eas than earthquakes with similar magnitudes in the western United States. The corollary that earthquakes in the East should have larger damage areas has been proven untrue, according to Arch Johnston, Center for Earthquake Research and Information, Memphis, Tenn., and T. C. Hanks, U.S. Geological Survey, Menlo Park, Calif. They presented their findings at the AGU Spring Meeting.

Their studies show that ratios of damage and felt areas for eastern and western North America range from a factor of 100 to a factor of 10, with little distinction between low and high intensity earthquakes. Johnston and Hanks show that the ratio is much lower than previously thought, and that it decreases from a high of 7 for felt areas to a factor of 2–3 for intensity 6, and approaches unity at intensity 7. Earthquake intensity is measured on a scale of 1–12, which gives felt and damage information. Intensity 1 represents an earthquake that is barely felt, and 12 an earthquake that causes substantial destruction. Damage is evident following earthquakes with intensities of 6 and 7.

Higher estimates of the ratio in the past was due to incomplete information on the seismic moments of earthquakes of eastern North America.

According to Johnston, these studies will have important implications for seismic hazard assessment in the east. The researchers believe that emphasis on larger eastern damage areas is misplaced—larger damage areas should not be used to argue for near-equality of hazard between east and west.—*Susan Bush*

Space Physicists Want Small Missions

PAGES 267–268

An overwhelming 91% of space physicists surveyed recently believe that the National Aeronautics and Space Administration should plan more frequent smaller missions, even at the expense of large missions. This was the most clearcut result of a NASA survey conducted by the Science Applications International Corporation.

"This result shows that people want access to space," said SAIC's Mark E. Pesses who, along with Rikhi Sharma, conducted the survey and presented the preliminary results at the AGU Spring Meeting. Respondents prefered smaller missions that are easier to participate in, over larger missions that take 10–15 years to fly.

The survey targeted members of AGU's Solar-Planetary Relationships section as well as members of the American Astronomical Society, NASA grant recipients, and other scientists who have expressed interest in NASA grants. About 40% out of a total 1770 questionnaires were returned—686 from researchers and 120 from graduate students.

Asked to identify which space physics program should receive a boost in funding, almost a third (30%) chose supporting research and technology, while 27% specified small missions, 14% space physics theory, and 11% mission operations and data analysis. Programs for large missions, guest investigators, suborbital, and other programs each received less than 10% of the votes.

Regarding research techniques, the largest blocs of respondents chose data interpretation and instrument measurements (36% for each area) as the highest priorities for increased funding. Theory and simulation was third with 26%.

Respondents were also asked to advise how NASA's Space Physics Division grants program could be changed. More than a third (35%) recommended fewer but larger-sized grants. "The same number of people would be funded but fewer proposals would have to be written," explained Pesses. Almost a quarter of the respondents (23%) advised NASA to distribute grants to ensure significant new research opportunities with lower funding levels—even assuming established researchers would receive fewer grants. The third largest segment (22%) recommended leaving the grant system as it is.

Among researchers who returned the surveys, more than half (56%) are research scientists, while 28% are professors, 8% are managers, and 4% are post-doctoral fellows. Over half (53%) work in universities, 15% have a NASA affiliation, 14% work in other government positions, 11% in industry, and 7% in other organizations. More than 120 respondents are supported by "soft" money, which means that "if the contract goes, their job goes," Pesses said.

The largest percentage of respondents (27%) identified magnetosphere and solar-terrestrial studies as their current research area, followed by 18% in solar research and 17% in ionosphere and thermosphere/mesosphere research. Cosmic and heliospheric research was the focus of 11%, astronomy 10%, plasma research 6%, planetary research 3%, and fusion 2%. Six percent listed other areas.

The survey also asked respondents to specify how their group would use supercomputers during 1991–1993. Simulation and modeling applications was chosen by 83%, followed by 9% who specified data visualization.

A separate section of the questionnaire was aimed at space physics graduate students. Research assistantships support 67% of the respondents, followed by fellowships (15%) and teaching assistantships (9%). NASA's space physics program supported 54% of the student respondents.

Three-quarters of the graduate students said they expected to continue in the U.S. space physics program after graduation, and 65% cited the excitement of research as the major motivation for their choice of profession, followed by 16% who cited the ability to obtain research funding, 11% who mentioned job security, and 7% who cited salary.

Pesses and Sharma are now refining their analysis of the survey results, to see if responses can be grouped by discipline—solar versus magnetospheric researchers, for example—and to see if experimentalists answered differently from theorists, as well as to look for other distinctions. The final survey results will be published in September as a NASA report.—*Lynn Teo Simarski*

ONR Seafloor Natural Laboratories on Slow- and Fast-Spreading Mid-Ocean Ridges

PAGES 268–270

Brian E. Tucholke, Ken C. Macdonald, and Paul J. Fox

Long-term Natural Laboratories for in-depth studies of the seafloor at both a slow-spreading (<30 mm/yr) and a fast-spreading (>60 mm/yr) mid-ocean ridge are being established by the Office of Naval Research. The two Natural Laboratories were selected for their representativeness of global mid-ocean ridge environments, and for their logistic accessibility. The Natural Laboratory region for the slow-spreading regime is on the Mid-Atlantic Ridge from Kane Fracture Zone north to about 27°30'N (Figure 1), and the fast-spreading counterpart is on the East Pacific Rise at about 8°–10°30'N, from Siqueiros to Clipperton Fracture Zone (Figure 2). Together, the two Natural Laboratories include most significant geologic variables that are thought to control both the shape and structure of the igneous crust and the scatter of acoustic wavefields from the bottom/subbottom (BSB) at low angles of incidence.

The Natural Laboratory concept has evolved over the past half-dozen years as an efficient mechanism to address the Navy's scientific interests in geological and geophysical variability of seabed properties [*Office of Naval Research/Naval Ocean Research and Development Activity*, 1988], and in acoustic-wavefield BSB interaction and scatter. Many of the geological and geophysical interests are similar to those embodied in the RIDGE (Ridge Interdisciplinary Global Experiments) program, although RIDGE is a more globally ranging effort [*University of Washington*, 1989]. The ONR Natural Laboratories and RIDGE program effectively com-

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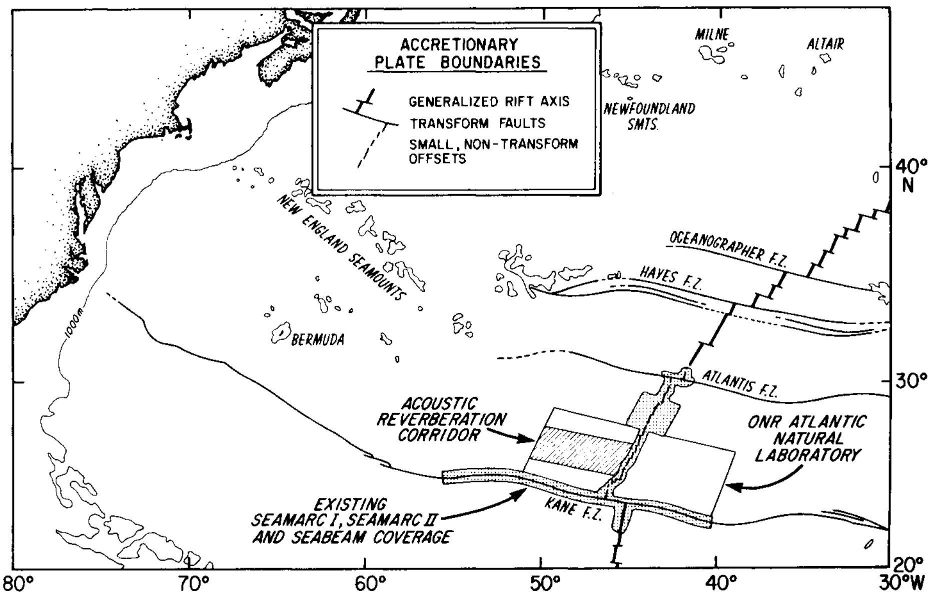

Fig. 1. Location of Atlantic Natural Laboratory on Mid-Atlantic Ridge near 24°–27°30′N. The west-flank Acoustic Reverberation Corridor is of immediate interest for ONR-sponsored research on acoustic bottom/subbottom reverberation.

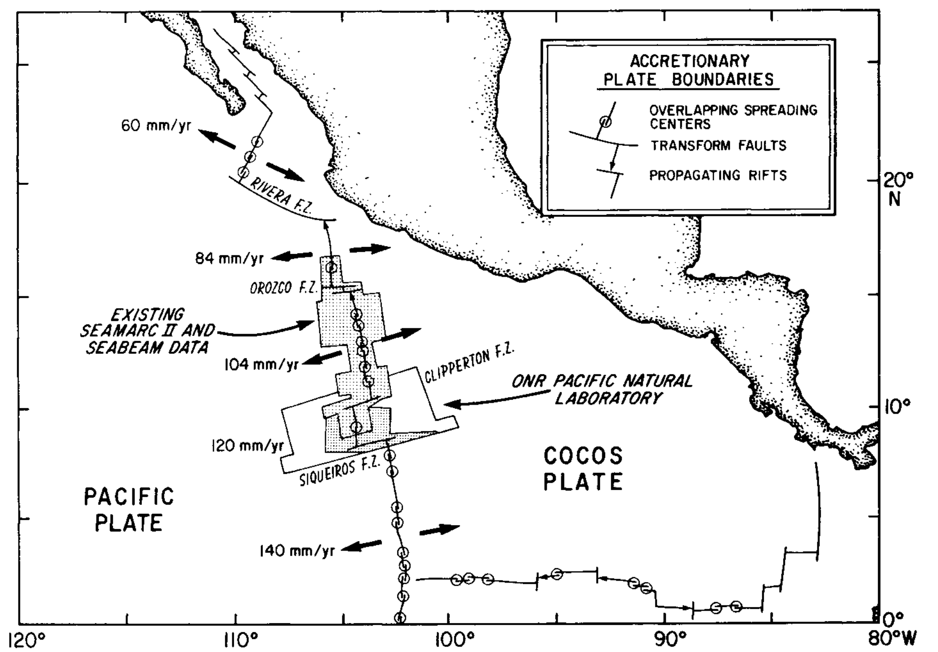

Fig. 2. Location of Pacific Natural Laboratory on East Pacific Rise at about 8°–10°30′N. The open box shows the bounds of potential future expansion of the Natural Laboratory; most of the area in the stippled, southern box was surveyed in late 1990.

plement and reinforce one another, providing broad opportunities for various scientific communities to accelerate their understanding of interrelations among the marine geological, geophysical, and acoustical characteristics of oceanic crust.

Specifically, the ONR Natural Laboratories will provide test beds to address issues such as the origin and evolution of oceanic crust, the mechanisms of BSB scatter of acoustic wavefields, and the calibration and intercomparison of bottom-sensing oceanographic instrumentation, models, and analytic techniques. Each of these is discussed briefly below. As *long-term* Natural Laboratories, the value of the two laboratories will increase with time as a wide variety of experiments and surveys are conducted.

Origin and Evolution of Oceanic Crust

The template that controls the pattern of crustal accretion and shape of the seafloor is the mid-ocean ridge. Significant progress has been made in the past 2 decades in the study of crustal accretion and tectonism at mid-ocean ridges, beginning with the FAMOUS (French-American Mid-Ocean Undersea Study) project and currently continuing with the RIDGE and FARA (French-American Ridge Atlantic) programs. For the most part, these studies focused on the axes of mid-ocean ridges and showed that over distances of tens to hundreds of kilometers the axes undulate up and down by hundreds of meters like a gentle roller coaster (Figure 3). The ridge axis is not strictly a continuous, linear structure along its length, but it is interrupted at deep points by ridge-axis discontinuities ranging in size from large offsets to small deviations in axial trend. Some of these discontinuities are transform faults and propagating rifts [*Wilson*, 1965; *Hey et al.*, 1980], but the more common discontinuities are nonrigid structures such as overlapping spreading centers (OSCs) [*Macdonald and Fox*, 1983].

The ridge-axis discontinuities create a fundamental segmentation of mid-ocean ridges on length scales of tens to hundreds of kilometers. The segments appear to behave independently of one another, so that the intensity (or phase) of tectonic activity, the crustal geochemistry, and the amount of magma available for eruption often vary between neighboring segments [*Langmuir et al.*, 1986; *Macdonald et al.*, 1988]. At least within longer wavelength segments, however, magmatic and tectonic activity tend to vary systematically; magmatism and volcanism are least active near discontinuities and most active near shallow areas between the discontinuities. This focusing of melting anomalies results in thicker crust and/or reduced upper mantle density near segment centers [*Kuo and Forsyth*, 1988; *Lin et al.*, 1990], and it may reflect a fundamental wavelength of instabilities in the melt zone of the subaxial asthenosphere [*Whitehead et al.*, 1984].

There appears to be a hierarchy in segmentation of mid-ocean ridges that can be classified by the scales of along-axis spacing and longevities of segments, and by the sizes and durations of the discontinuities that define them (Figure 3) [e.g., *Langmuir et al.*, 1986, *Macdonald et al.*, 1988]. The along-strike accretionary characteristics within any given scale of segment are punctuated by higher-order discontinuities (and thus finer-scale segments) that represent progressively shorter-term perturbations to the accretionary process.

First-order segments generally reach 200–800 km along mid-ocean ridge (MOR) axes, persist for millions to tens of millions of years or more, and are defined by large, first-order discontinuities such as major transform faults. These discontinuities are large enough (> tens of kilometer offset) to cause the edges of the plates on either side of the boundary to behave rigidly. First-order segments contain a number of finer-scale segments classified as second to fourth order.

Second-order segmentation, with along-axis spacing of 50–300 km, is defined by smaller offsets of the spreading center (commonly 3–20 km) that behave nonrigidly. Examples are OSCs on fast-spreading centers (>60 mm/yr) and small, oblique offsets of

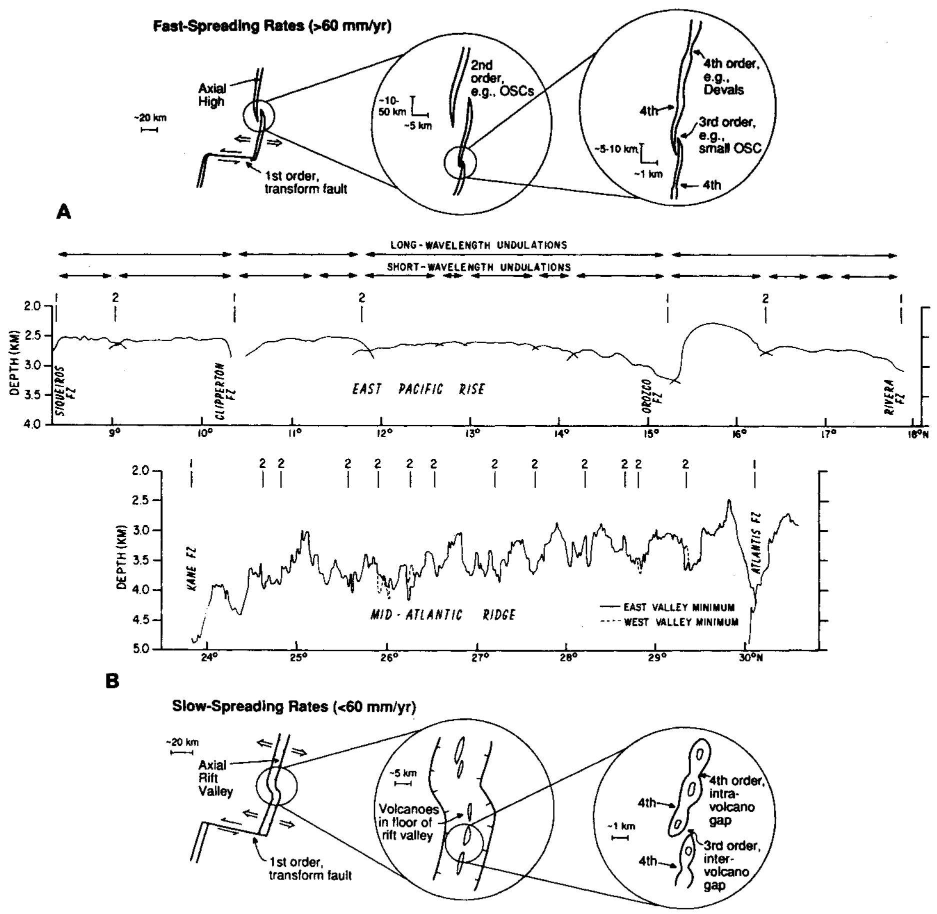

Fig. 3. (a) Hierarchy of ridge-axis discontinuities for fast-spreading ridges [from Macdonald et al., *1991], and axial depth profile of the EPR from 8° to 18°N extracted from Sea Beam records [from* Macdonald et al., *1988]. Discontinuities of order 1 and 2 (transforms and OSCs) are identified from Sea Beam and SeaMARC II records. (b) Axial depth profile of Mid-Atlantic Ridge between Kane and Atlantis fracture zones; the profile is based on Sea Beam data and is at the same vertical exaggeration as in (a) [adapted from* Sempere et al., *1990]. Locations of discontinuities of order 1 and 2 as defined by Sempere et al. are shown. Second-order discontinuities are small nontransform offsets with distinct off-axis discordant zones; note the greater frequency of these discontinuities in the slow-spreading Atlantic crust. Hierarchy of ridge-axis discontinuities for slow-spreading ridges [from* Macdonald et al., *1991] is at bottom.*

the axial rift valley on slow-spreading centers (Figure 3). Second-order discontinuities and the segments they define can last several million years [*Patriat et al.*, 1990]; they may last significantly longer, but regional high-resolution data to resolve this are not yet available.

Third-order segmentation of MOR axes occurs at spacings of ~30–60 km, and these segments are bounded by discontinuities that have small offsets (a few kilometers) and can be short-lived, lasting perhaps as little as 10,000–100,000 years; small OSCs on fast-spreading ridges are an example.

A fourth order of segmentation may occur at along-axis scales of 10–40 km and is defined by tiny bends and jogs along the ridge. The fourth-order segments and discontinuities are presumably very short-lived, perhaps less than 10,000 years, and they consequently occur on the scale and duration of discrete major eruptions along ridge axes.

The off-axis structural and geochemical traces of some segments and their bounding discontinuities persist for long periods of time (tens of millions of years), which documents their tectonic and magmatic integrity. In particular, large-offset segment boundaries such as transform faults appear to retain a stationary position on the plate boundary [e.g., *Tucholke and Schouten*, 1988]. In contrast, many of the smaller discontinuities such as OSCs migrate along the ridge axis with varying rates and directions so that the intervening ridge segments may grow or shrink with time or move along the strike of the ridge [*Macdonald et al.*, 1988; *Grindlay et al.*, 1991].

The distinctive "abyssal hill" terrain of the ocean basins is largely the preserved product of the temporal and spatial interplay of two primary processes at each ridge segment: the timing, location of eruption, volume, and lateral distribution of basaltic melts that accrete to form the crust; and primarily extensional tectonism that leads to crustal deformation, faulting, and dismemberment. Evidence suggests that along the global ridge system the relative importance of these magmatic and tectonic processes varies significantly with spreading rate [e.g., *Sempere and Macdonald*, 1987]. Some spreading centers, generally associated with faster opening rates (>100 mm/yr), appear to be magma dominated. There the morphologic continuity of ridge segments is striking, crustal magma chambers can be traced along-strike for tens of kilometers, and the architecture (structure, thickness) of the flanking crust is relatively uniform. In contrast, there are other accretionary environments, often associated with slower opening rates (<30 mm/yr) that appear to be characterized by large temporal and spatial variations in the amount of melt delivered to the ridge axis. Along these ridge segments, large-scale faulting and dismemberment of the crust is common, and marked contrasts in crustal structure, both along- and across-strike, are documented [*Brown and Karson*, 1988].

A significant component of MOR studies that is still lacking is detailed data in *across-axis* swaths that extend well onto both flanks of mid-ocean ridges to provide complete information through time on the processes of crustal accretion and tectonism. The ONR Natural Laboratories will help fill the need for these data. The rationale for obtaining detailed off-axis data is straightforward. If crustal accretion is episodic, as it is believed it to be [e.g., *Macdonald*, 1982; *Kappel and Ryan*, 1986; *Tivey and Johnson*, 1987; *Pockalny et al.*, 1988], then in *along-axis* surveys it becomes necessary to survey a great number of mid-ocean ridge segments in order to capture all phases of a volcanic/tectonic cycle, particularly if most of the "action" occurs in only a fraction of the cycle. By judicious *across-axis* surveying on both sides of the ridge axis, however, it is possible to capture the complete crustal record of a number of cycles. Furthermore, across-axis data allows evaluation of side-to-side asymmetries in the cycles, the range of natural variability through time, the effects imposed by changes in plate motion, and the nature of secondary "aging processes" of crust as it moves away from the rift axis.

Acoustic Studies

Over the past 2 years, ONR has developed and implemented an Acoustic Reverberation Special Research Project (ARSRP) [*Scripps Institution of Oceanography*, 1989]. The BSB component of this project is composed of an interdisciplinary research team (ocean acoustics and marine geology/geophysics communities) that will focus on the Atlantic Natural Laboratory.

The scientific objective of the ARSRP is to advance quantitative understanding of the scattering of low-angle-of-incidence acoustic wavefields (100–500 Hz) from the ocean bottom and subbottom, in the context of the geologic processes that formed the seafloor. The program encompasses several elements, including the following.

(1) Characterization of variations in seafloor and subbottom structure and properties at spatial scales that control the scatter of low-frequency acoustic wavefields.

(2) Development of theoretical and numerical techniques capable of predicting the low-frequency acoustic wavefield scattered from geologically realistic models of the BSB environment.

(3) Understanding from such models the dominant scattering mechanism in the context of observed geophysical/geological conditions.

(4) Acquisition of well-controlled acoustic and geological/geophysical data sets that can be used to test hypotheses and models developed under the foregoing elements.

The geological and geophysical characterizations in elements 1 and 4 are important components of the program that will provide a unique data set to further the understanding of the origin and evolution of oceanic crust.

Siting of the ARSRP on the Mid-Atlantic Ridge satisfied two important criteria. First, the ridge is representative of large areas of the global ocean floor, and there is a likelihood that meaningful statistical characterizations of the seafloor structure can be made [e.g., *Shaw and Smith*, 1987; *Goff and Jordan*, 1988], thus offering the potential to extrapolate results to unsurveyed or poorly surveyed areas. Second, because signals from near-surface acoustic sources are refracted away from the ocean bottom for water depths ~>4500 m, low-angle-of-incidence signals from long-range sources (greater than or equal to a convergence zone) will interact with the BSB predominately on the upper MOR flanks and not scatter from the lower flanks. By receiving scattered wavefields only in the direction facing toward the ridge flank, and not in the direction facing away, acousticians can break the right-left symmetry (ambiguity) problem associated with receiving arrays.

ARSRP field work will occur in three phases during 1991–1993: a preliminary Acoustic Reconnaissance Experiment to identify acoustic scattering centers on the west flank of the Mid-Atlantic Ridge (1991); reconnaissance geological/geophysical survey of the Acoustic Reverberation Corridor in 1992 (Figure 1); and detailed, high-resolution, near-bottom surveys and acoustic experiments on specific targets of acoustic-scattering interest in the corridor in 1993. Following the 1991 Acoustic Reconnaissance Experiment, the latitudinal position of the Acoustic Reverberation Corridor may be adjusted slightly to better include specific acoustic targets.

Calibrating and Comparing Instrumentation

The ocean bottom and subbottom in the Natural Laboratories will become highly characterized at horizontal and vertical scales of tens to hundreds of meters regionally, down to centimeter scales within progressively more restricted areas. In coming years, this detailed knowledge will facilitate a variety of calibration and intercomparison studies of bottom-sensing instrumentation, geologic and acoustic models, and analytic techniques. Examples include intercalibration of acoustic, laser-scanning, and photographic/video imaging of seafloor roughness; intercomparison of deterministic and statistical techniques in analysis of morphology; intercomparison of inversion and in situ sampling techniques to measure subbottom volumetric parameters; and comparison of scattered acoustic wavefields, measured in frequency ranges of 10 Hz–100 kHz, with predictions from scattering theory and numerical models that use quantitative surface and subsurface geologic data.

Characteristics of the Natural Laboratories

Mid-Atlantic Ridge

The region of the Atlantic Natural Laboratory encompasses a major transform-fault zone (Kane Fracture Zone) and its off-axis extensions, together with about eight spreading segments that are separated by small-offset, second-order discontinuities [*Sempere et al.*, 1990]. Off-axis, the region extends onto the lower ridge flanks (40- to 50-Ma crust) and could be extended westward in the future to include thickly sedimented seafloor on the eastern Bermuda Rise. The Mid-Atlantic Ridge (MAR) previously has been surveyed at and near its axis with Sea Beam multibeam bathymetry (Figure 1) [*Pockalny et al.*, 1988; *Sempere et al.*, 1990; *Patriat et al.*, 1990].

Within this region, most of the ARSRP effort will concentrate in an Acoustic Reverberation Corridor on the west flank of the Mid-Atlantic Ridge (Figure 1). The corridor will be approximately 150 km wide (along isochrons) and 450 km long so as to encompass at least two spreading segments and their bounding discontinuities and to cover a long (about 40 m.y.) record of crustal accretion and tectonism. The corridor has the following characteristics.

(1) It includes two complete ridge segments and their bounding small-offset second-order discontinuities, all of which appear to have migrated along the Mid-Atlantic Ridge axis with time [*Rona et al.*, 1976; *Schouten et al.*, 1987].

(2) The seafloor is unsedimented to thinly sedimented, with the thickest sediments (hundreds of meters) occurring only in local turbidite ponds.

(3) It abuts the "TAG" area on the MAR axis where active hydrothermal venting is documented and where existing surveys provide detailed data on the gravity field [*Rona et al.*, 1976, 1986] and on seafloor morphology [*Sempere et al.*, 1990].

(4) It merges along its southern margin with basement-structure mapping (250-m contour interval, adapted largely from Navy multibeam bathymetry) of a swath of crust along the Kane Fracture Zone [*Tucholke and Schouten*, 1988].

(5) The corridor is not influenced by major transform faults (for example, Kane Fracture Zone) or the associated edge effects of their old-side, cold-bounding lithosphere. However, future expansion of the Acoustic Reverberation Corridor to include the Kane Fracture Zone, and to build upon the existing data base there, is possible. Existing Kane Fracture Zone surveys include Sea MARC II coverage of the fracture zone on crust younger than 60 Ma [*Tucholke et al.*, 1988], as well as Sea Beam surveys, SeaMARC I coverage, *Alvin* dives, and ANGUS photographic coverage along the Kane transform and adjacent ridge axes [*Pockalny et al.*, 1988; *Kong et al.*, 1988; *Karson and Dick*, 1983].

East Pacific Rise

To address the question of how variability in crustal accretion relates to faster spreading rates and greater magma supply, the second ONR Natural Laboratory has been established on the East Pacific Rise (EPR) between about 8°N and 10°30'N (Figure 2). ONR-sponsored research in this region will be funded from the ONR Geology and Geophysics core program. The EPR Natural Laboratory was selected for the following characteristics.

(1) The spreading rate is fast (120 mm/yr) so that relief elements generated by seafloor spreading have good lateral separation and can be clearly resolved.

(2) The area is "typical" in that it contains the full range of scales of ridge segments and ridge-axis discontinuities (Figure 3).

(3) Both pelagic and terrigenous sedimentary sources create a range in the degree of sediment cover on the ridge flanks.

As a result of these factors, the area has the full range of sizes and shapes of seafloor morphology commonly produced at fast-spreading ridges. Analyses from this region can be extrapolated to most seafloor areas created at spreading rates from 60 to 180 mm/yr, more than roughly 50% of the deep seafloor. This area also has been selected as the primary target for long-term study on a fast-spreading ridge by the various RIDGE program working groups, and it is a prime site for focused, very deep drilling on a mid-ocean ridge by the Ocean Drilling Project.

A vast amount of both regional and high-resolution data already has been collected in the area, including nine Sea Beam cruises; one SeaMARC I and three SeaMARC II surveys; multichannel seismic reflection plus ocean-bottom seismometer (OBS) refraction surveys near the EPR axis (three legs) including the most detailed ridge-crest seismic tomography experiment to date; five legs of geochemical sampling; three Deep-Tow cruises; two *Argo-Jason* expeditions; and four *Alvin* expeditions. The available data, however, have been acquired almost entirely along the axis of the EPR, and they consequently define only the recent architecture of the plate boundary. An off-axis, spatial and temporal perspective, similar to that already noted for the Atlantic, is needed to define how the magmatic and tectonic elements have evolved. An ONR-funded SeaMARC II/Sea Beam/gravity/magnetics cruise recently surveyed part of the Pacific Natural Laboratory in late 1990 (Figure 2). Additional work in the 1991–1994 time frame is expected to focus on more specific targets within the Pacific Natural Laboratory. As in the Atlantic, a nested series of investigations will be conducted, and a wide range of geologic problems are available to be addressed by researchers in seismology, geochemistry, petrology, volcanology, structural geology and quantitative geomorphology.

Contributions to Crustal Study

The ONR Natural Laboratories open two kinds of new opportunities to the marine scientific community. First, surveys already planned will provide a wealth of new, off-axis data and insights that currently are unavailable. Second, the ONR commitment to specific "test beds," and to high levels of analyses therein, creates opportunities both within and outside the context of ONR funding for additional detailed research (for example, detailed geochemical sampling, crustal refraction studies, etc.) over large seafloor regions that already will be geologically well characterized at a reconnaissance level or better. Furthermore, such extended research can expand the study areas to adjacent or conjugate crust and clearly take advantage of the existing geologic "ground truth" within the Natural Laboratories.

The survey and analysis of data from the Natural Laboratories will contribute to fundamental understanding of the origin, evolution, and properties of oceanic crust in a number of ways. In the simplest case, detailed data from a single ridge flank can be used to address questions about the aging processes of oceanic crust. Is tectonism important off axis, and what are the scales and contributory mechanisms? Do off-axis volcanism and hydrothermalism play a significant role in modifying crustal structure and bulk properties? We know that seawater penetrates faults and can reach and hydrate lower crustal and upper mantle rocks; does this process stimulate significant serpentinite diapirism off axis, especially in the slowly accreted, highly tectonized crust of the Atlantic? What are the nature and rates of sedimentation and mass-wasting processes off axis, and how do they relate to changes in seafloor morphology and bulk properties of the oceanic crust? How do all these factors affect the BSB scatter of acoustic wavefields? In addition to addressing these questions, the multiscale bathymetric data to be acquired (resolution down to meter scale) will provide a fertile field to assess the degree of self affinity of seafloor fabric across scales. Is there some threshold scale or scales below which parameters of statistical characterization change in response to changing dominance of various geologic processes?

As detailed survey data are acquired on *both* ridge flanks within the Natural Laboratory regions, a whole new set of questions can be addressed, many of which have puzzled geoscientists for years. With off-axis data, a complete record (that is, both sides) of numerous cycles of crustal accretion and tectonism will be obtained. From this record, the nature of a typical cycle in both fast- and slow-spreading regimes can be reconstructed unambiguously, and the natural variability of the associated geologic processes can be assessed. In addition, it will be possible to fully determine flank-to-flank asymmetries in crustal structure, to relate these to overall asymmetries in seafloor spreading patterns, and to examine the mechanisms responsible for the variability.

Detailed surveys of conjugate ridge flanks extending over a significant period of geologic time (>4 m.y. in Pacific, about 40 m.y. in Atlantic) also will make it possible to investigate the response of crustal structure to changes in relative and absolute plate motion. Abyssal-hill fabric tends to be orthogonal to flow lines of relative plate motion [e.g., *Lonsdale*, 1977], probably because this is the least-work configuration of the system [*Lachenbruch and Thompson*, 1972). The long crustal records will facilitate identification of relative plate-motion changes and the sensitivity of orientation of seafloor fabric to these changes. Furthermore, the migration of ridge segments and their associated small bounding offsets will be clearly defined, so that possible correlations between migration and absolute plate motion [e.g., *Schouten et al.*, 1987] can be tested.

Finally, the off-axis data will provide for the first rigorous examination, over long time scales, of how ridge segments and small nonrigid offsets originate, grow, and decay, either in response to changes in plate motion or because of inherent instability in the locus or vigor of magmatic activity at the spreading axes. In the Pacific Natural Laboratory, the longer-term history of large-offset transforms (Clipperton, Siqueiros) in fast-spreading crust also will be illuminated.

The conceptual framework of spatial scales and mechanisms of crustal accretion and tectonism along mid-ocean ridges is now well-founded in observation and theory, and RIDGE-related efforts will test and expand these concepts with on-axis and near-axis studies. The off-axis Natural Laboratories add significant new and complementary opportunities to understand the additional dimensions of how these systems have operated and evolved over long periods of geologic time, and how their ocean-crust products control scattering of acoustic wavefields.

Acknowledgments

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L E G I S L A T I V E
U P D A T E

How the House Voted on Space Station

The House of Representatives voted 240 to 173 on June 6 to restore funding for Space Station *Freedom* in this year's appropriations bill for the National Aeronautics and Space Administration. Here is the breakdown of the vote, with representatives who favored the amendment restoring *Freedom* listed first.

Yeas

Democrats (107): Anderson (CA), Andrews (TX), Andrews (NJ), Annunzio (IL), Applegate (OH), Aspin (WI), Bacchus (FL), Barnard (GA), Bennett (FL), Bevill (AL), Boucher (VA), Brewster (OK), Brooks (TX), Browder (AL), Brown (CA), Bryant (TX), Bustamante (TX), Byron (MD), Cardin (MD), Chapman (TX), Coleman (TX), Cooper (TN), Cramer (AL), Darden (GA), de la Garza (TX), DeFazio (OR), Dicks (WA), Dixon (CA), Dooley (CA), Downey (NY), Eckart (OH), Edwards (TX), Edwards (CA), English (OK), Erdreich (AL), Fascell (FL), Fazio (CA), Feighan (OH), Frost (TX), Gaydos (PA), Gejdenson (CT), Gephardt (MO), Geren (TX), Gibbons (FL), Glickman (KS), Gordon (TN), Hall (TX), Hall (OH), Harris (AL), Hayes (LA), Hochbrueckner (NY), Horn (MO), Hubbard (KY), Hutto (FL), Jefferson (LA), Jenkins (GA), Jones (NC), Kennelly (CT), Kolter (PA), Kopetski (OR), Lantos (CA), LaRocco (ID), Laughlin (TX), Lehman (CA), Levine (CA), Lipinski (IL), Lloyd (TN), Long (IN), Matsui (CA), McCurdy (OK), McMillen (MD), Mineta (CA), Mollohan (WV), Moran (VA), Neal (MA), Oakar (OH), Ortiz (TX), Pallone (NJ), Pease (OH), Perkins (KY), Peterson (FL), Pickett (VA), Pickle (TX), Rahall (WV), Richardson (NM), Roe (NJ), Sarpalius (TX), Sawyer (OH), Slattery (KS), Stallings (ID), Stenholm (TX), Swett (NH), Swift (WA), Tallon (SC), Tanner (TN), Tauzin (LA), Taylor (MS), Thomas (GA), Thornton (AR), Torres (CA), Torricelli (NJ), Traficant (OH), Valentine (NC), Volkmer (MO), Wilson (TX), Wise (WV), Yatron (PA)

Independents (0)

Republicans (133): Allard (CO), Archer (TX), Armey (TX), Baker (LA), Ballenger (NC), Barrett (NE), Barton (TX), Bateman (VA), Bentley (MD), Bilirakis (FL), Bliley (VA), Boehlert (NY), Boehner (OH), Broomfield (MI), Burton (IN), Callahan (AL), Campbell (CA), Chandler (WA), Clinger (PA), Coleman (MO), Combest (TX), Cox (CA), Crane (IL), Cunningham (CA), Dannemeyer (CA), Davis (MI), DeLay (TX), Dickinson (AL), Doolittle (CA), Dornan (CA), Dreier (CA), Edwards (OK), Emerson (MO), Fawell (IL), Fields (TX), Franks (CT), Gallegly (CA), Gekas (PA), Gilchrest (MD), Gillmor (OH), Gingrich (GA), Goodling (PA), Goss (FL), Gradison (OH), Gunderson (WI), Hammerschmidt (AR), Hancock (MO), Hansen (UT), Hastert (IL), Hefley (CO), Herger (CA), Hobson (OH), Holloway (LA), Hopkins (KY), Horton (NY), Houghton (NY), Hunter (CA), Hyde (IL), Inhofe (OK), Ireland (FL), James (FL), Johnson (CT), Johnson (TX), Kasich (OH), Klug (WI), Kyl (AZ), Lagomarsino (CA), Lent (NY), Lewis (CA), Lewis (FL), Lightfoot (IA), Livingston (LA), Lowery (CA), Machtley (RI), Marlenee (MT), McCandless (CA), McCollum (FL), McCrery (LA), McDade (PA), McEwen (OH), McGrath (NY), Meyers (KS), Michel (IL), Miller (OH), Moorhead (CA), Morella (MD), Morrison (WA), Myers (IN), Nichols (KS), Oxley (OH), Packard (CA), Petri (WI), Porter (IL), Quillen (TN), Regula (OH), Rhodes (AZ), Ridge (PA), Riggs (CA), Rinaldo (NJ), Ritter (PA), Roberts (KS), Rogers (KY), Rohrabacher (CA), Santorum (PA), Saxton (NJ), Schaefer (CO), Schiff (NM), Schulze (PA), Sensenbrenner (WI), Shaw (FL), Skeen (NM), Slaughter (VA), Smith (OR), Smith (NJ), Smith (TX), Snowe (ME), Spence (SC), Stearns (FL), Stump (AZ), Sundquist (TN), Taylor (NC), Thomas (CA), Thomas (WY), Vander Jagt (MI), Vucanovich (NV), Walker (PA), Walsh (NY), Weber (MN), Wolf (VA), Wylie (OH), Young (FL), Young (AK), Zeliff (NH)

Nays

Democrats (145): Abercrombie (HI), Alexander (AR), Andrews (ME), Anthony (AR), Atkins (MA), AuCoin (OR), Beilenson (CA), Berman (CA), Bonior (MI), Boxer (CA), Bruce (IL), Carper (DE), Carr (MI), Clay (MO), Clement (TN), Collins (MI), Collins (IL), Condit (CA), Conyers (MI), Costello (IL), Cox (IL), Coyne (PA), DeLauro (CT), Dellums (CA), Derrick (SC), Dingell (MI), Donnelly (MA), Dorgan (ND), Durbin (IL), Dwyer (NJ), Early (MA), Engel (NY), Espy (MS), Evans (IL), Flake (NY), Foglietta (PA), Ford (TN), Ford (MI), Frank (MA), Gonzalez (TX), Gray (PA), Guarini (NJ), Hamilton (IN), Hatcher (GA), Hayes (IL), Hefner (NC), Hertel (MI), Hoagland (NE), Hoyer (MD), Hughes (NJ), Jacobs (IN), Johnson (SD), Johnston (FL), Jones (GA), Jontz (IN), Kanjorski (PA), Kaptur (OH), Kennedy (MA), Kildee (MI), Kleczka (WI), LaFalce (NY), Lancaster (NC), Lehman (FL), Levin (MI), Lewis (GA), Lowey (NY), Luken (OH), Manton (NY), Markey (MA), Mavroules (MA), Mazzoli (KY), McCloskey (IN), McDermott (WA), McHugh (NY), McNulty (NY), Mfume (MD), Miller (CA), Mink (HI), Moakley (MA), Montgomery (MS), Moody (WI), Murphy (PA), Murtha (PA), Nagle (IA), Natcher (KY), Neal (NC), Nowak (NY), Oberstar (MN), Obey (WI), Olin (VA), Orton (UT), Owens (NY), Owens (UT), Panetta (CA), Parker (MS), Patterson (SC), Payne (NJ), Payne (VA), Pelosi (CA), Penny (MN), Peterson (MN), Poshard (IL), Price (NC), Rangel (NY), Ray (GA), Reed (RI), Roemer (IN), Rose (NC), Rostenkowski (IL), Rowland (GA), Roybal (CA), Russo (IL), Sabo (MN), Sangmeister (IL), Savage (IL), Scheuer (NY), Schroeder (CO), Schumer (NY), Serrano (NY), Sharp (IN), Sikorski (MN), Skaggs (CO), Skelton (MO), Smith (FL), Smith (IA), Solarz (NY), Spratt (SC), Staggers (WV), Stark (CA), Stokes (OH), Studds (MA), Synar (OK), Towns (NY), Traxler (MI), Unsoeld (WA), Visclosky (IN), Washington (TX), Waters (CA), Waxman (CA), Weiss (NY), Wheat (MO), Whitten (MS), Wolpe (MI), Wyden (OR), Yates (IL)

Independents (1): Sanders (VT)

Republicans (27): Bereuter (NE), Bunning (KY), Camp (MI), Coble (NC), Coughlin (PA), Duncan (TN), Fish (NY), Gilman (NY), Grandy (IA), Green (NY), Henry (MI), Kolbe (AZ), Leach (IA), McMillan (NC), Molinari (NY), Nussle (IA), Paxon (NY), Pursell (MI), Ramstad (MN), Ravenel (SC), Ros-Lehtinen (FL), Roth (WI), Roukema (NJ), Shays (CT), Upton (MI), Weldon (PA), Zimmer (NJ)

Not Voting

Democrats (14): Ackerman (NY), Bilbray (NV), Borski (PA), Campbell (CO), Dymally (CA), Foley (WA), Huckaby (LA), Kostmayer (PA), Martinez (CA), Mrazek (NY), Sisisky (VA), Slaughter (NY), Vento (MN), Williams (MT)

Independents (0)

Republicans (5): Gallo (NJ), Martin (NY), Miller (WA), Shuster (PA), Solomon (NY)