, where the oceanic plateau is covered with thick (~900 m) sediments. Tests of the HYACE tools during Leg 191 are dependent on ODP Site Survey Panel (SSP) site approval and successful results from land tests.

BACKGROUND

Borehole Seismic Observatories

The scientific importance of establishing long-term geophysical stations at deep ocean sites has been acknowledged by the earth science and ODP communities and is expressed in various reports (JOI-ESF, 1987; Purdy and Dziewonski, 1988; JOI/USSAC, 1994; Montagner and Lancelot, 1995; Ocean Drilling Program Long Range Plan, 1996). The objective is to understand the processes driving Earth's dynamical systems from a global to a regional scale by imaging the Earth’s interior with seismic waves. Unfortunately, few seismometers are located on the 71% of the Earth's surface covered by oceans; this makes high-resolution imaging of some parts of the mantle impossible. Many new ocean-bottom sensors, whose locations will be carefully selected to maximize results (Fig. 1), are needed to accomplish the goals of the international geoscience programs that rely on earthquake data. Aside from Site WP-2, which will be drilled and instrumented during Leg 191, several other western Pacific sites have been selected for instrumentation. Observatories at Sites 1150 and 1151, on the inner wall of the Japan Trench, were installed during Leg 186 (Suyehiro, Sacks, Acton, et al., in press). In addition, Site WP-1, located in the Philippine Sea, is scheduled to be drilled and instrumented during Leg 195. The instrumentation for these enumerated long-term borehole observatories has been developed by an ongoing national program of Ocean Hemisphere Network Project (OHP) within Japan. The data from these observatories will eventually become accessible worldwide through the OHP Data Center.

Aside from plugging an important gap in the global seismic array, the Site WP-2 observatory will produce high-quality digital seismic data. Tests with other borehole seismometers show that the noise level for oceanic borehole instruments is much less than most land counterparts (e g., Stephen et al., 1999; Fig. 5). Recent studies that exploit high-quality digital seismic data obtained on land have shown exciting new phenomena on mantle flows. In the western Pacific, for example, Tanimoto (1988) showed that there exists a strong l = 2 (angular order) pattern of deep (>550 km) high-velocity anomalies from waveform inversions of *R2*, *G1*, *G2*, *X1*, and *X2* surface waves. This suggests a complex interaction of subducting slabs with the surrounding mantle, including the 670-km discontinuity in the region (Tanimoto, 1988). However, because of sparse global coverage by existing seismic stations, current seismic wave resolution is insufficient to image the actual interaction of the plates with the mantle. More recent studies show the potential of new mantle-imaging techniques, with finer scale images having been obtained in certain locations where high-quality data are dense. Two examples are the deep extension of velocity anomaly beneath ridges (Zhang and Tanimoto, 1992; Su et al., 1992), and the fate of subducted plates at 670-km discontinuity (van der Hilst et al., 1991; Fukao et al., 1992). These detailed conclusions result from the extraction of more information from existing seismograms. Such studies are limited by sparse data coverage, a barrier that new ocean-bottom stations can help break.

Seismic Observatory Design

The WP-2 observatory is to be equipped with two broadband seismometers (Guralp CMG-1) attached to a pipe hung from the reentry cone (Figs. 6, 7), situating the seismometers near the bottom of the drilled hole. Installation of two identical seismometers is a step designed to add redundancy to the observatory. Digital seismic signals from the seismometers are passed uphole by wires using RS-422 Serial Interface Protocol to be recorded in a data control box of multiple-access expandable gateway (MEG) data. The observatory will be continuously powered for about three years by four units of six-Watt batteries (SWB1200, Kornsburg Simrad) attached to a frame that sits on the reentry cone (Figs. 6, 7).

In September 1989, a feedback-type accelerometer capsule was installed in Hole 794D in the Japan Sea during Leg 128 (Ingle et al., 1990; Suyehiro et al., 1992, 1995). The instrument recorded a teleseismic event (body-wave magnitude [Mb] = 5.4 at ~4000-km epicentral distance) that clearly showed a surface wave dispersion train (Kanazawa et al., 1992). In May 1992, a comparison of seafloor and borehole (Hole 396B) sensors was made using a deep-sea submersible for installation and recovery (Montagner et al., 1994). Although at this stage there is no consensus as to how we should establish seafloor seismic observatories, it is becoming clearer that oceans can provide low-noise environments. In August 1999, a seismometer and a strainmeter were cemented at Sites 1150 and 1151 in the deep-sea terrace of the Japan Trench during Leg 186 (Suyehiro, Sacks, Acton et al., in press). The cementing was done to stop fluid motion around the sensors to make the noise level lower and to achieve highly sensitive broadband seismic observations. Because it is imperative that no fluid motion occurs around the broadband seismometers at proposed Site WP-2, the sensors will be cemented during Leg 191 as well. Once instruments are installed in the hole, an ROV will activate the observatory by handling underwater mateable connectors (UMC). In November 2000, Kaiko, an ROV (Fig. 3) designed to operate in water depths up to 10,000 m by the Japanese Agency of Marine Science and Technology Center (JAMSTEC), is scheduled to visit Site WP-2 to begin observations.

Hard-Rock Reentry System

The HRRS is being developed to provide ODP with the ability to establish a reentry casing on sloped and fractured hard-rock outcrops on the seafloor. The system uses a Model 260 downhole fluid hammer developed by SDS Digger Corporation of Canning Vale, Western Australia, along with a bit to advance the hole while casing is installed simultaneously. Presently, 13-3/8-in casing is being used in the prototype development program. The rough sea states encountered during Leg 179 tests demonstrated the need for more robust bits that could withstand the torque, lateral pivoting (i.e., rocking) movements, and weight on bit fluctuations experienced during this first offshore trial. All three of these parameters contributed to the premature failure of the bits tested on that leg.

The next generation of bits developed for the HRRS testing program during Leg 191 were all tested onshore. Corrections and improvements to the bits were made based on the observations of these land tests. Despite the limited onshore testing, the next generation of bits appear much superior to those used during Leg 179.

There are five primary objectives for testing the HRRS during Leg 191. These goals include:

1. Characterization of the Model 260 fluid hammer operating parameters (i.e., flow rates, pump pressures, and weight on bits).

2. Characterization of the hammer-drill and bit-spudding capabilities without casing.

3. Testing of the entire HRRS system by drilling in 20+ m of 13-3/8-in casing in a fractured hard-rock environment with little or no overlying sediment or talus and with little or no slope.

4. Testing of the entire HRRS system by drilling in 20+ m of 13-3/8-in casing in a sloped fractured hard-rock environment with little or no overlying sediment or talus.

5. Testing of the entire HRRS system by drilling in 20+ m of 13-3/8-in casing in a sloped fractured hard-rock environment with overlying sediment or talus.

Two new bit types have been developed for testing on Leg 191; these include an underreamer and ring-type bit. There are two different versions of the underreamer bits that will be tested as well as two versions of the ring-type bits. Underreamer bits have retractable arms to open a larger hole than the pilot bit they are mated onto. Ring bits are composed of two major parts that include a casing shoe and pilot bit. The casing shoe has a ring of tungsten carbide buttons that works in tandem with the pilot bit. However, unlike the underreamer bits, which are totally recovered at the completion of the installation process, the casing shoe is left in the hole on the bottom of the casing after the pilot bit and hammer are withdrawn.

Geologic Setting

The Leg 191 sites are located in the northwest Pacific Ocean east of Japan. The Mesozoic M-series magnetic lineations in the region (Fig. 4) show that the lithosphere in this area was formed in Late Jurassic to Early Cretaceous time (Larson and Chase, 1972; Sager et al., 1988; Nakanishi et al., 1989). Paleomagnetic studies indicate that this part of the Pacific plate formed ~30° south of its present position, near or slightly north of the equator (Larson and Lowrie, 1975; Larson et al., 1992). The magnetic bight created by the intersection of "Japanese" and "Hawaiian" lineations implies that the spreading ridges that formed the lithosphere met at a triple junction that defined the northwest corner of the growing Pacific plate (Larson and Chase, 1972; Sager et al., 1988). Shatsky Rise, an oceanic plateau with an area about the same as California, began to form in latest Jurassic time coincident with a major reorganization of the spreading ridges and triple junction (Sager et al., 1988; Nakanishi et al., 1989). Evidently the plateau formed rapidly at first, perhaps from a nascent mantle "plume head" (Sager and Han, 1993; Sager et al., 1999). The plume seems to have captured the triple junction and kept it at the plume location until the plume waned just before the Cretaceous Quiet Period (Nakanishi et al., 1999).

The history of the northwest Pacific plate since the formation of the lithosphere and Shatsky Rise seems to be one of northward drift and low sedimentation. Sediments atop Shatsky Rise are as thick as 1.2 km in thickness, because the rise top remained above the carbonate compensation depth and thick pelagic carbonate sediments accumulated (Sliter and Brown, 1993). Sediments in the adjacent abyssal basins are thin, typically 300-500 m thick (Ludwig and Houtz, 1979), owing to seafloor depth and distance from major sediment sources.

SCIENTIFIC OBJECTIVES

Structure of the Pacific Ocean Plate and Underlying Mantle

There are many bathymetric highs in the northwestern Pacific (e.g., Shatsky Rise and Hess Rise) whose roots are poorly known. Body wave studies have not been able to determine the thickness of the plate, although large-scale anisotropy and lateral heterogeneity have been detected (e.g., Shimamura et al., 1983). Accumulation of broadband seismic wave data, including information of wave paths through the basin part of the Pacific plate, is needed to obtain a detailed understanding of the structure of the lithosphere and asthenosphere.

Important Component of ION

A global seismographic network was envisioned by the Federation of Digital Seismographic Networks to achieve a homogeneous coverage of the Earth’s surface with at least one station per 2000 km in the northwestern Pacific area (Fig.1). Thus, the Site WP-2 seismic observatory will provide invaluable data, obtainable in no other fashion, for global seismology. Data from this observatory will help revolutionize studies of global earth structure and upper mantle dynamics by providing higher resolution of mantle and lithosphere structures in areas now poorly imaged. In addition, this observatory will provide data from the seaward side of the northwest Pacific trenches, giving greater accuracy and resolution to earthquake locations and source mechanisms.

MORB Chemistry and Ocean Crust Formation

Drilling at Site WP-2 will core ~100 m of the upper basaltic crust, making it one of a small number of sites at which significant penetration of the ocean crust has been achieved. Geochemical and isotopic analyses of the basalt samples will add to knowledge of mid-ocean ridge basalt (MORB) chemistry and emplacement (e.g., Hart, 1988; Janney and Castillo, 1996, 1997). This site may display the influence of the mantle plume assumed to have formed Shatsky Rise, as is postulated for Site 304 (DSDP Leg 32; Janney and Castillo, 1996, 1997). In addition, planned Formation MicroScanner (FMS) and ultrasonic borehole imager (UBI) logs (see "Logging Plan" section) will image the borehole walls, allowing geologists a detailed view of upper crust igneous structures. Such data, allied with physical properties, geochemical, and other data collected by cores and logs, can be used to better understand the volcanic structure and emplacement of the crust.

Pacific Plate Paleolatitude and Tectonic Drift

Paleomagnetic measurements of basaltic cores are important because oriented samples are difficult to obtain from the oceans. The basalts record the direction of the magnetic field at the time the basalts were emplaced and can be used to infer the paleolatitude of the site (e.g., Cox and Gordon, 1984). Although it is unlikely that enough flow units will be cored at Site WP-2 to average secular variation adequately, the results are useful in combination with other Deep Sea Drilling Project (DSDP) and ODP basalt core paleomagnetic data, which can be used to calculate a Cretaceous paleomagnetic pole for the Pacific plate (Cox and Gordon, 1984; Sager and Pringle, 1988).

Age of Anomaly M8

Although widely used for dating the ocean lithosphere, anomalies of the M-series are poorly dated because there are few places where the anomalies have been directly dated (e.g., Gradstein et al., 1994). Site WP-2 is located on Anomaly M8 and may allow radiometric dating of this anomaly, if basalts suitable for dating are recovered.

Microbiology of the Deep Ocean Lithosphere

Recent findings from boreholes suggest that microorganisms can be found buried deep (~900 meters below seafloor [mbsf]) within the lithosphere. Several glass samples recovered during Legs 185 and 187 showed textural evidence for microbial alteration, leaving the intriguing question of whether microbiological activity is still active in volcanic basement. Additionally, there is a major effort to determine community composition by DNA extraction, in situ hybridization, characterization of microbes isolated from enrichment cultures, and culturing of microbes from samples collected during Leg 185 that were maintained at in situ pressure. Drilling at Site WP-2 will give the opportunity to examine samples of old Pacific lithosphere for microorganisms and will allow comparison with measurements made in the vicinity of ODP Leg 185 (Plank, Ludden, Escutia, et al., in press).

Age and Geochemistry of Shatsky Rise

Although numerous holes have been drilled on the southern Shatsky Rise edifice (Texas A&M University [TAMU] Massif), none has recovered basalt. In addition, all dredged samples have been badly altered, so no direct dating of this LIP is available (Sager et al., 1999). Understanding LIP formation has been recognized as an important goal for ODP studies (ODP Long Range Plan, 1996). Isotopic studies of dredged samples suggest that Shatsky Rise has both ridge and plume characteristics (Tejada et al., 1995). If basalt is recovered during the engineering tests planned for Leg 191, it will be the first recovery of such material. Geochemical, isotopic, and radiometric dating of these samples would be invaluable for understanding how this and other ocean plateaus were formed.

PROPOSED SITES

Site WP-2A and Alternate Site WP-2B

Proposed Site WP-2A is situated on flat seafloor at a depth of 5500 m. It lies atop magnetic lineation M8 in the Japanese lineations northwest of Shatsky Rise (Fig. 4; Sager et al., 1999; Nakanishi et al. 1999). The sedimentary section at Site WP-2A is predicted to be 420 m thick based on seismic sections showing a two-way traveltime of 0.5 s to a reflector thought to represent igneous basement (see seismic line in "Site Summary" section). Seismic reflection profiles in the region typically display an upper transparent layer and a strong smooth reflector. Comparison of seismic profiles with DSDP and ODP holes in the region (Site 193 [Creager, Scholl, et al., 1973], Sites 194-197 [Heezen, MacGregor, et al., 1973], Sites 303-304 [Larson, Moberly, et al., 1975], Sites 578-581 [Heath, Burkle, et al., 1985; Duennebier, Stephen, Gettrust, et al., 1987], and Site 1149 [Plank, Ludden, Escutia, et al., in press]) shows that the upper transparent layer consists of mid-Miocene to Pliocene silty radiolarian oozes and clays, with some ash layers from nearby arc volcanoes, that grade downward to pelagic brown clays, often poorly dated because of sparse or absent microfossils. The strong smooth reflector denotes the occurrence of chert and porcellanite within Early Cretaceous pelagic clays. These overlie igneous basement, which is usually recognized in hindsight as a less-prominent reflector 100-200 ms below the top of the cherty layer. Using lithologic and seismic velocity data from nearby DSDP holes (Sites 303, 304, and 581), we infer a sediment column at Site WP-2 consisting of an upper layer (~310 m thick) of silty radiolarian clays and a lower layer (~110 m thick) of cherty clay. The sedimentary section at alternate Site WP-2B (see seismic line in "Site Summary" section), located 9 km to the southeast of Site WP-2A, is similar in thickness.

Site SR-1 and Alternate Site SR-2

Proposed Sites SR-1 and SR-2 (alternate) are located on flat-topped basalt ridges on the southern (TAMU Massif) and central (Ocean Research Institute [ORI] Massif) volcanic edifices of Shatsky Rise (Fig. 4; see seismic line in "Site Summary" section). These ridges were probably formed in the late stages of the eruptions that formed the basaltic edifices (Sager et al., 1999). SR-1 lies at a water depth of ~2075 m, whereas Site SR-2 is at a depth of ~3188 m. The summits of both ridges are inferred to be sediment free using 3.5-kHz records showing a seafloor characterized by strong, hyperbolic reflectors (see seismic lines in "Site Summary" section).

Site SR-3

Proposed Site SR-3 is tentatively located ~15-20 km east of Site SR-1. The sedimentary cover over the oceanic plateau at Site SR-3 is ~900 m thick and consists of Late Cretaceous pelagic clays.

DRILLING STRATEGY

ION Site

The Site WP-2 drilling program consists of drilling two holes (A and B) to characterize the site before installing a reentry cone, casing string, and drilling a third hole (C) in which to install the ION instrument string. Time estimates to accomplish these objectives are estimated to be around 26 days. Drilling Holes A and B will consume ~11 of the 26 days allocated for the ION work. Installation and setting up the reentry cone and casing for Hole C is estimated at 10 days. The remaining five days on site are devoted to the installation of the instrument and battery package (Figs. 6, 7).

Piston coring (advanced hydraulic piston corer [APC]) to refusal (~180 mbsf) will be used in the first hole to ensure the most complete recovery and characterization of the upper sedimentary section. Below that, single extended core barrel (XCB) and rotary core barrel (RCB) coring will be used to drill the remaining sedimentary rock above basaltic basement (~420 mbsf), and an additional 10 m into basement, if possible. Hole B will be washed/drilled down with the RCB to

~380 mbsf. Coring will commence and continue ~100 mbsf into the basaltic basement. A full suite of wireline logging will then be initiated (see "Logging Plan" section).

A reentry cone will then be assembled and lowered to the seafloor with ~60 m of 16-in casing. It will be washed to depth and the reentry cone released on the seafloor. The drill string will then be recovered and a drilling bottom-hole assembly (BHA) made up with a 14-3/4-in tricone bit will be reassembled. Hole C will then be reentered and the hole deepened to ~460 mbsf. The drill string will again be recovered before making up ~445 m of 10-3/4-in casing. The casing string will be lowered to just above the seafloor before approaching the reentry cone. The 10-3/4-in casing will be run to depth and then cemented in place. The drill string will again be recovered before making up the final BHA to drill a 9 7/8-in hole. Because the instrument string should be located in a relatively homogeneous and unfractured zone, the hole is planned to be 100 m in basalt basement. Actual penetration will be decided in the field. This decision will be based on information provided by the cores and wireline logs from Hole B, drilling data provided by the drillers, and the amount of allowable time remaining in the program to complete the leg objectives.

After the hole is drilled to depth and the drill string recovered, the instrument package will be made up in a carrier and then crossed over to 4-1/2-in casing. The instrument package for Leg 191 consists of two seismometers (Fig. 6). Centralizers will be equally spaced on the casing string to keep it centralized within the borehole (Fig. 7). Once lowered into place, the instruments will be cemented in place through the drill string and support tubing. Afterward, the drill string will be disconnected from the 4-1/2-in casing, leaving it at a predetermined height above the reentry cone (Fig. 7). A battery package will then be lowered into the throat of the reentry cone (Fig. 7) before releasing the drill string and recovering it back onto the ship.

Engineering Tests at Shatsky Rise

HRRS

The first objective of the actual drilling plan for the HRRS (Figs. 8, 9) is to familiarize the drillers with how the fluid hammer operates and with the weight on bit requirements for these types of bits. Also, since the fluid hammer operates with very high pressure and flow requirements, it will allow the pumps and other ancillary pieces of equipment to be checked out to ensure that adequate drilling parameters will be maintained during the course of the HRRS work. This will be accomplished by first deploying the fluid hammer with an underreamer bit and without casing. The ring bits must be run with casing and will only be picked up if the hammer can be adequately operated with the flow and pressure generated by the mud pump system.

A number of shallow holes will be made while instructing the drilling crew in the proper drilling technique required for this fluid hammer. The drill string will be round tripped; this bit will most likely be changed to the other type of underreamer bit so that information can be gained as to how it drills compared to the first underreamer bit. A similar number of shallow holes will also be drilled with this bit to establish operating characteristics. After the BHA is recovered, a decision will then be made as to which type or version of bit will be run with the first casing string.

Based on the drilling results of the first two underreamer bits and the sea states, a short length of 13-3/8-in casing (~20 m) will be picked up and mated up to the lower section of HRRS casing running tool. Once assembled, the running tool and casing will be lowered from the rig floor to be supported on the moonpool doors while the hammer and BHA are assembled. When the BHA and upper section of the running tool are assembled, they will be lowered and mated up with the lower section of the running tool.

Once assembled and with space-outs confirmed, the whole casing/BHA will be lowered to the seafloor on drill pipe. The vibration-isolated television (VIT) camera will be deployed to help locate an appropriate location in which to spud. The bit will be placed on the seafloor while the VIT camera is recovered. The casing will then be drilled to depth. Next, the VIT camera will again be deployed to confirm that the casing is in the proper position before installing the free-fall funnel (FFF). When positioning is confirmed, the VIT camera will be recovered and the FFF assembled around the drill string. The FFF will be released and the VIT camera once again deployed to verify proper position of the FFF before releasing the running tool. Upon verification, a dart will be pumped down the drill string to shift a sleeve so that the BHA and pilot bit can be withdrawn from the installed casing. Before recovering the VIT camera, it will be used to survey the site and installed casing.

If all operations have gone as planned, the scenario will be repeated two more times but with progressively longer strings of casing as the comfort level increases and the success of the operation is achieved. The additional lengths of casing might include 35 and 50 m. However, these lengths will be solely dependent upon the success of the previous installation.

Depending upon the amount of time remaining in the HRRS program schedule, a smaller Model 185 fluid hammer will be tested inside one of the installed 13-3/8-in casing strings. The ideal scenario would be to deploy the Model 185 fluid hammer to deepen the 14-3/4-in hole beneath the casing with a 9-7/8-in bit. The 185 fluid hammer has been suggested as the next smaller size fluid hammer that may be used in the HRRS system to install a nested casing string.

HYACE

The gas hydrate autoclave sampling and monitoring system known as the HYACE System, modified at the Technische Universität Berlin with support from the European Commission and from ODP, is also scheduled to be tested during Leg 191, pending SSP approval and the success of land tests. Testing of the HYACE tools (i.e., the autoclave downhole rotary corer and the autoclave percussion corer) has been allotted a maximum of 72 hours at the end of the HRRS tests. Once all the HRRS operations are completed, the ship will be repositioned, and the APC/XCB BHA will be deployed so that the HYACE tools can be deployed. The hole will remain in the sediment section of the formation and will not penetrate more than 300 m.

LOGGING PLAN

The logging program is designed to measure physical properties and hole shape and to determine in situ stress, porosity, and fracture characteristics of the rock and sediment around the hole. These determinations are important for a site as a long-term seismic observatory. The Formation MicroScanner (FMS) will provide a detailed resistivity image of the borehole, including fractures and conductive zones. Temperature logs will be emphasized for identification of permeable zones and inflow/outflow from both drilling-induced and natural fractures in the hole. The spontaneous potential (SP) log will provide in situ measurement of the streaming potential, which is related to electrochemical and electrokinetic changes and pore-water flow in permeable formations. The ultrasonic borehole imager (UBI) will be used to characterize the shape and volume of the borehole in the vicinity of the seismometers. This will significantly improve grouting procedures for the instruments.

At Site WP-2A, we will run the standard triple-combo tool string, the FMS/sonic tool string, and, if time permits, the UBI. The triple combo tool string includes the natural gamma-ray sonde (NGS) to measure natural radioactivity, the accelerator porosity sonde (APS), to measure porosity, the hostile environment lithodensity sonde (HLDS) to measure density, and the dual induction tool (DIT-E), to measure resistivity. The triple combo tool string also measures the spontaneous potential and makes a caliper measurement. The FMS/sonic tool string includes the Formation MicroScanner and the dipole shear sonic imager (DSI), along with a natural gamma-ray tool (NGT). We anticipate that it will take ~33 hr for logging operations (two runs of each tool string) at Site WP-2A.

UNDERWAY GEOPHYSICS

Standard ODP practice is to collect magnetometer and 3.5- and 12-kHz echo-sounder data during transit to each site. Additionally, Leg 191 will likely conduct a short air-gun survey (~6 hr) to ensure that the location of Site WP-2 is on top of a high in the oceanic basement, where the anticipated chert-chalk sequence is thinner.

SAMPLING PLAN

The Sample Distribution, Data Distribution, and Publications Policy is posted at: http://www-odp.tamu.edu/publications/policy.html. The Sample Allocation Committee (SAC), which consists of the two co-chiefs, the staff scientist, the ODP curator onshore, and the curatorial representative on board ship, will work with the entire science party to formulate a formal Leg 191-specific sampling plan for shipboard and postcruise sampling.

During Leg 191, we expect to recover <1 km of sediment, sedimentary rock, and basalt. All sample frequencies and sample volumes taken from the working half of the core must be justified on a scientific basis and will be dependent on core recovery, the full spectrum of other requests, and the cruise objectives. All sample requests must be made on the standard Web sample request form and approved by the SAC. Leg 191 shipboard scientists may expect to obtain as many as 100 samples of no more than 15 cm^3 in size. Additional samples may be obtained upon written request onshore after initial data are analyzed. Depending on the penetration and recovery during Leg 191, the number of samples taken may be increased by the shipboard SAC. For example, studies requiring only small sample volumes (1 cm^3 or less, e.g., for veins, fluid inclusions, etc.) may require >100 samples to characterize a long section of core. The SAC will review the appropriate sampling interval for such studies as the cores are recovered. Samples larger than 15 cm^3 may also be obtained with approval of the SAC. Request for large samples must be specified on the sample request form. Sample requests may be submitted by shore-based investigators as well as the shipboard scientists. Based on sample requests received two months precruise, the SAC will prepare a temporary sampling plan, which will be revised on the ship as needed. Some redundancy of measurement is unavoidable, but minimizing redundancy of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

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

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FIGURE CAPTIONS

Figure 1. **A.** Location map of seismic station coverage in the northwest Pacific. **B**. Location of stations needed in the oceans worldwide. At least five major plates with consuming boundaries interact in the northwest Pacific, causing subduction, back-arc opening, slab collisions, terrane accretion, and island arc development. Solid circles (A) indicate land seismic stations, whereas open circles are current and proposed seafloor borehole observatories. Note that a few borehole stations effectively complement and expand the existing network. M = magnitude. YSS = Yuzhno Sakhalinsk, Russia, 46.9583°N, 142.7610°E; NMR = Nemuro, Japan, 36.1525°N, 145.7430°E; PHN = Pohang, Korea, 36.03°N, 129.36°E; HCH = Hachijo-shima, Japan, Reserved; OGS = Chichi-jima, Japan, 27.0570°N, 142.2030°; MCSJ = Minami-tori-shima, Japan, 24.290°N, 153.978°E; ISG = Ishigaki, Japan, 24.3793°N, 124.2347°E; PATS = Ponsei, Micronesia, 6.8367°N, 158.3125°E; PMG = Port Moresby, Papua New Guinea, -9.41°N, 147.16°E; TGY = Tagaytay, Philippines, 14.10°N, 120.94°E.

Figure 2. Location map showing proposed Leg 191 drill sites (squares) and pre-existing DSDP and ODP sites (circles) in the northwest Pacific.

Figure 3. Photograph of the Japan Marine Science and Technology Center's (JAMSTEC) ROV, the Kaiko. All seafloor assembly electrical connections, the data storage unit, and the data handling and control unit (see Fig. 6A and 6B) can be removed and replaced by such an ROV. The Kaiko is scheduled to visit Site WP-2 in November 2000 to activate the borehole observatory.

Figure 4. Leg 191 drill sites and their tectonic context. Thick lines show magnetic lineations and fracture zones; thin lines show 500-m bathymetry contours (from Sager et al., 1999; Nakanishi et al., 1999).

Figure 5. Noise spectra from the borehole seismometer at Site JT-1 (Leg 186) off Sanriku, Japan (from Suyehiro et al., 1999). The noise level is positioned at a satisfactory level between the High Noise Model and the Low Noise Model. The rise of noise around 0.01 Hz is known to be infragravity wave noise induced from a long-period surface wave in the ocean. At Site WP-2, the borehole seismometer will be installed in the basement so that such serious noise should be sufficiently suppressed. The seismometer in Hole 1150D (Leg 186) has a vertical (V) and two

horizontal components that are perpendicular to each other. The direction of the horizontal components could not be determined during installation of the instrument; therefore, H1 and H2 denote the noise spectra from records of two horizontal components of the seismometer. dB=decibels. m**2 is fortran code for m^2 and m**4 is fortran code for m^4.

Figure 6. A. Schematic block diagram of the seismic observatory components. **B.** Schematic configurations of the instrument package for broadband seismometry. All the equipment in this assembly is accessible to an ROV (remote operating vehicle). Cables from the sensors grouted at ~500 mbsf terminate in a four-way underwater-mateable connector block. The data control unit (MEG [multiple-access expandable gateway]) plugs into this connector block. A single output from the top of this package is coupled (by ROV) to the battery/recorder unit (PAT) installed after the sensors are grouted. A data recording unit (SAM) can be retrieved by an ROV when required. PAT = Power supply access terminal. SAM = storage acquistion module.

Figure 7. Schematic of the seafloor assembly with expected lithologies extrapolated from Leg 185. PAT = Power supply access terminal. SAM = storage acquistion module.

Figure 8. Schematic diagram of the hammer-drill hard-rock reentry system.

Figure 9. Schematic diagram of the hammer-drill system showing bits and casings.

A

B

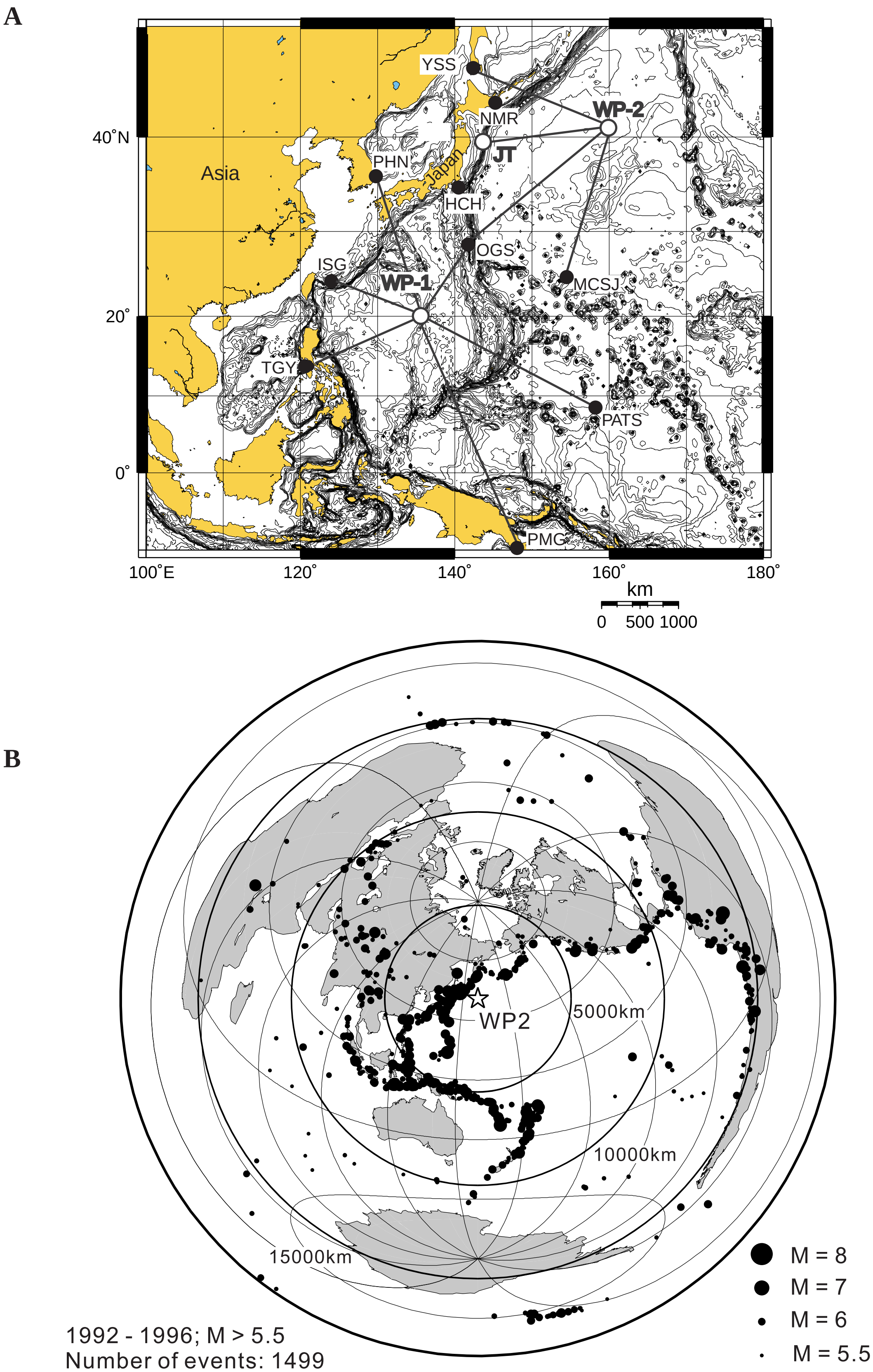

YSS
NMR
WP-2
JT
PHN
Japan
Asia
HCH
OGS
ISG
WP-1
MCSJ
TGY
PATS
PMG
40°N
20°
0°
100°E
120°
140°
160°
180°
km
0 500 1000
WP2
5000km
10000km
15000km
M = 8
M = 7
M = 6
M = 5.5
1992 - 1996; M > 5.5
Number of events: 1499

Figure 1

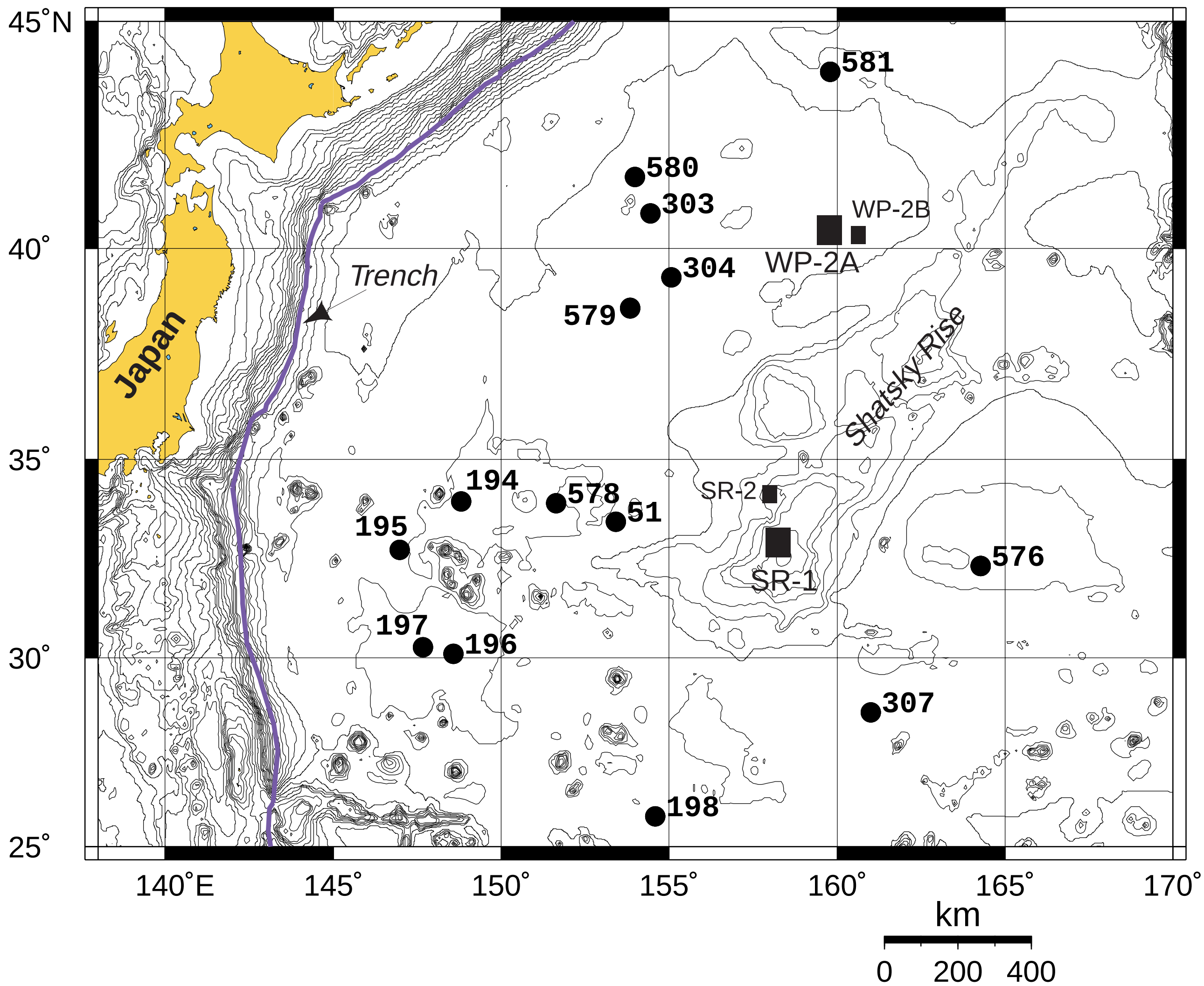

45°N
40°
35°
30°
25°
140°E
145°
150°
155°
160°
165°
170°
Japan
Trench
Shatsky Rise
581
580
303
304
579
WP-2B
WP-2A
194
578
51
195
SR-2
SR-1
576
197
196
307
198
km
0
200
400

Figure 2

Figure 3

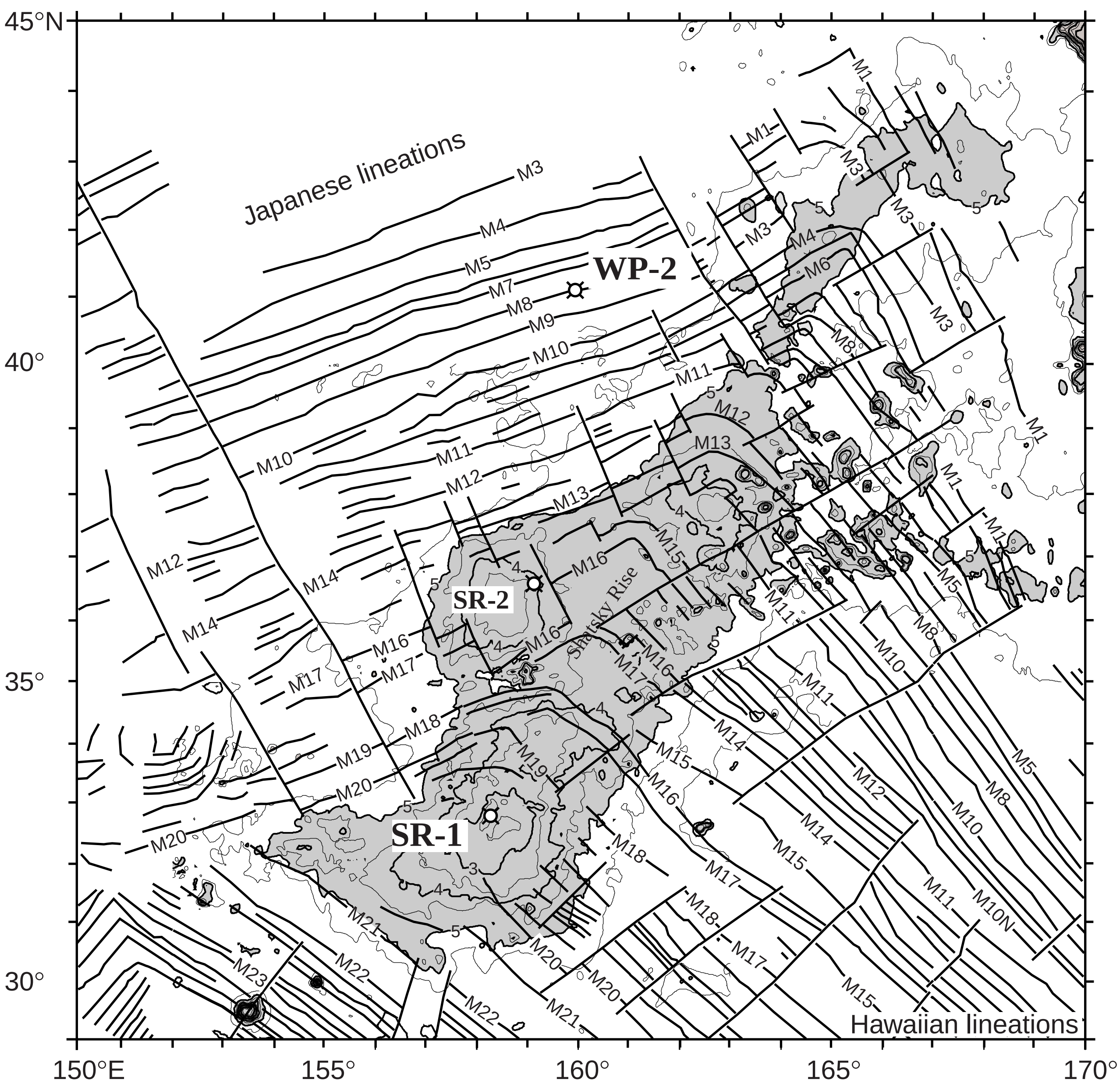

Japanese lineations
Hawaiian lineations
Shatsky Rise
WP-2
SR-2
SR-1
45°N
40°
35°
30°
150°E
155°
160°
165°
170°

Figure 4

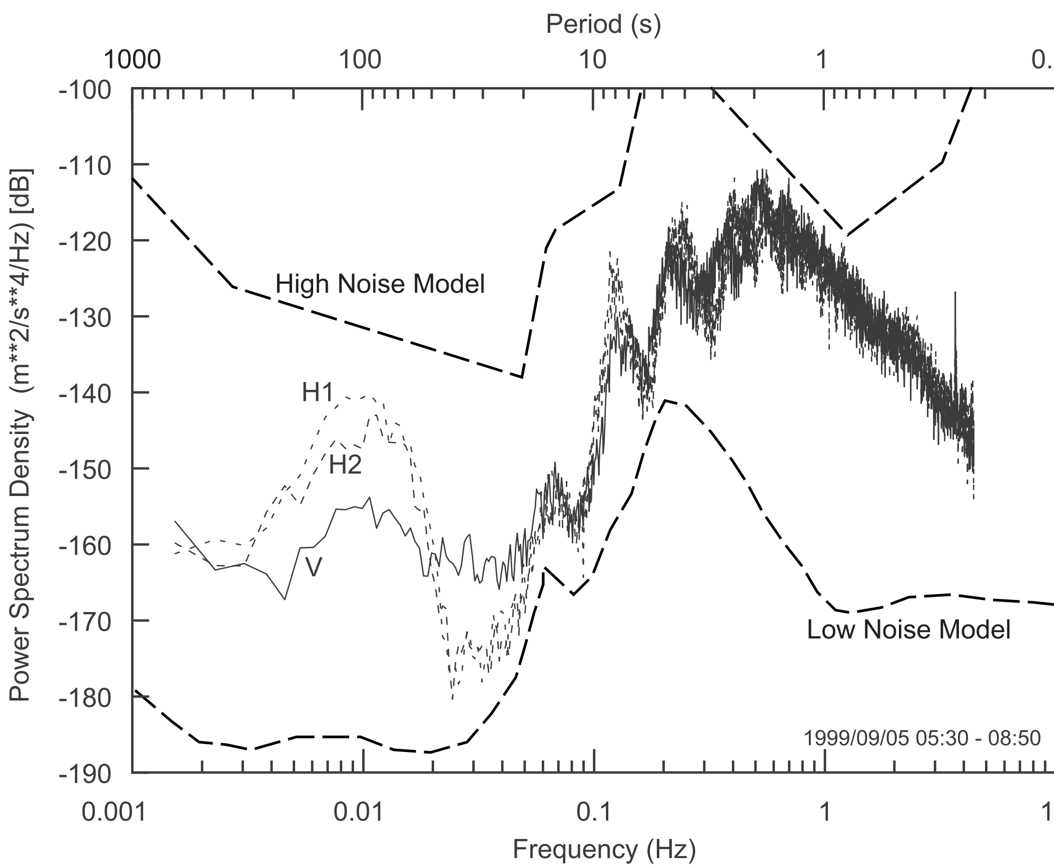

Period (s)
1000
100
10
1
0.1
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
Power Spectrum Density (m**2/s**4/Hz) [dB]
High Noise Model
H1
H2
V
Low Noise Model
1999/09/05 05:30 - 08:50
0.001
0.01
0.1
1
10
Frequency (Hz)

Figure 5

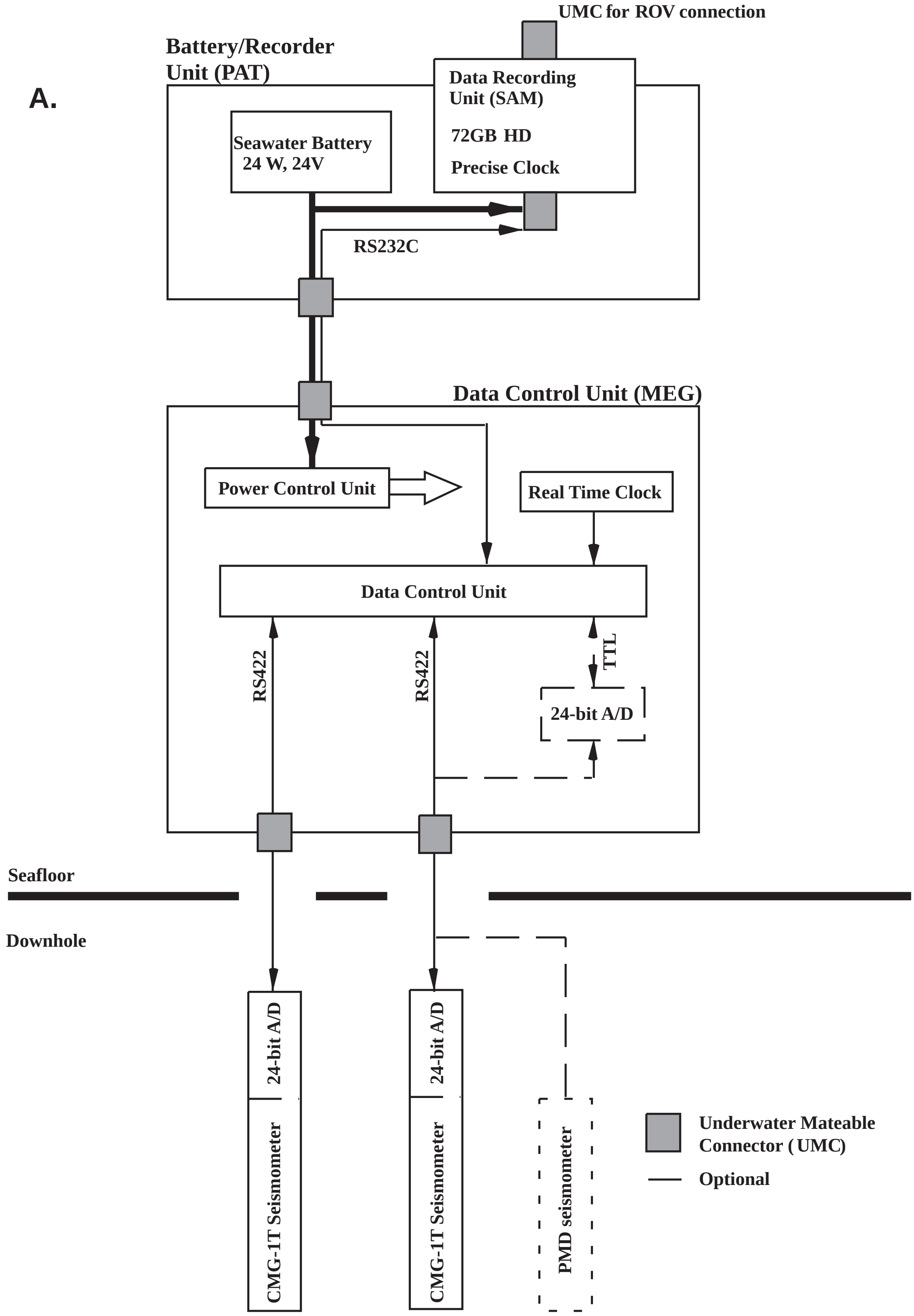

UMC for ROV connection
Battery/Recorder
Unit (PAT)
A.
Data Recording
Unit (SAM)
72GB HD
Precise Clock
Seawater Battery
24 W, 24V
RS232C
Data Control Unit (MEG)
Power Control Unit
Real Time Clock
Data Control Unit
RS422
RS422
TTL
24-bit A/D
Seafloor
Downhole
24-bit A/D
CMG-1T Seismometer
24-bit A/D
CMG-1T Seismometer
PMD seismometer
Underwater Mateable
Connector (UMC)
Optional

Figure 6

B.

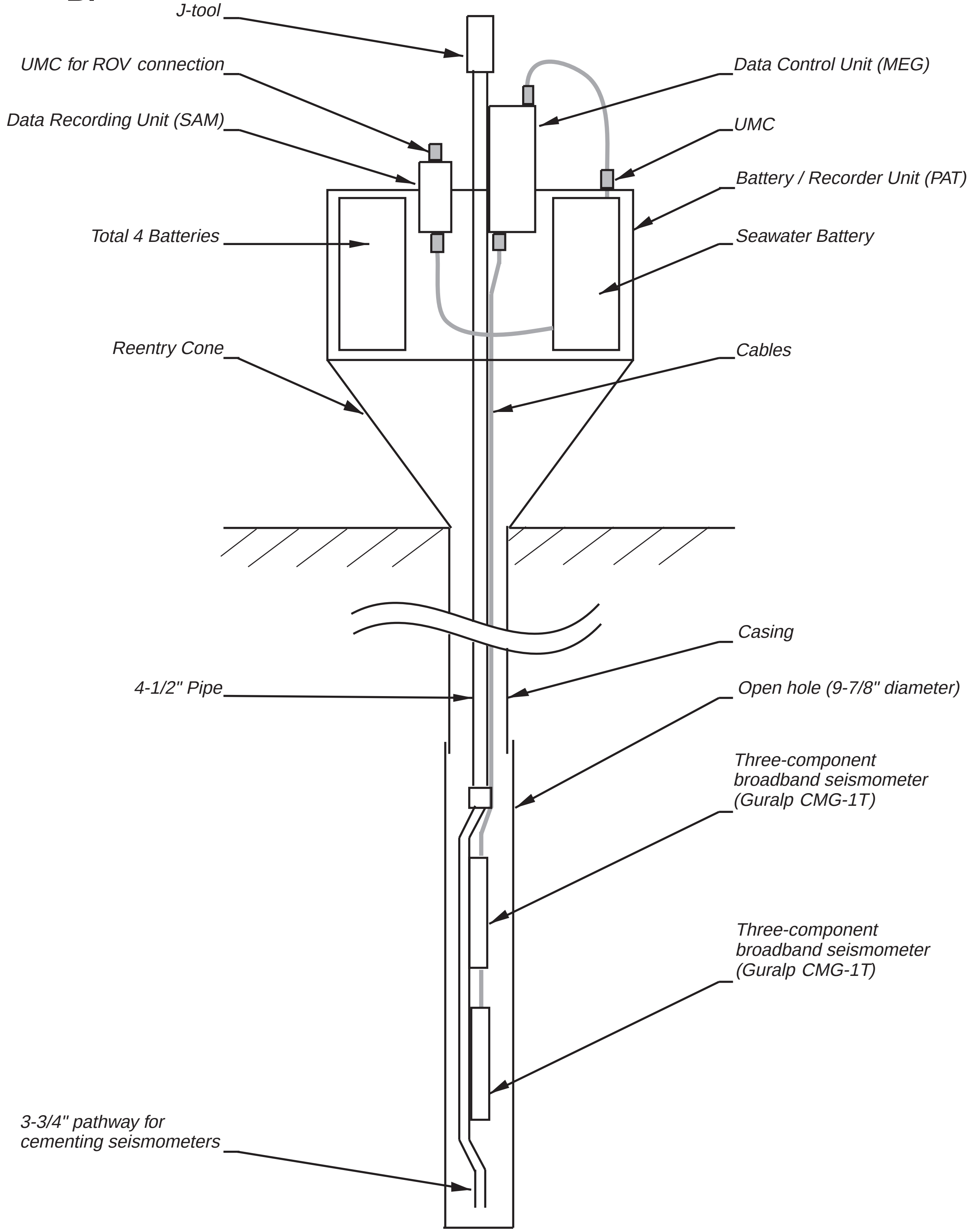

J-tool
UMC for ROV connection
Data Recording Unit (SAM)
Total 4 Batteries
Reentry Cone
4-1/2" Pipe
3-3/4" pathway for
cementing seismometers
Data Control Unit (MEG)
UMC
Battery / Recorder Unit (PAT)
Seawater Battery
Cables
Casing
Open hole (9-7/8" diameter)
Three-component
broadband seismometer
(Guralp CMG-1T)
Three-component
broadband seismometer
(Guralp CMG-1T)

Figure 6

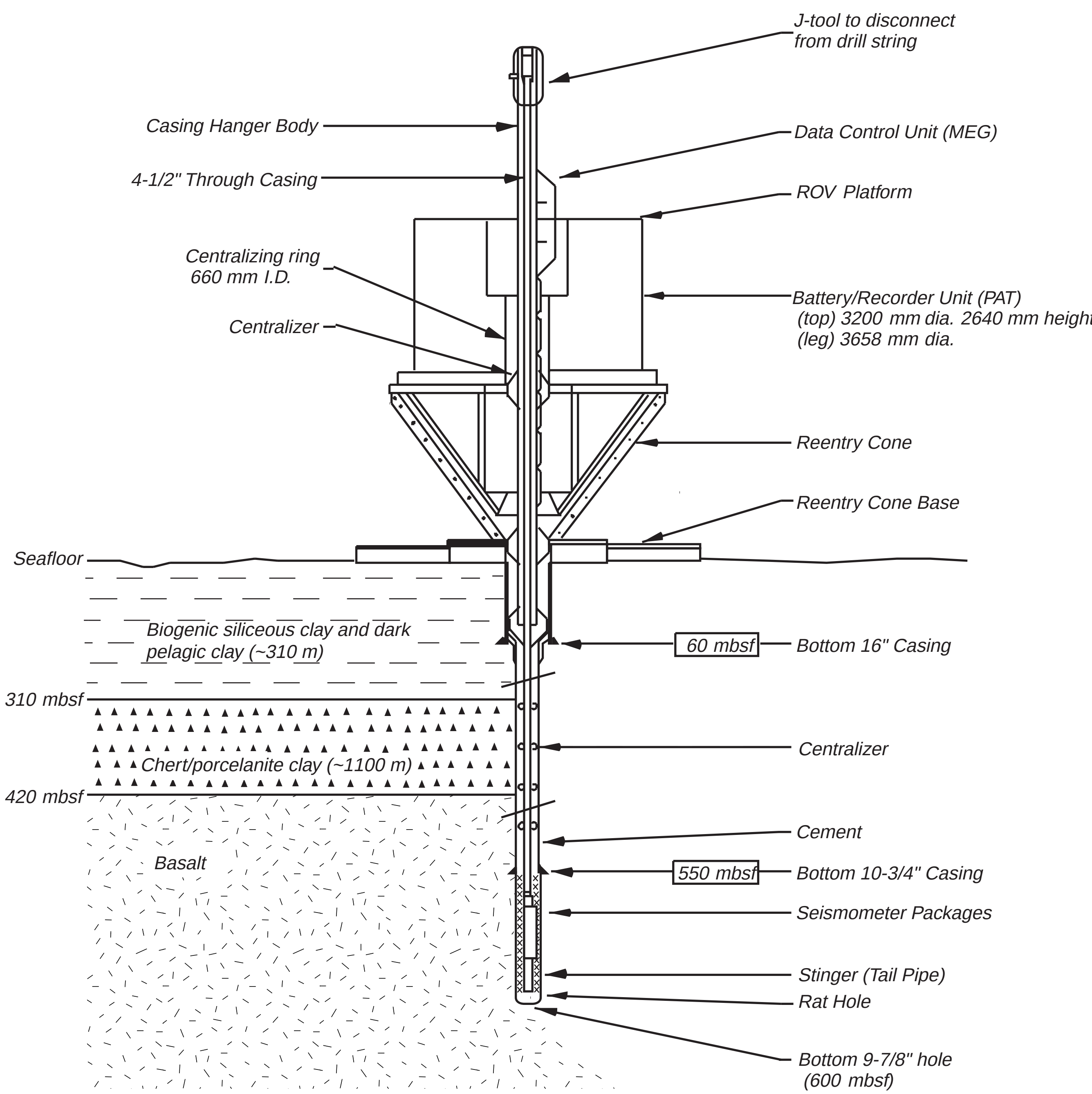
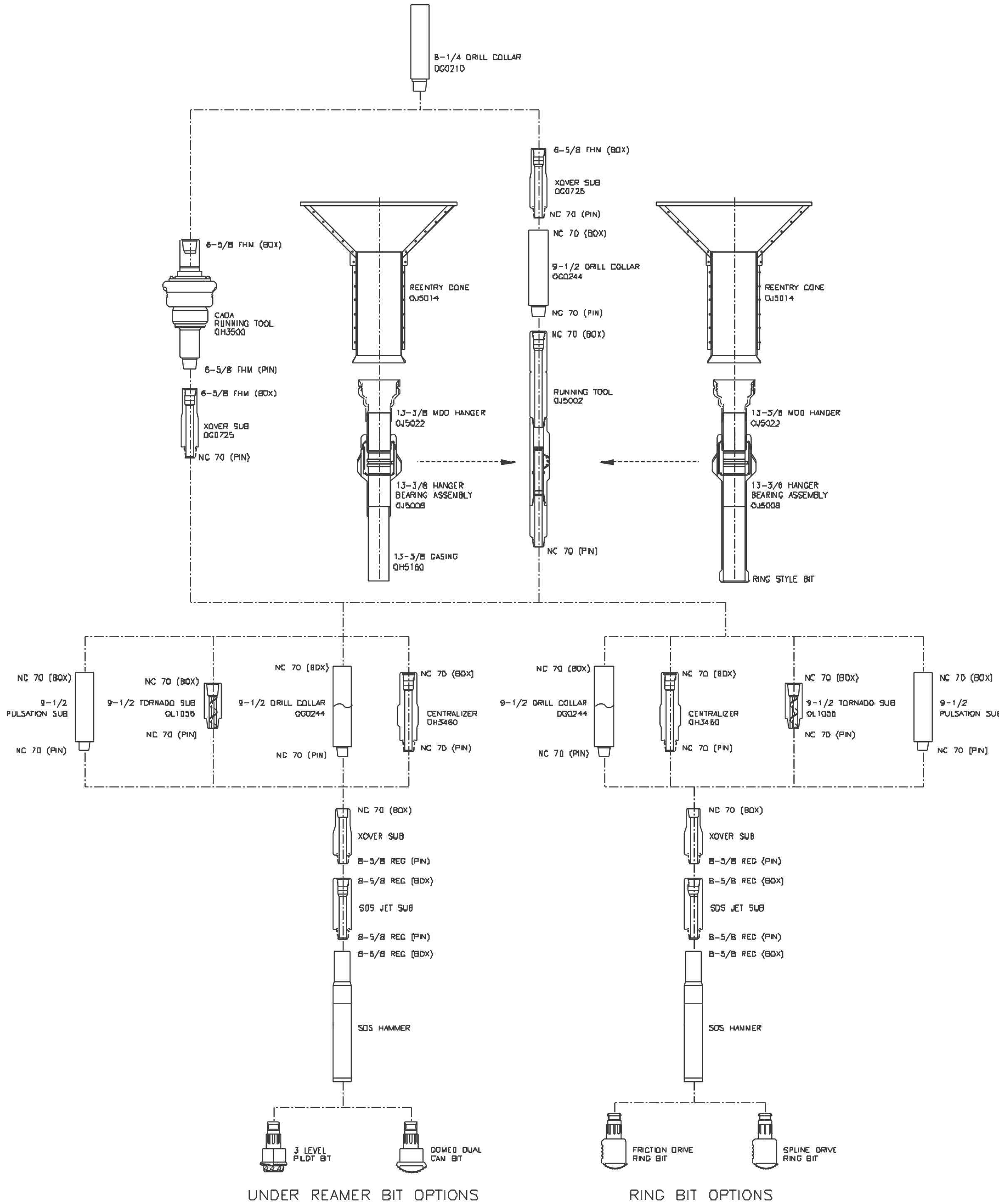

J-tool to disconnect from drill string
Casing Hanger Body
Data Control Unit (MEG)
4-1/2" Through Casing
ROV Platform
Centralizing ring 660 mm I.D.
Battery/Recorder Unit (PAT)
(top) 3200 mm dia. 2640 mm height
(leg) 3658 mm dia.
Centralizer
Reentry Cone
Reentry Cone Base
Seafloor
Biogenic siliceous clay and dark pelagic clay (~310 m)
60 mbsf
Bottom 16" Casing
310 mbsf
Centralizer
Chert/porcelanite clay (~1100 m)
420 mbsf
Cement
Basalt
550 mbsf
Bottom 10-3/4" Casing
Seismometer Packages
Stinger (Tail Pipe)
Rat Hole
Bottom 9-7/8" hole
(600 mbsf)

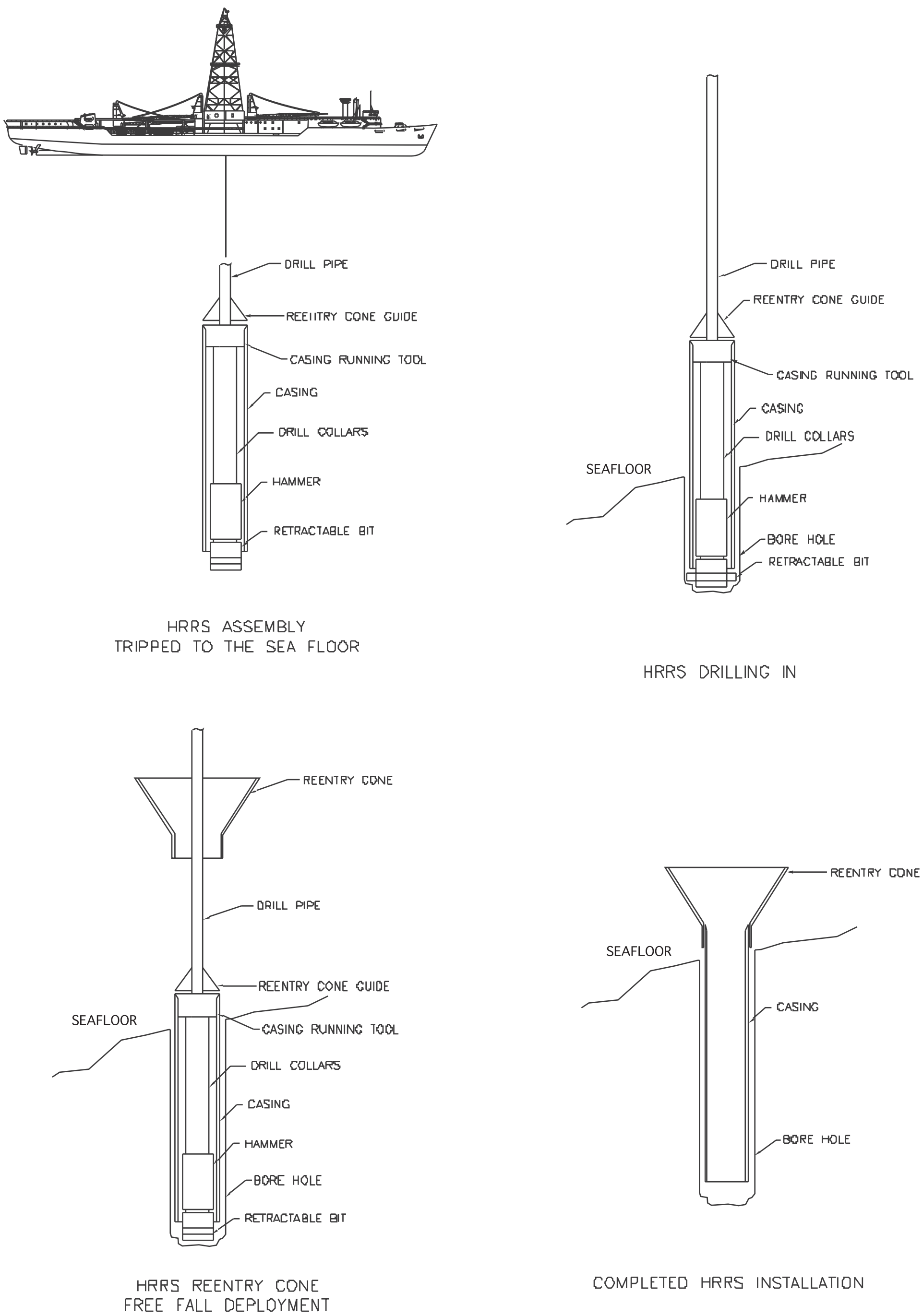
Figure 7



HAMMER DRILL SET-UP

NOTE: ALL NC 70 CONNECTIONS ARE CUT ON 9-1/2" OD BODIES.

Figure 8



HARD-ROCK REENTRY SYSTEM (HRRS) DEPLOYMENT

Figure 9

Preliminary Operations Plan and Time Estimate

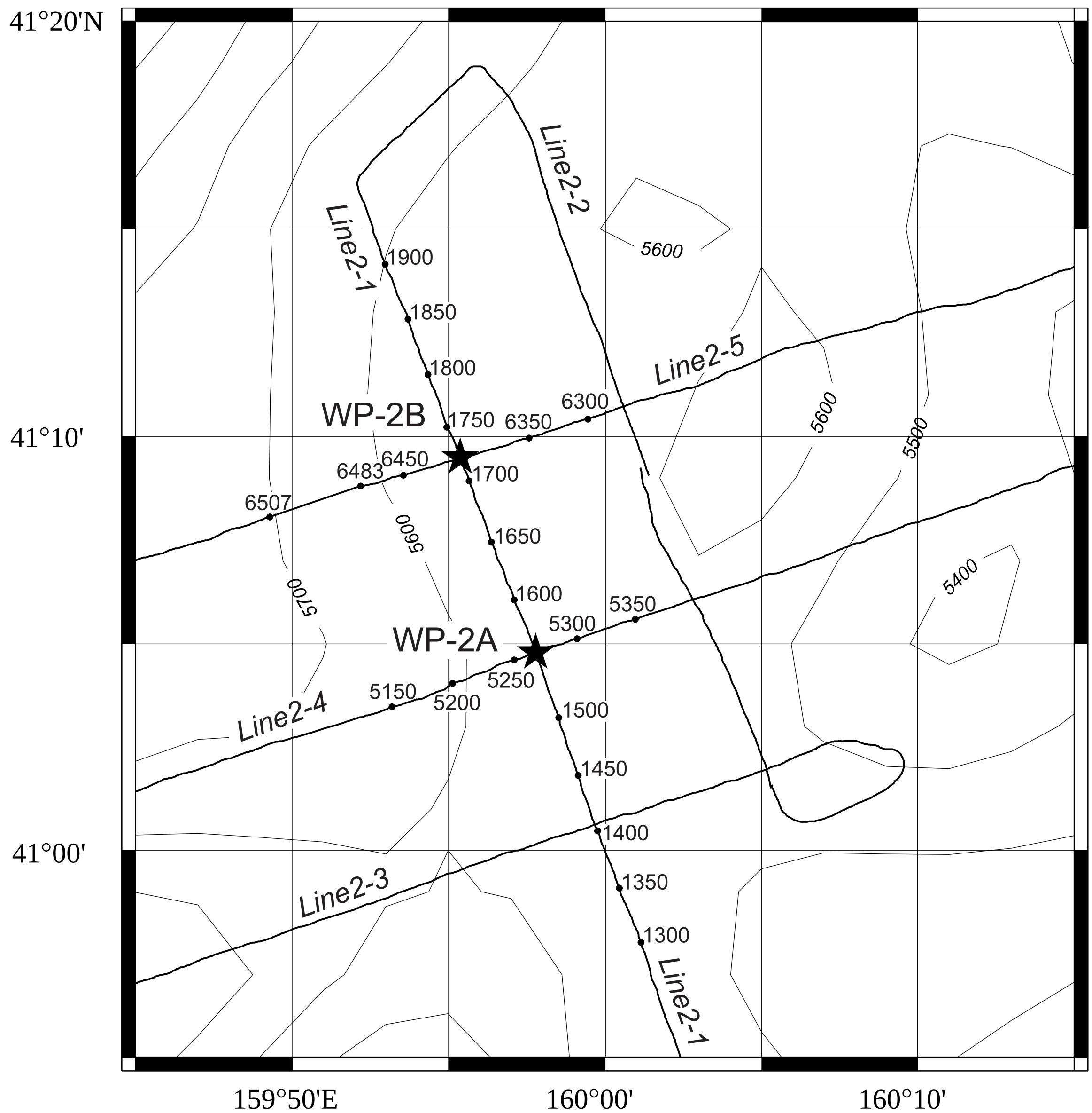
Site No.	Location Lat/Long	Water Depth	Operations Description	[hrs]	Transit (days)	Drilling (days)	Logging (days)	Total On-site
PRIMARY SITES:								
Yokohama	36°00.0'N		Transit ~977 nmi from Yokohama to WP-2A @ 10.5 kt	[93.0]	3.9			
	139°48.0'E							
WP-2A	41°04.793'N	5548m	A: APC/XCB to ~510 mbsf (10 m into basement contact ?)	[141.5]		5.9	0.0	5.9
	159°57.789'E		plus jet-in test for reentry cone emplacement in "C" hole					
			B: Drill ahead to ~480 mbsf (~30 m above TD of XCB hole), recover			5.4	1.0	6.4
			ctr bit, RCB core to ~600 mbsf (~100 m into basement)	[129.1]				
			wireline log (1-triple combo and 2-FMS-sonic runs)	[23.0]				
			C: Deploy reentry cone w/~60 m 16" csg, drill 14-3/4" hole	[250.3]		13.8	0.0	13.8
			to ~550 mbsf, cement csg shoe at ~535 mbsf, drill out shoe,					
			drill 9-7/8" hole to ~600 mbsf					
			Deploy instrument pkg on 4-1/2" csg, cement in open	[80.0]				
			hole below casing shoe and deploy battery package					
			Total days on-site:	**26.1**				
			Transit ~537 nmi f/WP-2A to SR-1 (HRRS test site) @ 10.5 kt	[51.1]	2.1			
SR-1	32°48.220'N	2060m				12.5		12.5
(HRRS)	158°20.370'E		A: "Dual cam" bit spud testing and crew training (U/R style)	[48.0]				
			B: "3 level bit" spud testing and crew training (U/R style)	[48.0]				
			C: Hammer csg test (12-1/4" ring bit/~20 m 13-3/8" csg), FFF	[48.0]				
			D: Hammer csg test (12-1/4" ring bit/~35 m 13-3/8" csg), FFF	[60.0]				
			E: Hammer csg test (11-3/4" ring bit/~50 m 13-3/8" csg), FFF,					
			185 hammer drill test (TD depth TBD),	[96.0]				
			Transit 15-20 nmi from SR-1 to SR-3 (HYACE test site)	[2.5]	0.10			
SR-3	TBD	2500	A: HYACE testing in a dedicated hole	[69.5]		2.9		2.9
HYACE	TBD		NDT inspect BHA, layout drill collars, secure for transit					
			Total days on-site:	**15.4**				
Guam	13°20.00'N		Transit ~1370 nmi from SR-1 to Guam @ 10.5 kt	[130.5]	5.4			
	144°30.00'E							
			Port call days:	**5.0**	**11.5**	**40.5**	**1.0**	**41.5**
			NOTE: Total includes port days.		**TOTAL DAYS:**		**58.0**	

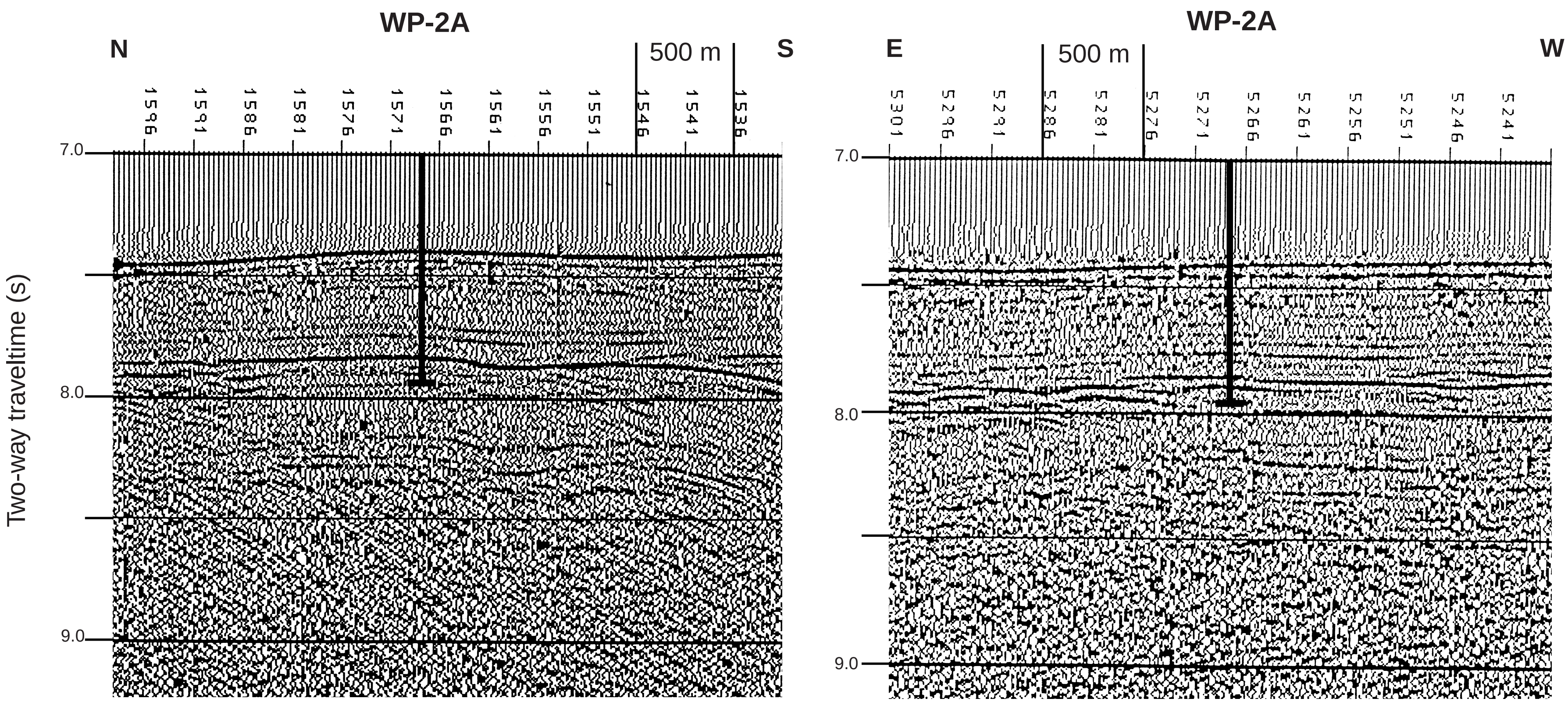
Revised 23 March 2000 M. A. Storms

Alternate Site Plan and Time Estimate

Site No.	Location Lat/Long	Water Depth	Operations Description	Drilling (days)	Logging (days)	Total On-site
			ALTERNATE ION SITES:			
WP-2B	41°09.502'N	5559m	Same drilling plan as at the primary Site WP-2A.	25.1	1.0	26.1
	159°55.382'E					
			ALTERNATE ENGINEERING TEST SITES:			
SR-2	36°58.63'N	3200m	Same test plan as at the primary Site SR-1.	12.5	0.0	12.5
	159°19.83'E					
Site 809	31°3.439'N	1820m	Same test plan as at the primary Site SR-1.	12.5	0.0	12.5
	139°52.721'E					

Revised 23 March 2000 M. A. Storms


41°20'N
41°10'
41°00'
159°50'E
160°00'
160°10'
Line2-1
Line2-2
Line2-3
Line2-4
Line2-5
WP-2A
WP-2B
5600
5700
5500
5400
1900
1850
1800
1750
1700
1650
1600
1500
1450
1400
1350
1300
6300
6350
6450
6483
6507
5150
5200
5250
5300
5350



Line 2-1-(1)
KH96-3 Leg-1

Line 2-4-
KH96-3 Leg-1

SITE SUMMARY

Site: WP-2A

Priority: 1
Position: 41°04.79´N, 159°57.78´´E
Water Depth: 5548 m
Sediment Thickness: ~420 m
Target Drilling Depth: 600 mbsf
Approved Maximum Penetration: 800 mbsf
Seismic Coverage: Intersection of KH96-3 Leg 1 Line 2-4 with Line 2-1

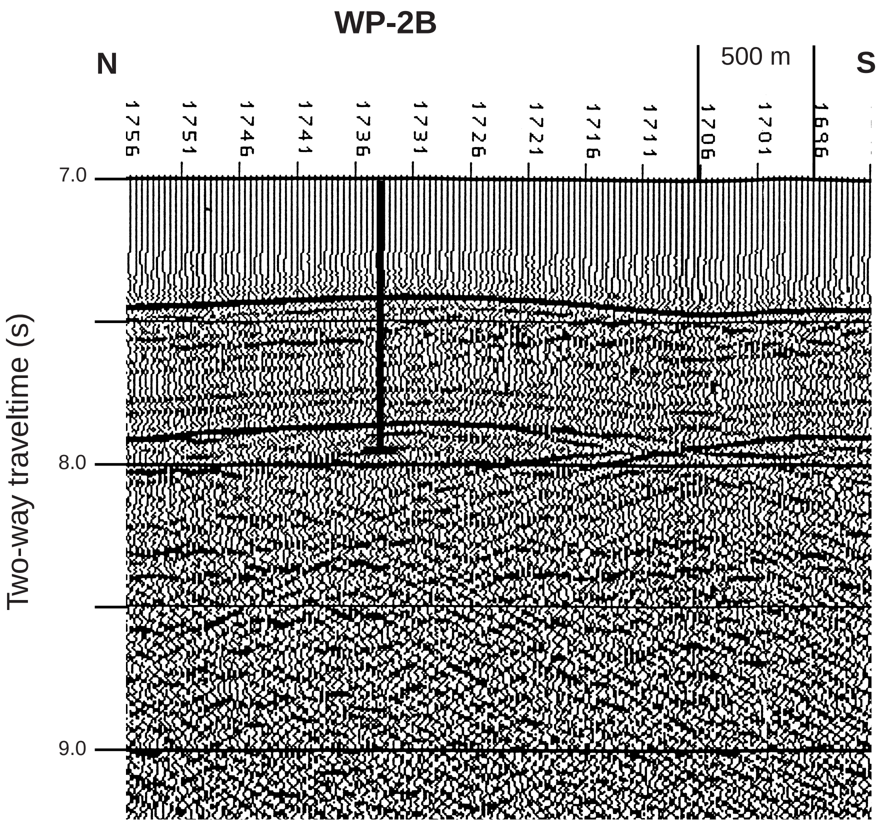
Objectives: The objectives of Site WP-2A are:

1. Install long-term borehole seismic observatory to monitor global seismicity.
2. Core 100 m of the upper basaltic oceanic crust to add knowledge of MORB chemistry and emplacement.
3. Determine Pacific plate paleolatitude and tectonic drift.
4. Determine nature of Cretaceous basement and age of Anomaly M8.

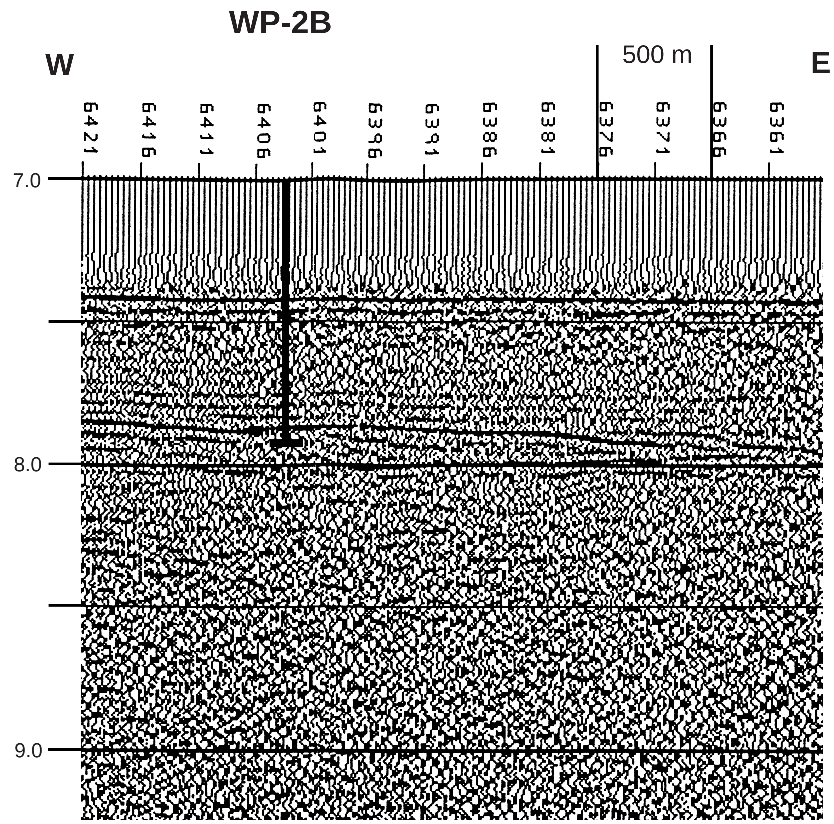
Drilling Program: APC to 180 mbsf, XCB to refusal (200 mbsf), RCB to 100 m into basement (~600 mbsf). Drill instrumented borehole to ~600 mbsf, install reentry cone, and case through unstable section

Logging and Downhole Operations: Triple combo, FMS/sonic/temperature, BHTV; install long-term sensor package and cement at the bottom

Nature of Rock Anticipated: Upper layer ~310 m thick of biogenic silica-bearing clay and dark brown pelagic clay; lower layer ~110 m thick of interbedded radiolarian chert, porcelanite, and siliceous clay, 100 m of basalt flows and pillow basalts



Line 2-1-(2)
KH96-3 Leg-1



Line 2-5-(2)
KH96-3 Leg-1

Site: WP-2B

Priority: 2
Position: 41°09.50´N, 159°55.38´E
Water Depth: 5559 m
Sediment Thickness: ~500 m
Target Drilling Depth: 600 mbsf
Approved Maximum Penetration: 800 mbsf
Seismic Coverage: Intersection of KH96-3 Leg 1 Line 2-5 with Line 2-1

Objectives: This is an alternate site to WP-2A. The objectives at Site WP-2B are:

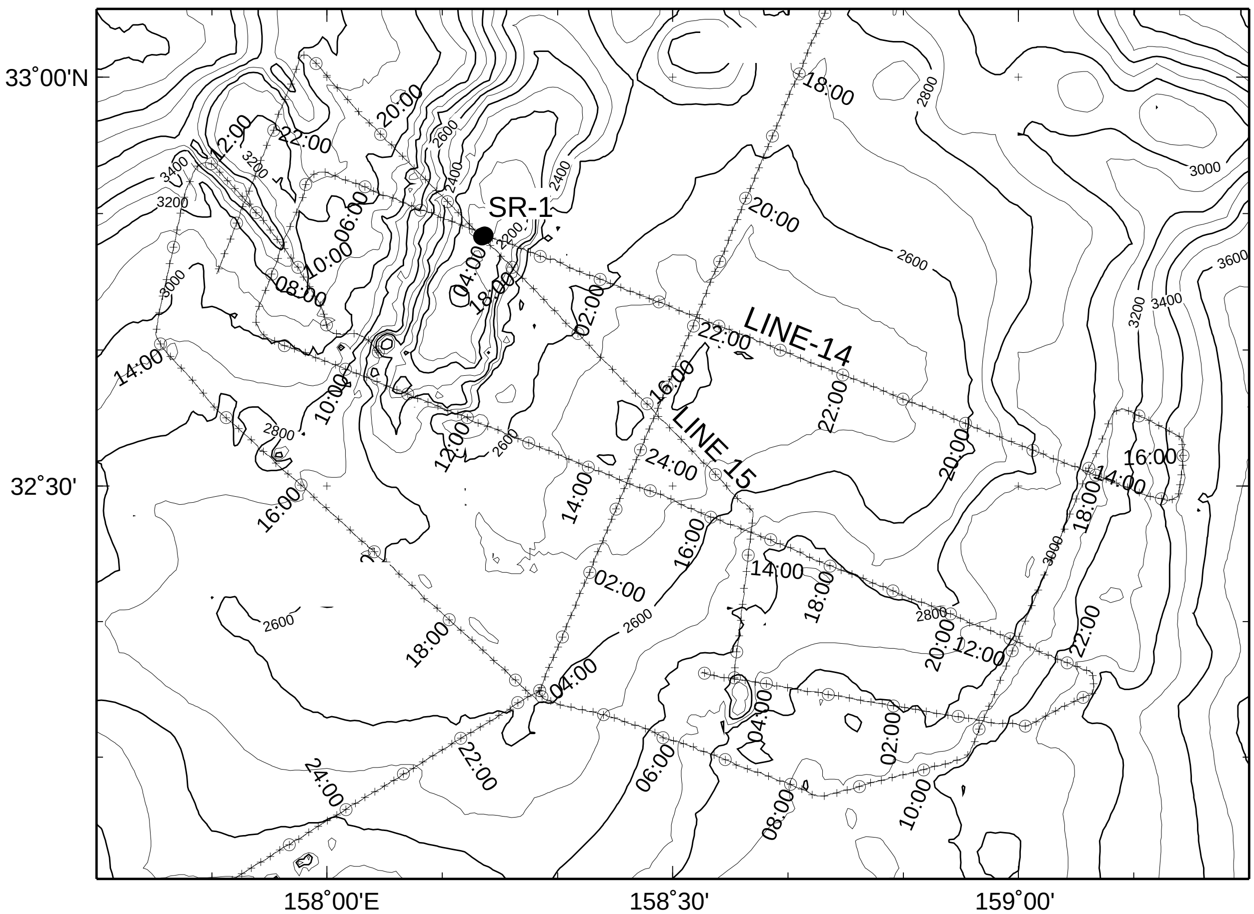
1. Install long-term borehole seismic observatory to monitor global seismicity.
2. Core 100 m of the upper oceanic crust to add knowledge of MORB chemistry and emplacement.
3. Determine Pacific plate paleolatitude and tectonic drift.
4. Determine nature of Cretaceous basement and age of Anomaly M8.

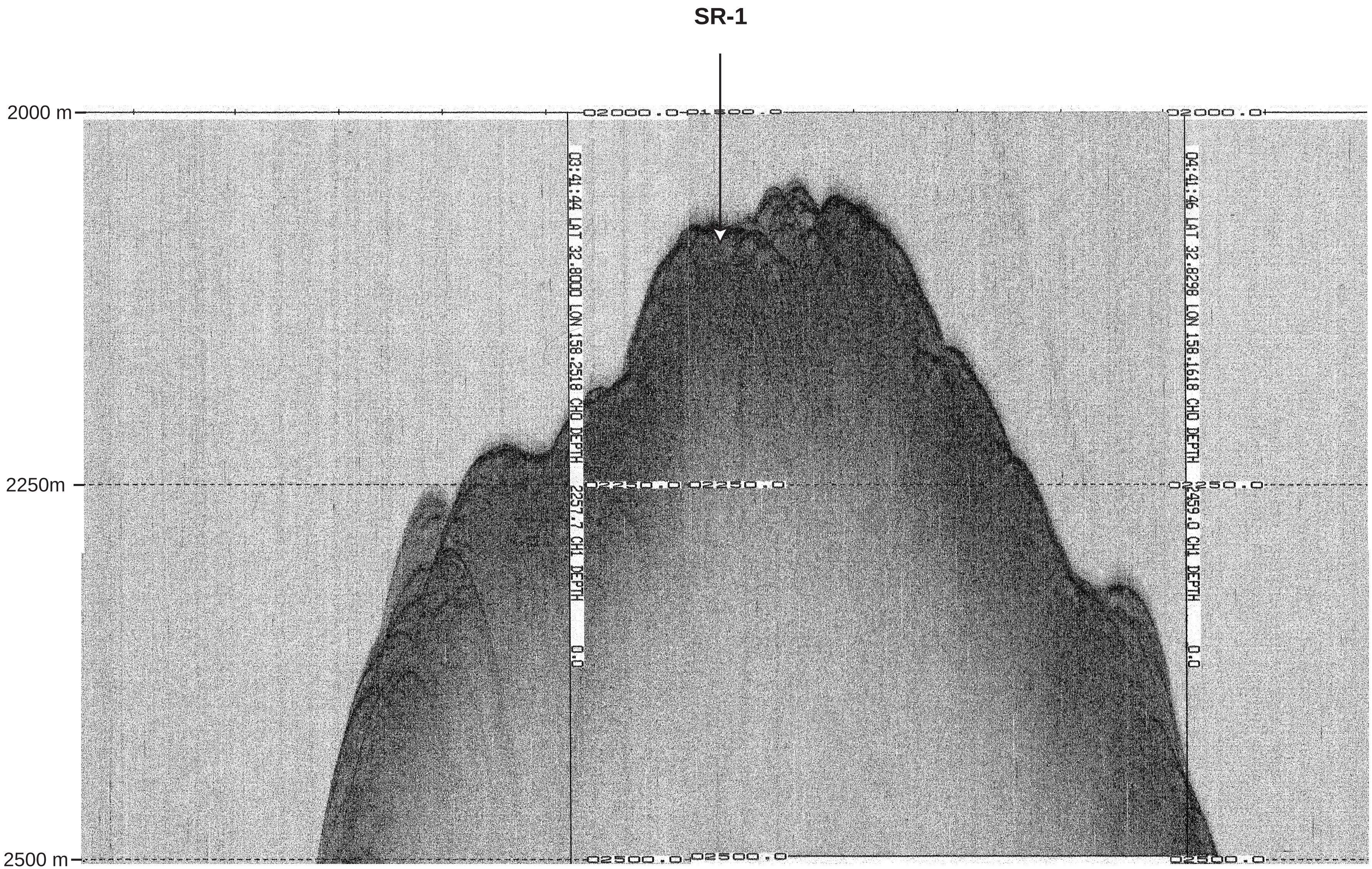
Drilling Program: APC to 180 mbsf, XCB to refusal (200 mbsf), RCB to 600 mbsf. Drill instrumented borehole to ~600 mbsf, install reentry cone, and case through unstable section

Logging and Downhole Operations: Triple combo, FMS/sonic/temperature, BHTV; install long-term sensor package and cement at the bottom

Nature of Rock Anticipated: Upper layer ~310 m thick of biogenic silica-bearing clay and dark brown pelagic clay; lower layer ~110 m thick of interbedded radiolarian chert, porcelanite, and siliceous clay, 100 m pillow basalts and basalt flows

Shatsky Rise central South High HRRS (SR-1) Site Location




SR-1
2000 m
2250m
2500 m
03:41:44 LAT 32.8000 LON 158.2518 CH0 DEPTH 2257.7 CH1 DEPTH 0.0
04:41:46 LAT 32.8298 LON 158.1618 CH0 DEPTH 2459.0 CH1 DEPTH 0.0

Site: SR-1

Priority: 1
Position: 32°08.22´N, 158°20.37´E
Water Depth: 2060 m
Sediment Thickness: 0 m
Target Drilling Depth: 100 m
Approved Maximum Penetration: 200 m
Seismic Coverage: TN037, Lines 14 and 15

Objectives: The objectives of Site SR-1 are:

1. Characterize the 260 hammer operating parameters; i.e., flow rates, pump pressures, weight on bits, etc.

2. Characterize the hammer-drill and bit-spudding capabilities without casing.

3. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a fractured hard rock environment with little or no overlying sediment of talus and with little or no slope.

4. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a sloped fractured hard rock environment with little or no overlying sediment or talus.

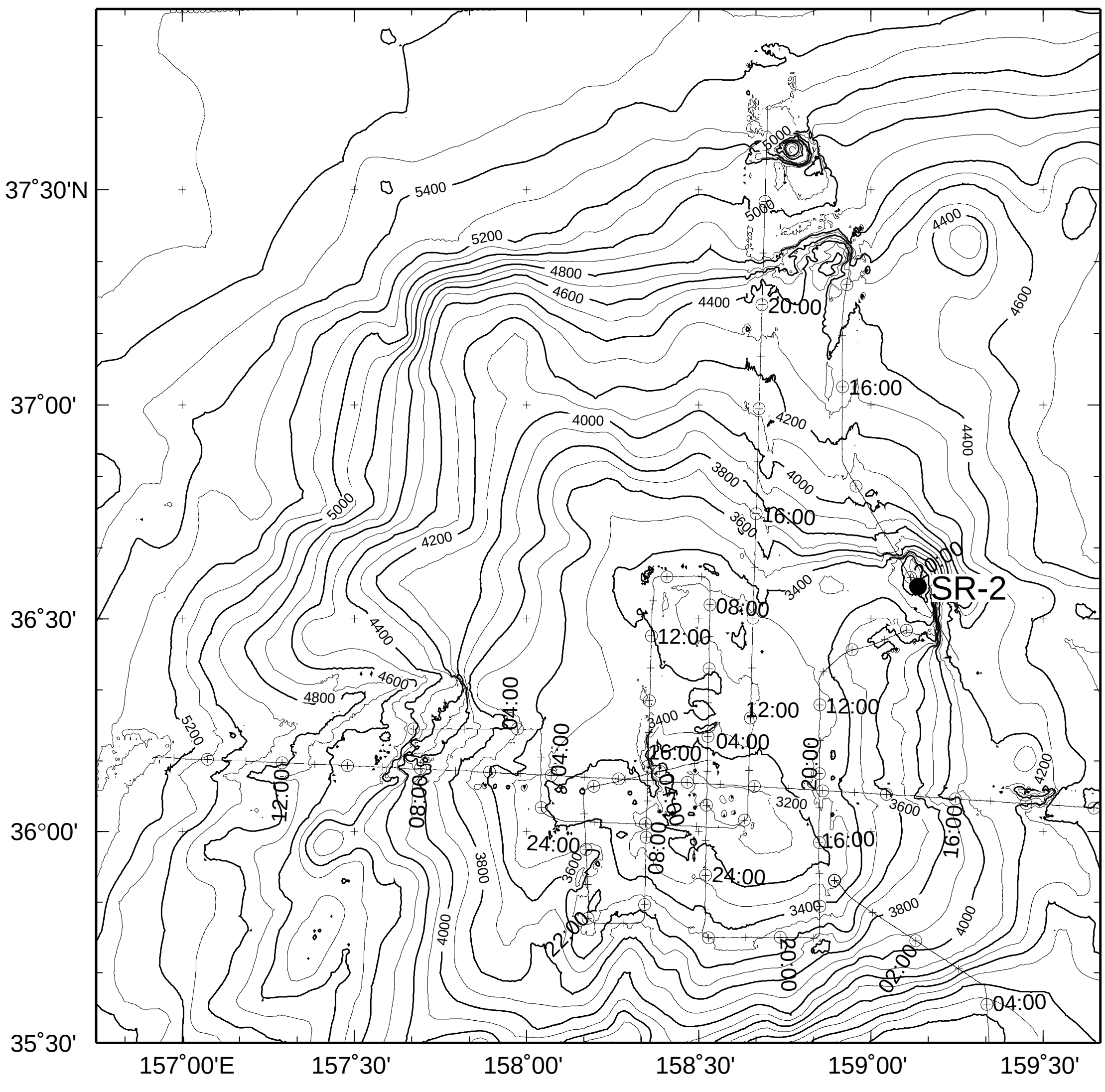
5. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a sloped fractured hard rock environment with overlying sediment or talus.

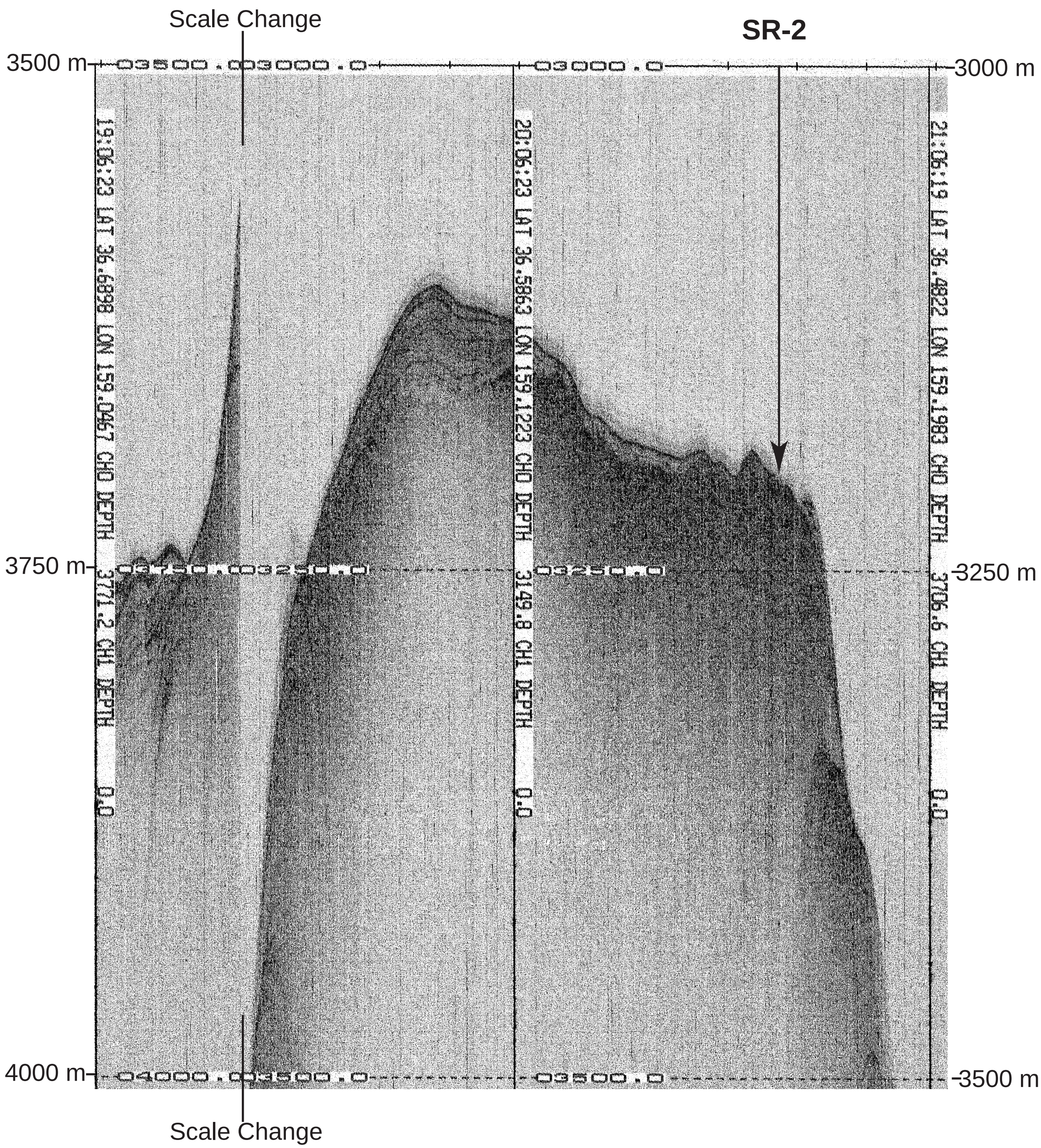
Drilling Program: Test different bit types before attempt to drill in casing with hammer-drill system

Logging and Downhole Operations: None planned

Nature of Rock Anticipated: Outcropping basalt

Shatsky Rise Central High Drill HRRS (SR-2) Site Location




Scale Change
SR-2
3500 m
3750 m
4000 m
3000 m
3250 m
3500 m
19:06:23 LAT 36.6898 LON 159.0467 CH0 DEPTH 3771.2 CH1 DEPTH 0.0
20:06:23 LAT 36.5863 LON 159.1223 CH0 DEPTH 3149.8 CH1 DEPTH 0.0
21:06:19 LAT 36.4822 LON 159.1983 CH0 DEPTH 3706.6 CH1 DEPTH 0.0
Scale Change

Site: SR-2

Priority: 2
Position: 36°58.63´N, 159°19.83´E
Water Depth: 3149 m
Sediment Thickness: 0 m
Target Drilling Depth: 100 m
Approved Maximum Penetration: 200 m
Seismic Coverage: TN037: 17-08-94, 21:00 hrs

Objectives: This is an alternate site for SR-1. The objectives of Site SR-2 are:

1. Characterize the 260 hammer operating parameters; i.e., flow rates, pump pressures, weight on bits, etc.

2. Characterize the hammer-drill and bit-spudding capabilities without casing.

3. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a fractured hard rock environment with little or no overlying sediment of talus and with little or no slope.

4. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a sloped fractured hard rock environment with little or no overlying sediment or talus.

5. Test the entire HRRS system by drilling in 20+ m of 13-3/8" casing in a sloped fractured hard rock environment with overlying sediment or talus.

Drilling Program: Test different bit types before attempt to drill in casing with hammer-drill system

Logging and Downhole Operations: None planned

Nature of Rock Anticipated: Outcropping basalt

Site: SR-3

Priority: TBD
Position: TBD
Water Depth: 2500 m
Sediment Thickness: ~900 m
Target Drilling Depth: 200 m
Approved Maximum Penetration: Pending PPSP approval
Seismic Coverage: TN037, Lines 14 and 15

Objectives: The objective is to test the technical feasibility and modes of operation of the HYACE tools that are being developed to drill and core gas hydrates.

Drilling Program: Test the HYACE tools

Logging and Downhole Operations: None planned

Nature of Rock Anticipated: Pelagic clays

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