A Seismic and Geologic Study of Gulf of California Rifting and Magmatism

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The Rupturing Continental Lithosphere (RCL) initiative of the MARGINS program aims to understand the processes and controlling parameters of continental rifting. This initiative focuses on basic questions about the stresses that drive rifting; the deformational mechanisms responding to those stresses; the role of magmatism in localizing strain; parameters such as crustal thickness, composition and temperature that control deformational style; and parameters such as mantle temperature, volatile content, and small-scale convection that control magmatic input. The Gulf of California was chosen as one of two focus sites for this initiative (the central/northern Red Sea is the other) at the RCL TEI in Snowbird, Utah, January 2000 (see MARGINS Newsletter no. 5).

The Gulf of California is an excellent location to study continental rifting for a variety of reasons. It is one of the very few regions of the world where active rift processes can be studied across an entire, complete rift. The regional tectonic and geologic histories are reasonably well understood, and reconnaissance seismic profiles exist to guide future experiments. Extensional style varies along the length of the province, presumably because of differences in key parameters affecting rift development. Continental rifting is active in the northern Gulf and active extension along low-angle normal faults is observed onshore. Spreading segment boundaries are clear in bathymetric and potential field data, enabling geophysical transects to be located within single rift segments. The rift is likely only modestly volcanic, so that rift-related structures can be seismically imaged unobscured by thick lava. In addition to these scientific factors, the Gulf is located in a logistically convenient, highly accessible, politically stable, and well-studied part of the world, in a country with first-rate earth scientists, including scientists from CICESE, which is the premier earth science research institute of Mexico and is located on the Baja California peninsula. These characteristics ensure that the infrastructure exists to support long-term, coordinated interdisciplinary studies of the sort envisioned by the MARGINS program and make it likely that the Gulf of California will host the number and diversity of allied studies that, taken together, promise a quantum step forward in our understanding of rift processes.

Here we describe an integrated geological and seismological study of Gulf of California rifting that will begin in the Fall of 2002. This program will determine the first-order spatial and temporal patterns of extension and magmatism in the Gulf of California and thus will provide a regional foundation for subsequent studies in this focus area. An excellent review of the tectonic history of the region was presented by Martín-Barajas et al. in MARGINS Newsletter no. 6, and so here we will focus on describing the design and principal objectives of our program with only a minimum of geologic background. (The full text of the proposal for this program is available from the MARGINS web site.)
The Gulf of California

Rifting in the Gulf of California initiated as a response to major plate-boundary reorganization. The western margin of what is now the Baja California Peninsula was a subduction boundary prior to ~29 Ma, with the Farallon plate descending eastward beneath North America. The East Pacific Rise intersected the trench offshore of northern Baja California at ~28 Ma, initiating the Pacific-North American plate boundary as a transform margin that grew southward by ridge jumps, transferring Farallon-plate lithosphere to the Pacific plate and shutting off subduction magmatism from north to south as the offshore triple junction migrated southward. As subduction slowed and then ceased, parts of western North America became coupled to the Pacific plate along the former subduction zone, driving rift initiation in the Gulf of California and the transfer of the Baja Peninsula lithosphere onto the Pacific plate. Extension in the Gulf of California began at ~12 Ma in an east-northeast direction roughly orthogonal to the rift margins, with the remaining component of Pacific-North American relative plate motion taken up along dextral faults of the continental borderland near the trench. Since ~6.5 Ma, most plate-boundary slip has been concentrated in the Gulf, where long dextral transforms link short spreading centers, and at present nearly all of the modern Pacific-North American relative plate motion is accommodated within the Gulf and the Salton Trough.

Significant north-to-south variations in rift-basin morphology exist within the Gulf that probably represent consequences of along-axis differences in key parameters such as initial crustal thickness, initial geotherms, and syn-rift sedimentation. Rifting initiated throughout the Gulf at approximately the same time, and roughly the same amount of strain has accumulated across the various basins north to south. In the south, Alarcón Basin has rifted to completion and begun seafloor spreading (Fig. 1). Most of the extensional deformation here is present below sea-level, and the spreading center is lightly sedimented. Further north in the Guaymas Basin, distinct NE-trending overlapping spreading-center grabens are contained within bathymetric deeps with significant overlying sediment, which is intruded by spreading-center magmas. In the northern Gulf, where extension in the region of the Delfín Basin has not achieved seafloor spreading, much of the deformation is subaerial, including active high- and low-angle normal faults within the extensional province to the west (Fig. 1). The current locus of extension is heavily sedimented and has scarps and bathymetry that trend N-S rather than NE-SW. Nagy and Stock [2000] speculate that strength differences due to different arc-magmatic and extensional histories have played a role in creating along-Gulf differences in extensional deformation.

Scientific objectives

Our seismic and structural geologic program will delineate the geometries and patterns of crustal extension and rift magmatism along three main conjugate-margin transects across the Alarcón, Guaymas, and Delfín Basins, and an east-west profile across the Wagner basin (Fig. 1). The primary scientific objectives of this program include the following.

- **Determine the partitioning of strain throughout the extensional province.**

Our current view of lithospheric rupture relates extensional style (e.g. pure versus simple shear, or wide versus narrow rifts) to an interplay of lithospheric strength, crustal thickness, internal buoyancy forces, thermal conditions, magmatism, and strain rate. Spatial and temporal patterns of crustal extension are the primary proxy for the style of lithospheric extension. We will quantify these patterns of extension in the Gulf of California through a series of seismic transects that will provide detailed images of crustal thickness, velocity structure, stratigraphy, and internal deformation throughout the basins and across the margins, and through a structural geology program that will synthesize new and existing geologic data on the timing, sense, and magnitude of onshore deformation with the new seismic results. These linked efforts will produce a unified view of crustal extension across the province, enabling us to test models of rifting by assessing the symmetry of conjugate margins in terms of crustal thinning and structures accommodating strain.

- **Constrain rift magmatism and its role in strain localization and subsidence.**

Constraints on syn-extensional magmatism within a rift are key to understanding the mechanics of continental rupture. In addition to the need to measure the volume and distribution of new igneous material in order to assess extensional crustal thinning, rift magmatism is an indicator of asthenospheric mantle temperature and dynamics, which play a central role in the evolution of rifting. Rift magmatism also directly impacts the mechanics of extension through advection of heat and the weakening effects of dikeing. Also, the relative roles of mantle temperature and convective processes in generating rift magmatism remains a matter of considerable debate, and studies in the Gulf of California provide an opportunity to study these issues. The Gulf of California is underlain by a large negative upper-mantle shear-wave velocity anomaly, which, if due to higher temperatures, should imply excessive regional rift magmatism. Geological evidence suggests that the rift is relatively non-volcanic, however, presenting a paradox. Rift-related magmatic additions can generally be distinguished seismically from extended continental crust, and so the new data, in addition to clarifying the role of magmatism in rifting, will also help resolve this paradox.
Figure 1. Layout of the seismic experiment. White dots represent OBSs and blue dots represent onshore seismographs. The experiment involves 70 OBSs and 60 RefTek seismographs. Additional blue lines indicate approximate line lengths of MCS shooting that will be performed in addition to the main wide-angle/MCS transects. Final determination of the additional MCS shooting pattern will be made at sea based on real-time stacks of the MCS profiles. Road systems on the mainland are shown for the rift-normal Guaymas Basin transect to indicate feasibility of the deployment. Nominal instrument spacing on all of the transects is ~10 km. Approximate cross-Gulf tie points from Nagy and Stock [2000] are shown as stars on either end of the Delfín Basin transect to indicate the degree of conjugacy that can be expected across each basin. The dashed blue line crossing Delfín and Tiburón Basins is the transect of the CORTES-P96 seismic profile. The San Pedro Mártir fault is an active listric normal fault with extension in the direction of the Wagner Basin transect, and so its expression at depth may be imaged along that transect and with additional MCS profiling. Note that the Alarcón Basin transect crosses an apparent failed rift towards the center of the profile. The Tiburón basin, which has no significant bathymetric expression on this figure, is a similar feature along the upper Delfín basin transect.
• Relate along-axis differences in extensional style to controlling factors.

Along-strike differences in extensional style and rift-to-drift structure exist in the Gulf of California. In the north, rifting has not proceeded to seafloor spreading but rather is accommodated by broad continental extension, whereas in the south, clear seafloor spreading anomalies and a well-defined mid-ocean spreading center exist. Because total extension is relatively constant along the length of the Gulf, these variations must be due to other factors, such as differences in initial crustal thickness, lithospheric composition or thermal state, or the effects of sedimentation. The new data will assess the degree of variation in extensional style and some pre-rift parameters, providing an opportunity to examine the effects of these parameters on rift evolution.

• Assess the influence of sedimentation.

The strong variation in sediment input from north to south provides an opportunity to study the impact of sedimentation on subsidence, crustal deformation, and magmatic style during rifting. Rapid sedimentation in the north may have inhibited the formation of "normal" ocean crust, inhibiting the development of a mid-ocean spreading center and contributing to a wide transition zone in which extension is accommodated by a combination of magmatic intrusion and extension of sedimentary crust. Confined rift basins with substantial surrounding topography are not uncommon, and determining the influence of sediment input on margin architecture may clarify the origin of "transitional" crust on ancient non-volcanic rifted margins.

Research program

These objectives are best met through a linked seismic and geologic program. Marine seismic methods are ideally suited for the detailed imaging of crustal features offshore at a variety of scales. Multi-channel seismic (MCS) images will delineate faults and basement structure and will image Moho in many places. Velocity images derived from wide-angle seismic data recorded on closely spaced (~10 km) ocean-bottom seismometers (OBSs) and onshore seismographs will provide detailed crustal thickness measurements and will delineate internal crustal velocity structure at a resolution comparable to the instrument spacing. Extensional deformation extends onshore as well, and in the Gulf of California this extension was initially normal to the rift as opposed to the present-day oblique extension. To assess the spatial and temporal patterns of extension onshore, we include an onshore/offshore seismic program and a linked structural geology program. The history and patterns of upper crustal deformation can be determined onshore from geologic mapping, and are in fact reasonably well known in many parts of the region. Structural geology investigations that will incorporate this important body of knowledge into our delineation of structure along the main transects are thus a fundamental component of our program. This component includes both synthesis of existing data and new geologic data collection in key regions of interest.

The four main transects crossing the Alarcón, Guaymas, Delfín, and Wagner basins have been chosen to capture the along-axis variability in rift processes. The Alarcón, Guaymas and Delfín transects follow the present-day flow lines of oblique rifting and cross the active rift centers of these basins. The Wagner basin transect runs perpendicular to the locus of transtensional deformation there and in the direction of extension in this northernmost region where, to the west, active extension is accommodated along the listric Sierra San Pedro Mártir fault. This transect provides our best opportunity for imaging a low angle detachment fault and a style of deformation that may have been characteristic in the other basins at earlier stages of rifting. In addition to the wide-angle/MCS data along these main transects, ~800 km of additional MCS profiles will be acquired within each of the three basins. These additional profiles will focus on imaging the transition between oceanic and extended continental crust and assessing three-dimensional patterns of faulting and deformation.

The aim of the geologic component of this project is to provide geologic constraints on the timing, sense and magnitude of extension on land. A significant product of the structural geology program will be map-view palinspatic restorations of the Gulf of California extensional province. The geologic program will integrate existing data with data collected in targeted locations near the main seismic transects. This new mapping and structural analysis is critical for developing progressive deformation models of rifting in the Gulf extensional province because modern plate motion across the province is strongly transtensional, with right-lateral wrenching exceeding margin-perpendicular rifting by a factor of ~3. Transtensional shearing produces highly three-dimensional strain, including systematic rotation of tectonic blocks and fault arrays with progressive deformation. Progressive deformation models can only be established through detailed field studies, beginning with an inventory of the distribution, kinematics and relative ages of faults where they can be identified onshore. Satellite imagery will be used to identify fault traces, define offset makers, and focus field studies to examine fault surfaces and characterize fault kinematics. This information is critical for interpreting two dimensional seismic profiles that will likely traverse non-two-dimensional structures.

The structural investigations will be concentrated at the NW and W ends of the main transects in Baja California. In the north, there is strong evidence that east-dipping low-angle normal faulting was important in the evolution of the Baja California peninsula where the northern transects come onshore. There, the rift is in a segment where the dominant
transport direction of faults is top-to-the-east. The steep rift flank is bounded on the west by the active Sierra San Pedro Mártir listric fault (Fig. 1). Farther east and north, low-angle normal faults of Gulf age exist and some are apparently still active. Reconnaissance and detailed geologic mapping around the NW end of the northern transect will evaluate the locations of low-angle normal faults, the direction and magnitude of slip on them, and their ages. These data will be key to tying seismically imaged structure to exposed geology of the Peninsula and to evaluating the evolution of strain partitioning in this complex oblique rift. The central transects cross onto the Baja California peninsula where Luis Delgado of CICESE is involved in major projects. We will coordinate a summary and comparison of the known geology here and fill in areas where Delgado has not worked. In the south, extensive ongoing structural geologic projects exists. Major objectives of the geology program in the south are to coordinate and link the existing databases from north and south, to fill in the gap along the coast of Baja between La Paz and Loreto, and to continue the initial studies of Fletcher and Umhoefer on the islands south of the Alarcón. The geology of these islands is especially key as they offer a window into the upper crust that can be studied in detail. This work will be done in coordination with Tobias Schwennicke of the Universidad Autónoma de Baja California Sur in La Paz.

**Foundation for future studies**

New data from this program will enable us to begin reconstructing the tectonic, sedimentary, and magmatic histories of the rift from initiation to seafloor spreading. Results from this work, however, will not answer all outstanding questions relating this history to processes and controlling parameters. Additional types of data are clearly needed, including passive seismic measurements of deeper mantle structure, heat flow measurements across the Gulf, detailed swath bathymetry images, and further geologic work that extends beyond the scope of this proposal, including constraints on strain partitioning along the peninsula’s western margin. The information resulting from our project will establish an observational framework of crustal architecture that can be used by all investigators in their anticipated future work in this MARGINS focus site.

**References**


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The central/northern Red Sea region was selected as a MARGINS Rupturing Continental Lithosphere (RCL) initiative focus site by the research community during the January 2000 MARGINS workshop in Snowbird, Utah. From this, an organizational meeting for the Red Sea component of RCL was held during March 17-23, 2001, in Sharm el-Sheikh on the Egyptian Sinai Peninsula. A first-order objective of this meeting was to provide a forum to discuss the logistical requirements of working in the various countries bordering the Red Sea region. In addition, the meeting served to bring together researchers from the U.S. and the countries in the Focus Site region working on common geological problems relevant to the MARGINS RCL objectives. It has always been clear that the success of the MARGINS program can only be achieved by active collaboration with scientists from countries associated with the focus sites.

As a direct follow-up of the Sharm el-Sheikh meeting, the MARGINS Office arranged for the visit of a small U.S. delegation (comprising Bilal Haq, James Cochran and Garry Karner) from 31 August to 5 September 2001, to visit Saudi universities and institutes to:

- introduce the MARGINS program to Saudi researchers,
- discuss and formulate ways in which U.S. and Saudi researchers can collaborate and extend the excellent work already completed or currently being undertaken towards an understanding of the geological and tectonic development of the Red Sea region,
- define the logistical requirements of fieldwork in Saudi Arabia, both onshore and offshore, and
- seek advice on how to access to Saudi geological and geophysical databases.

During the meeting, the U.S. delegation met with researchers and representatives of the Saudi Geological Survey (Jeddah), the King Fahd University of Petroleum and Minerals (Dharan), the King Saud University (Riyadh) and the USGS Mission (Jeddah). The Saudi scientists were particularly receptive to being involved since the MARGINS RCL initiative was in the early stages of proposal preparation, thus allowing full participation of Saudi researchers in the planning and proposal process. Most importantly, the Saudi Geological Survey (SGS; http://www.sgs.org.sa) offered to act as the point-of-contact between the MARGINS Office and U.S. researchers to help facilitate invitations for visas, field logistics and fieldwork permits for onshore and offshore surveys. This is in addition to being involved actively with the MARGINS proposal process.

The SGS has made available a series of 1:250,000 geological maps of the coastal plain, escarpment and shield along the Red Sea margin in addition to aerial photographs, topographic maps, and road maps to help with MARGINS proposal planning. The SGS will also help to facilitate communication between U.S. and Saudi researchers and help to host future MARGINS workshops in Jeddah. By government decree, the SGS will be the repository for all Earth scientific data within the Kingdom and will make available these data to the community (note that there are no restrictions concerning access to Saudi potential field data). The MARGINS Office has a list of Saudi researchers interested in collaborating with their U.S. counterparts. A copy of this list and/or short-term loan of SGS reports and maps for proposal and fieldwork planning can be arranged through the MARGINS Office.

Despite the unparalleled events in the U.S. and overseas in the last few months, the planning of MARGINS projects continues in full earnest. The implementation of subsequent field programs will necessarily depend on future world events that could compromise the enactment of MARGINS experiments. Nevertheless, our meeting with the SGS and Saudi universities has presented the U.S. Earth scientific community with an unprecedented opportunity to reopen research initiatives in the Red Sea region in general, and in Saudi Arabia in particular. This opportunity has been formalized by the signing of a Memorandum of Understanding between the SGS and the MARGINS Office. The next step is for a similar MARGINS delegation to return to Cairo in order to define an Egyptian "facilitator" to help secure the necessary approvals and permissions for fieldwork in Egypt and obtaining permissions for the release of geological and geophysical data.
Two of the primary initiatives of the MARGINS Program are the Seismogenic Zone and the Subduction Factory. A series of workshops from 1997 to 1999 reinforced the significance of the Central America subduction zone as a prime focus for each of these initiatives. Field programs are underway, one drilling leg has occurred and a second is planned to focus on these objectives. By the summer of 2001 a significant amount of data had been obtained and processed, and it was time to assess what exists, to integrate land and marine data, and to discuss what is needed for the future. It is also a time to encourage modeling of these processes and to more fully integrate Central American scientists into these efforts.

A workshop was held July 9-13, 2001, at the Hotel La Condesa in Heredia, Costa Rica. Convenors were Eli Silver and Tim Dixon, and the Steering Committee consisted of Julie Morris, Marino Protti, Roland von Huene, and Donald Fisher.

Major foci of the workshop included:
• geodynamics of the seismogenic zone,
• distribution of fluids and chemical tracers through the subduction system,
• effect of the incoming plate on differences in seismicity and volcanic products along the arc system
• impacts of these processes on the human populations
• planning for the next generation of integrated studies

The importance of holding this workshop in Central America was to foster closer interaction between local scientists and foreign researchers, and to increase the integration of local scientists and their expertise into the interpretive phases of these programs.

Support for US and Central American participants was provided through NSF-MARGINS and International Programs funding. Additional support to cover some of the costs of field trips before and after the workshop was granted by the UCSC branch of the Institute for Geophysics and Planetary Physics (IGPP) and its Center for Study of Imaging and Dynamics of the Earth (CSIDE).

Summary of Recommendations

Seismogenic Zone

Role of incoming plate structure and plate kinematics on earthquake behavior and tsunami generation:

What is the role of seafloor structure, bathymetry and seamount subduction in controlling seismic behavior?

High-resolution seismic images along seamount chains from trench through seismogenic depths using a combination of reflection/refraction and passive source seismology to better determine the structure, mechanisms and location of the seismic activity are required. Theoretical modeling of seamount subduction is also needed. Studies of forearc deformation and its association with seafloor roughness need to be refined and extended beyond central Costa Rica.

Figure 1. Map showing the plate boundaries, locations of major earthquakes and arc volcanos in the Costa Rica-Nicaragua region.
What controls the difference in seismic behavior between the Costa Rican and Nicaraguan Subduction Zones?

Ongoing experiments are collecting data from the Nicoya and central Costa Rican segments that will allow characteristics of the seismogenic zone to be determined, such as its up and down dip limits, geometry and variations in seismic coupling, and thermal structure. Similar information characterizing the seismogenic zone in Nicaragua is not available but is required to understand the apparent differences in seismic coupling between these subduction zone segments and the tendency of the Nicaraguan margin to generate tsunami earthquakes.

What is the role of the upper plate in controlling earthquake behavior?

The resolution of this issue requires better imaging of the detailed structure of the margin wedge and slope sediments of the inner forearc through combined refraction/reflection. Information about timing, kinematics and rates of deformation is critical and necessitate integration of geodetic data, passive source seismology, onland studies of structure, uplift rates from marine terraces, and incision rates from fluvial terraces. A multidisciplinary approach is necessary to develop geodynamic models that characterize short term deformation in the context of average long term behavior.

How does aseismic slip occur, as continuous motion or as strain transients?

Installation of borehole strainmeters in these regions (where aseismic slip is inferred) is required to better assess the temporal spectrum of strain events.

Role of fluid, mass, heat, and volatile fluxes on mass fluxes and seismogenic behavior:

A strongly integrated approach that combines geophysical characterization, surface mapping of fluid flow patterns, subsurface measurements, laboratory and theoretical studies is crucial for a more complete understanding of the flux patterns in the forearc and seismogenic zone processes. Although the ultimate location of a deep-riser drilling site might be fundamentally constrained by the location that will allow the seismogenic zone to be drilled at the appropriate water (<2.5 km) and subsurface (<5-6km) depths, the site must be placed in the context of the surrounding forearc thermal, diagenetic, and fluid flow systems. A staged non-riser and riser-drilling program focused on transects running from outboard of the trench to the volcanic arc would provide this necessary context.

What are the initial physical, mechanical, chemical, thermal, and hydrologic conditions of the incoming plate along strike?

Constraints are needed on initial conditions and along strike and across strike variability in the incoming plate and forearc region. Shallow/surface measurements of pore pressure, temperature, chemistry, and fluid flux are required to constrain patterns of fluid escape through the forearc. Measurements should be placed in the context of high-resolution seismic reflection surveys. Additionally, non-riser investigations of the hydrologic properties and hydration state of the upper oceanic basement will be required. Further non-riser holes might also be highly beneficial if drilled through hydrologically active structures in the forearc and into the forearc basement complex.

How do these conditions change/evolve with depth down-dip?

Transects of non-riser shallow drilling and deep riser drilling are necessary and must penetrate into and, if possible, through the forearc basement complex, whose composition and hydrologic properties are at this time very poorly understood. The riser and non-riser transect would have a combined focus on (a) in situ measurements of thermal, hydrologic, and chemical state, (b) direct sampling of materials updip from or within the seismogenic zone, and (c) active hydrologic and geophysical experiments. Subsequent laboratory and theoretical studies will be key in extending these observations to (a) estimate conditions and mechanical properties at greater depth and (b) evaluate the effects of along-strike variability in initial state.

What are the volatile fluxes through the forearc and underthrust basement, and how do they vary along strike?

Addressing the question of fluxes requires repeated geophysical and hydrologic surveys combined with laboratory experiments and drilling, to define physical properties (e.g., porosity, rigidity, Poisson’s ratio) remotely - over large areas, at depths greater than those sampled by drilling, and potentially to monitor temporal changes - from acoustic properties and flow patterns.

How do fault properties and state change during pre-, syn-, and post- earthquake rupture periods?

Long-term monitoring both at the surface and in bore holes is necessary to understand interseismic (and perhaps seismic) changes in strain, pore pressure, chemistry, seismicity, and fluid expulsion patterns. A variety of novel experiments might be conducted including, as one example, shear wave splitting experiments to study changes in fracture dilation patterns that might provide important constraints on changes in forearc stress and fluid flux patterns. Continued earthquake seismology and geodesy will also be required to define along-strike differences in plate coupling, plate boundary properties, asperity geometry, and changes in interface properties that occur during the seismic cycle. Integration of earthquake seismology with appropriate laboratory experimental constraints is also clearly needed.
to improve the utility of earthquake seismology as a tool to probe fault properties and their temporal variability.

**Subduction Factory**

Effect of incoming plate structure on arc geochemistry and volcano behavior:

1. Accurate plate tectonic reconstructions are needed to allow prediction of what was subducted during recent Central American volcanic history.

2. Seismic experiments should be able to detect whether serpentinization of the uppermost mantle is present or absent during the bending that accompanies the steep subduction beneath Nicaragua. Seismic experiments can also determine the gross geophysical structure of the arc crust.

3. Drilling is necessary to quantify the element fluxes out of the subduction system in the forearc, a goal of upcoming ODP leg. Drilling can also determine the nature of the altered oceanic crust currently being subducted in Central America.

4. Continuing GPS measurements are necessary to allow detection of sliver motion and should allow refinement of Cocos-Caribbean plate motion vector and quantification of oblique component of plate motion. Detailed studies of active fault zones in Nicaragua would allow some of these questions to be addressed.

5. The effect of subduction erosion on the geochemical signature of the subducted Cocos Plate can be analyzed with further drilling to provide transects for paleobathymetric study. Additional methods for approaching this problem include the utilization of existing (corporate) wells for paleobathymetric study, field study of the Osa Peninsula (where recent uplift may have unroofed this process), and 3-D multichannel seismic study of the shelf basins offshore Nicaragua.

6. Determining the magma flux rate for several of the largest volcanic centers would greatly improve the estimate of output flux during the last 105 to 106 years. Current age dates of the active volcanic centers are completely inadequate. Volcanic ash layers on the Cocos Plate could provide a long term measurement of flux of silicic ashes.

7. Volcanological research shows huge variations in volcanic gas flux rates and huge gas excesses at the initiation of many large eruptions. Much better measurements are needed both of large eruptions and of the integrated flux of gas species through the flanks and groundwater systems of volcanoes during long-term quiescence.

8. Experimental petrology has not provided a full range of experimental controls on dehydration and other metamorphic reactions that are likely to be involved in the generation of slab-derived hydrous fluxes and/or silicic melts. This includes both phase relations and partition coefficients of incompatible elements. Furthermore, the melting in the mantle, caused by addition of hydrous, silicic fluxes, is not well constrained.

**Crust and mantle fluxes and evolution**

Very high priority should be given to active and passive seismic imaging of transects across central Nicaragua, Guanacaste, and the Central Valley, Costa Rica. High priority should also be given to completion of the geochemical characterization of late Quaternary volcanic rocks throughout Nicaragua and Costa Rica. Because of the large along-strike differences in 10Be and U-series disequilibria in volcanic rocks from these volcanoes, efforts should be made to relate new observations to these differences in order to constrain timescales and agents of element transport from slab to surface. Similarly, as tomographic images of the mantle wedge improve, it will be important to relate geochemical models of mantle melting to those images, especially inferred differences between decompression and flux melting.

A key uncertainty for interpretation of the magmatic output in this region is the nature of along-strike differences in the upper plate, both crust and mantle. Costa Rica may be the best modern arc for assessing the role of oceanic plateaux in the development of continental crust.

Another key uncertainty is the geological history of the arc and its inputs. Notable gaps are the origin and boundaries of the Caribbean Plateau, the pre-Miocene arc history, the timing and effects of the arrival of the Cocos Ridge, and the spatial-temporal extent and geochemical signature of the OIB volcaniclastic input to the arc.

The location and depth of hydration and dehydration of the basaltic crust and mantle of the subducting plate need better constraint. Key observations needed to test these ideas are heat flow measurements across the forearc, seismic studies designed to assess deep hydration on the outer rise and the loci of dehydration below the seismogenic zone, and experimental studies of mineral dehydration equilibria and kinetics and element partitioning therein.

Finally, an integrated petrological, geophysical, and geochemical study of an active volcano is necessary, emphasizing the origin of the magma, depths and volume of magma storage, differentiation and eruption processes and timescales, and hazard assessment. The longest-lived eruption in the area (indeed, in the world) is at Arenal for which some baseline data are available for such an integrated study.

**Natural Hazards and Effects on Local Populations**

The combined focus of two MARGINS research initiatives in Central America (Subduction Factory and SEIZE) presents a unique opportunity to advance our understanding of geologic hazards in this densely populated region. Collaborative, multidisciplinary research will yield significant new insights into the processes that generate natural hazards, their distribution and frequency, and the magnitude of their impacts on local
populations. As ambassadors of the international geoscience community, MARGINS scientists share a collective obligation to transfer their knowledge to local science, government, and education institutions in support of natural hazards mitigation efforts.

**Potential applications of MARGINS research**

**Volcanic hazards:** A significant contribution of MARGINS research in Central America will be the development of a comprehensive regional perspective on the overall characteristics and behavior of the volcanic arc. Detailed stratigraphic and geochronologic studies of volcanic sequences will greatly improve our understanding of the nature and frequency of volcanism throughout the region. Volcanic hazards assessments will benefit from studies of magma generation and movement, volatile and fluid fluxes, ground deformation and edifice stability, and the relationship between regional tectonic stress and volcanic activity.

**Earthquake and tsunami hazards:** Historically, the most damaging seismic events in this region are shallow upper plate earthquakes located within the volcanic arc. Additional seismic hazards include large normal faulting events in the outer arc, deep intraslab extensional earthquakes, and tsunamiigenic events on the subduction thrust. MARGINS research can help advance earthquake and tsunami hazards mitigation in Central America by: developing better crustal models for earthquake location; exploring triggering mechanisms between megathrust events and shallow intraplate seismicity; evaluating crustal deformation rates through geomorphic and geodetic studies; modeling the stress state within the subducted slab and the overriding plate; examining the frequency and hazards of poorly understood intraplate events; characterizing the source of tsunami earthquakes; and evaluating the potential tsunami hazards posed by submarine landslides along the offshore trench slope.

**Landslides and lahars:** Landslides and lahars pose a significant and widespread hazard throughout southern Central America. These phenomena are initiated through a complex interaction between local site conditions and triggering mechanisms. MARGINS research can improve our understanding of these hazards by exploring the relationships between geologic materials, rock weathering, hydrology, climate, tectonics, and topographic relief. Research results may reveal new insights on a number of important subjects including: the combined impacts of tectonic and climatic forcing on slope stability; the geochemical and hydrologic controls behind volcanic edifice collapse; the frequency and mechanics of mass wasting events as recorded in the stratigraphic record; and the role of mass wasting in the total flux of sediment off of the volcanic arc.

**Framework for knowledge transfer**

The effective application of MARGINS science to natural hazards reduction requires an efficient transfer of knowledge. This can be accomplished by following several general recommendations: 1) As part of their research goals, all MARGINS scientists should consider the applications of their research program toward understanding geologic hazards; 2) The MARGINS community as a whole should develop a strategy for communicating research results to local scientific institutions; 3) These local institutions should then serve as a natural interface with local governments, policy makers, educators, and the general public; 4) The transfer of hazards knowledge to local educators and into school curricula is particularly important; 5) Appropriate data should be compiled and incorporated into a regional database that can be used for hazard mapping; 6) The MARGINS community should help organize “disaster response teams” designed to bring appropriate scientific expertise into affected areas in support of local institutions.

**Additional funded MARGINS Programs 2001:**

When the list of funded MARGINS Programs for 2001 was compiled for no. 6 of this newsletter, one project was inadvertently omitted from the list made available to the MARGINS Office. It is therefore our pleasure to announce one more funded MARGINS proposal. The proposal text will be available on the MARGINS web site:

**NSF Award number 0118478:**

**Collaborative research: Long-term continuous monitoring of pressure, fluid chemistry, and hydrology in instrumented boreholes at the Costa Rica Subduction Zone**

M. Kastner
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This project will continuously monitor the pressure, fluid chemistry, and hydrology in two instrumented boreholes at the Costa Rica subduction zone, using long-term observatories (CORK and ACORK) installed during ODP Leg 203. The field program will 1) deploy pressure gauges and data loggers, OsmoSamplers, and osmotic flow meters in 3 CORKed boreholes along a transect across the deformation front of the subduction zone and 2) retrieve the OsmoSamplers, data stored in the data loggers and deploying new OsmoSamplers and pressure gauges, with the submersible Alvin. The fluid stored in the OsmoSamplers will provide a continuous 1.3 year record of fluid conditions collected at in situ conditions at weekly resolution, in three distinct hydrogeologic systems. The first flow system is the upper oceanic crust of the incoming Cocos Plate, the second is the return of a deeply sourced fluid along the decollement and the third is in the underthrust sediment section driven by compaction dewatering. By documenting the nature of these hydrogeologic systems it will be possible to better understand the effects of fluid flow at convergent margins on the shallow thermal structure and fluid content of the downgoing plate, the physical properties of the subduction zone interface, deformation style and transport of elements to the oceans.
The MARGINS Steering Committee appointed a group of scientists who met on 27-28 August at NSF Headquarters with the specific intent of composing an executive summary for the Source to Sink initiative. Specifically, the group was charged with outlining the implementation plans for research in the Waipaoa and Fly River dispersal systems and to highlight the compelling science this research will accomplish. The outcome of these deliberations were posted on MARGINS Website in early September and are contained in the Executive Summary to the Science Plan. An abstract of this Executive Summary is presented below.

Most of the events that shape the Earth’s surface both above and below sea level leave a record of their impacts in the sediment sequences that accumulate on continental margins. Yet, despite decades of intensely studying sedimentary systems, it remains unclear exactly how the stratigraphic record is constructed, or, for that matter, how to decipher the record so we can isolate the various climatic, tectonic, and eustatic processes that interacted to form it.

From the perspective of the Source-to-Sink community, the exciting challenge is to define and quantify the behavior of sediment dispersal systems. Clearly this challenge will require a holistic approach from mountain tops to the deep sea. There is strong optimism because, for the first time, the combined expertise of terrestrial and marine earth scientists will be focused on studies of sediment production, transport and accumulation in carefully selected study areas as part of the MARGINS Program. The Source-to-Sink initiative, therefore, aims to study the material flux from source regions to the rock stratigraphic record, and to significantly advance our understanding of the following fundamental questions:

- What processes control the rate of sediment and solute production in a dispersal system?
- How does transport through the system alter the magnitude, grain size, and delivery rate to sediment sinks?
- How is variability of sediment production, transport, and accumulation in a dispersal system preserved by the stratigraphic record?

Source to Sink will proceed as focused field investigations of landscape and seascape evolution, and of sediment transport and accumulation in selected dispersal systems. A key feature of this program is the collective effort to investigate well-selected field sites, where the complete source-to-sink system can be analyzed. Quantitative modeling will be integrated into the research: model predictions should help guide aspects of select field programs; field observations will validate/verify model outputs; numerical modeling will explore forward and inverse source-to-sink questions; and a comprehensive modeling effort will link the suite of products through a Community Sediment Model, akin to the Princeton Ocean Model or the Community Climate Model.

### General Science Plan

Sediment dispersal systems have distinct morphodynamic segments arranged in a serial fashion, and we are going to build on this structure by posing fundamental questions about process and stratigraphy linking the segments. Signal transfer through a system can be investigated as a “forward” or an “inverse” problem, or both (see Fig. 1)

The forward problem asks: what are the effects of various processes on signal transfer between a succession of environments and on the signature imparted to the preserved strata? In contrast, the inverse problem asks: what signatures in the stratigraphic record can be used to interpret sediment source dynamics in order to deduce the role of climate, tectonics, and sea-level variation in its formation? The answer to the forward problem may range from significant transfer of a pulse through segments of the dispersal system (top option in Fig. 1) to complete attenuation of the pulse along the dispersal system, such that locally generated signals (e.g., from sediment dynamics) are recorded in the lower segments of the system (middle option in Fig. 1). The time scales for these two approaches generally fall into one of three time categories: short term (present to 1 kyBP), medium term (1k to 18 kyBP), and long term (>18 kyBP), corresponding to sea-level conditions of highstand, transgression, and lowstand, respectively.

At present, we have little predictive ability to address the forward problem and limited stratigraphic criteria for the inverse problem. It is our central argument that the only way these two fundamental questions can be addressed is through a well-structured, nested research plan involving collaborative efforts of individuals from disparate backgrounds integrating whole systems, and including all morphodynamic segments present in those systems.

To tackle these problems, a general program of investigation should be composed of:

- computational and physical model building/testing to illuminate mechanisms of sediment transport and stratigraphy generation under various controls;
- field investigation of sediment production, transport and accumulation, and associated mechanics and rates; and
• stratigraphic documentation at appropriate spatial concentration to provide desired temporal resolution.

Fiscal and practical considerations will require some sequencing of these efforts. For example, documentation of the stratigraphy can be done in phases, such as by working through the different storage elements of the morphodynamic segments, and by varying the temporal resolution through a progression between the finest-scale deposits of the past thousand years and longer, deeper records. Monitoring and modeling of active processes are examples of work that should occur throughout the course of the studies.

**New Zealand and Papua New Guinea Opportunities for Research**

In order to generate a comprehensive understanding of processes producing, transporting, and accumulating sediment on the Earth’s surface, investigation of more than one dispersal system is needed to encompass a range of environmental processes and stratigraphic styles. The community identified two study sites for investigation, New Zealand and Papua New Guinea, and decided that the first efforts would be undertaken in the Waipaoa and Fly dispersal systems. Plans presently exist for these systems (see full Executive Summary), and subsequent workshops will develop implementation plans for later portions of New Zealand and Papua New Guinea (South Island and Markham River, respectively).

Fundamental differences between the Waipaoa and Fly systems result from their latitudinal settings (temperate versus tropical) and basin size, for example:

- sediment residence time in drainage basins - Waipaoa, short; Fly, long;
- seasonal river discharge - Waipaoa, episodic; Fly, steady;
- dominant oceanographic variability - Waipaoa, cyclonic storms; Fly, trade winds;
- sediment sources - Waipaoa, only fluvial siliciclastic; Fly, mixed siliciclastic and carbonate
- shelf stratigraphic architecture - Waipaoa, basin infill; Fly, clinoform progradation.

These and other contrasting sedimentary considerations provide a wide variety of processes and stratigraphic signatures, which will not only help with development of a global understanding for sedimentation, but also will allow greater fundamental insights through comparison of the mechanisms and patterns found in the two areas.

**Waipaoa Dispersal System**

The Late Holocene Waipaoa sediment dispersal system is compact and easily accessible, extending from terrestrial uplands to the continental slope. The system is characterized by large sediment fluxes and a high-resolution sedimentary record required to determine the response from Holocene environmental changes and to identify relatively small-scale perturbations in terrestrial conditions. Because of the small scale of the system and the large signals, the Source-to-Sink goal of quantifying sediment production, transport and accumulation in various morphodynamic segments during the Holocene can realistically be achieved. Episodic and highly concentrated river outflow into an energetic coastal environ-

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*Figure 1. Several scenarios might explain how a sediment discharge “signal” varies through the morphodynamic segments of sediment dispersal systems. Three scenarios are displayed and can be viewed from a “forward” modeling perspective or an “inverse” modeling perspective, as discussed in the text. The time scale is shown as arbitrary, but needs to be defined in order to identify the processes responsible for impacts on the signal transitions. The first row of graphs shows a strong uplands input that progressively attenuates downstream, but is still visible in the marine record. The second row shows a negative signal damping completely downstream and being replaced with a signature driven by tidal, shelf or deep-water transport dynamics. A third scenario shows that even without variations in source sediment, local processes can lead to significant temporal variation in sediment flux. The two focus sites have strong signals generated, but little is known about how the signals are transferred.*
Workshop Report

Planning a workshop?
...Theoretical and Experimental Institute (TEI)?
...any other MARGINS activity?

Use the services of the MARGINS Office

An important role for the MARGINS Office is to assist with the logistics of organizing workshops and TEI’s. We look forward to working with Principal Investigators wishing to prepare proposals for these activities. Before writing proposals or articles for publication, please coordinate your efforts with the MARGINS Office, so we may optimize our service to the MARGINS science community. Our contact information is on page 19.
EarthScope is a new Earth science initiative that will constitute a "telescope into the Earth". The main purpose of EarthScope is to provide geophysical instrumentation with an unprecedented coverage of the continental United States, giving a more comprehensive, time-dependent image of the North American continent than any single discipline could provide. To this end, the EarthScope includes four components:

**USA**
- Array: a dense network of portable and permanent seismic stations that over the course of a decade will cover the continent with a grid of 2,000 sites.
- **The Plate Boundary Observatory (PBO)**: a distributed observatory of high-precision geodetic instruments designed to image the on-going deformation of western North America. PBO will extend from the Pacific coast to the eastern edge of the Rocky Mountains, and from Alaska to Mexico.
- **The San Andreas Fault Observatory at Depth (SAFOD)**: a 4-km-deep observatory drilled directly into the San Andreas Fault zone near the nucleation point of the 1966 Parkfield earthquake.
- **The Interferometric Synthetic Aperture Radar (InSAR)**: a satellite mission that will provide dense spatial (30 to 100 m) and temporal (every 8 days) measurements of the North American and Pacific plates as they move past each other and deform the surrounding regions.

On October 10 to 12, 2001, the workshop "EarthScope, Making and Breaking a Continent" was held in Snowbird, Utah, with the aim to discuss and develop further the science objectives for EarthScope. The workshop was attended by c. 200 earth scientists, and was organized around a few invited keynote talks and extensive group discussions.

The workshop began with a presentation of the status of EarthScope and the objectives of the workshop by Tom Jordan of the EarthScope Working Group. As a direct follow-up, Herman Zimmerman of the National Science Foundation summarized the present status of EarthScope funding. Although Congress has not approved EarthScope, NSF is optimistic that the proposal will likely appear in the President’s next budget. The only uncertainty is how recent and possible future terrorist and war activities will influence future budgets. It was emphasized that EarthScope still is in the beginning of the start-up phase. NASA and the USGS are also supporting the EarthScope initiative.

Two more invited talks followed: Roberta Rudnick talked about "Making Continents", emphasizing the importance of integrated multidisciplinary studies to deduce the processes that shape the continents. Peter Molnar then gave a presentation about "Large Scale Continent Dynamics", also stressing that multidisciplinary studies are vital to address how mantle dynamics affect continental tectonics.

In the afternoon of the first day, participants separated into working groups for discussions of the science focus of EarthScope. The working groups were divided along the scientific themes relevant to the study of the continents:

1. Fault properties and the earthquake process
2. Short time/distance scale deformation - crustal strain transfer
3. Large-scale continental deformation
4. Continent structure and evolution
5. Deep Earth structure - interaction mantle-crust
6. Convergent margin processes - Magmatic-volcanic processes

The outcome of these group discussions was presented on the following morning. The long lists of science questions raised by the working groups are much too extensive to be summarized here. Still, it was remarkable how similar the science goals of the MARGINS Program are to those defined for EarthScope by the workshop participants.

Bill Holt then presented an invited talk about "Using surface observations to constrain the direction and magnitude of mantle flow beneath western North America", whereafter the working groups reconvened to address the operations focus of EarthScope.

There was some discussion concerning data management issues. While all groups were in favor of making raw data available, there was extensive discussion about what derivative databases should be constructed, and how they should be implemented. A translation of the data sets to a level where they can be understood and manipulated by non-specialists would greatly aid in accomplishing a truly integrated and multidisciplinary application of the data. To this end, all working groups recommended the development of easy-to-use and readily available software tools for manipulating the data. The final discussion topic in this round was "How can communication be established/maintained with complementary research efforts?" Several groups stressed MARGINS and the overlapping research interests, and the desirability of extending EarthScope into the offshore areas was...
also emphasized.

The late afternoon session started with the last of the invited talks, when Wayne Thatcher talked about "EarthScope and natural hazards research". This naturally led on to the final round of working group sessions, which focused on the EarthScope product. One main topic was education and outreach. It was stressed that EarthScope provides excellent opportunities for interactions with the public, and approaches in the style of "EarthScope comes to your neighborhood" were suggested. A workshop specifically devoted to education and outreach within EarthScope will be held on 31 January to 1 February 2002 in Boulder, Colorado.

The final day began with a summary of the previous day’s activities, and proceeded to a panel discussion with the EarthScope Working Group on the next steps and action items. The list of topics included: 1) communication within and beyond EarthScope; 2) data management and information technology requirements; 3) education and outreach; 4) evaluation of funding requests, and finally; 5) non-MRE components necessary to EarthScope success. The majority of the workshop participants, had to leave before this discussion had reached any conclusions. A prepublication version of a Review of EarthScope Integrated Science as well as a brief workshop report was published on the EarthScope web site (http://www.earthscope.org) while this report was written.

Although the science targets overlap significantly between MARGINS and EarthScope, the geographic overlap is limited to a portion of the Gulf of California/Salton Trough focus site. Also, the EarthScope program does not include any offshore parts of the continents or the continental margins. As mentioned above, the necessity for going offshore was expressed several times over the course of the meeting, as well as the need to expand EarthScope into the neighboring countries, particularly Canada and Mexico.

However, in the Review of EarthScope Integrated Science the items most pertinent to the MARGINS community are not given any priority. Regarding extending the EarthScope effort to the offshore regions, the review committee recommends that "the EarthScope Working Group actively pursue coordination between the EarthScope and ocean sciences programs, including NEPTUNE, to ensure that the establishment of EarthScope facilities and the deployment of GPS-acoustic, strainmeter, and OBS arrays supported by the marine geological and geophysical community are complementary". This implies that EarthScope will not be responsible for any aspect related to offshore instrumentation, but will instead depend on individual, PI-driven proposals from the marine geological and geophysical community. We feel that this is possibly the wrong approach — EarthScope should take responsibility for the purchase and deployment of offshore/underwater OBS’s in order to insure adequate instrument and thus data coverage.

Likewise, during the workshop it was repeatedly expressed that excluding Canada or Mexico and Central America from EarthScope would leave gaps in the coverage that could seriously diminish the scientific value of the EarthScope product. The review committee’s statement that it "endorses the intent of EarthScope proponents to seek collaborations with colleagues in Canada and Mexico to extend the understanding of crustal and lithospheric dynamics beyond the borders of the United States" indicates that no active steps are presently intended to extend EarthScope to include Central America or Canada as crucial components of the plate boundary study.

The review ends on a positive note, as the committee "enthusiastically endorses the total program [of EarthScope] and all of its components". The committee is "confident that through broad earth science community involvement, the detailed plans and scientific benefits will be similarly well conceived and articulated [as the plan for the integrated EarthScope facilities]". Since EarthScope is still in the early stages of the startup phase, we believe that this is an appropriate time for the planning committee to include equipment funds for those areas of the continental offshore and Central America/Canada pertinent to the Earthscope mandate. This would automatically integrate two MARGINS Focus Sites — Gulf of California and Costa Rica/Nicaragua — and EarthScope, thus optimizing the utilization of resources, and maximizing the scientific output generated by both programs.
The introduction of an NSF-MARGINS Data Policy

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NSF is in the final stages of releasing a data policy for the MARGINS Program. The MG&G community is also reviewing its data acquisition and archiving procedures in light of the successful Database Management workshop in La Jolla held earlier this year. Ultimately, NSF will issue a document with the recommendations from the workshop. However, the MARGINS Program has been in operation for the last two years and its data policy issues need to be resolved now. The need for such a policy is clear. In order for the MARGINS Program to be successful, data and results need to be shared as rapidly as possible in order to maximize collaboration and data transfer within the program, attract new researchers, and optimize the construction and testing of hypotheses. MARGINS funding carries with it a fundamental responsibility for data sharing, archiving and dissemination because MARGINS is a time-limited program.

In order to encourage the integration of science within and across the MARGINS initiatives, MARGINS data need to be rapidly released and available to researchers. At the heart of the data policy is the principle that accepting NSF support obligates Principal Investigators to meet a series of data management requirements. For example,

- All raw data must be made freely available two years after data acquisition, consistent with the data release policies of IRIS, PASSCAL and OBSIP. In the case of datasets that are not available to the investigators at completion of the field-season/cruise, for example, because they are assembled by the relevant data-center before distribution, the two year moratorium period begins on the date that the complete dataset is made available to investigators. However, Principal Investigators are encouraged to release data to other focus site investigators as soon as possible following the end of a field season or completion of dataset processing.
- Processed, derived and interpreted datasets must be made publicly available as soon as possible, certainly within the lifetime of the grant. This policy applies even to those data and results that Principal Investigators have traditionally not been required to make publicly available (e.g. stacked and migrated seismic sections, geochemical analyses, DEMs and other rasters, geological samples and geochemical analyses).
- Basic metadata (e.g., data types, sample locations, cruise tracklines, etc.) must be provided to the MARGINS Office within 60 days of ending a field program. In due course and in collaboration with ongoing efforts in MG&G, the MARGINS Office is currently developing tools for preparing and formatting these metadata files.
- All raw data must be made freely available two years after data acquisition, consistent with the data release policies of IRIS, PASSCAL and OBSIP. In the case of datasets that are not available to the investigators at completion of the field-season/cruise, for example, because they are assembled by the relevant data-center before distribution, the two year moratorium period begins on the date that the complete dataset is made available to investigators. However, Principal Investigators are encouraged to release data to other focus site investigators as soon as possible following the end of a field season or completion of dataset processing.

An appropriate plan for data archiving and dissemination is a new and important element in consideration of proposals for funding. A data archive and dissemination plan will now be a necessary component of all MARGINS proposals. Investigators who cannot meet the conditions for rapid and complete release of data and results should state why in their proposed data plan.

It is the responsibility of the Principal Investigator(s) to provide to the MARGINS Office, for publication on the MARGINS Office web-site, details of and links to all datasets acquired or generated with MARGINS funding. NSF Program officers may seek information from the MARGINS Office about compliance with the MARGINS data policy when considering future funding decisions. Proposals funded through the NSF MARGINS Program after November 1, 2001, need to comply with the letter of this policy. All proposals funded through the NSF MARGINS Program since its inception in 1999 and prior to November 1, 2001 are required to make field program metadata and project data available to investigators as soon as is practically possible.

MARGINS Post-Doctoral Fellowship to be announced

Even though the fellowship details are still being finalized within NSF, we are bringing this fellowship scheme to the notice of the community so that application planning can begin in anticipation of the formal document from NSF. The success of the NSF-MARGINS Program requires a healthy exchange of ideas and research techniques between researchers and communities throughout the world. A post-doctoral appointment is a unique opportunity for a first-rate, early-career scientist to solidify research skills, build a track record, establish peer relationships, and acquire professional self-confidence. The MARGINS Steering Committee has therefore decided to initiate a MARGINS Post-doctoral fellowship.
Fellowship Program, pending final NSF approval, to provide support for post-doctoral researchers wishing to conduct research related to the MARGINS initiatives with MARGINS research groups, or individuals, based at United States institutions. Each fellowship will provide up to two years support, and although the research must be carried out at a U.S. institution, there is no citizenship requirement. The candidates will be selected by a sub-committee of the MARGINS Steering Committee and the NSF Program Managers, which will evaluate the relevance and priority of the proposed research to the MARGINS Program.

The MARGINS Post-doctoral Fellowship with all relevant information and application forms will be announced on the MARGINS web site and mailing list (http://www.ldeo.columbia.edu/margins) as soon as the fellowship is approved by the NSF.

The new InterMARGINS address:

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InterMARGINS Office moves to Southampton Oceanography Centre

The InterMARGINS Office is in the process of moving from Geomar in Kiel, Germany to the Southampton Oceanography Centre in UK. The Southampton Office will be run by Professor Bob Whitmarsh for at least the next two years. The address is given below. InterMARGINS is very grateful for the efforts of Dr Warner Brueckmann in running the Office in Kiel for the last three years and in getting InterMARGINS, which is still a fledgling organisation, up and running.

InterMARGINS is an international and interdisciplinary initiative concerned with all aspects of continental margins research. It is designed to encourage scientific and logistical co-ordination, with particular focus on problems that cannot be addressed as efficiently by nations or national institutions acting alone or in limited partnerships. At present InterMARGINS has a small number of fully paid-up members but a number of other countries have scientific programmes or scientists whose work strongly relates to the InterMARGINS objectives. Further information can be found at http://www.intermargins.org

InterMARGINS will co-host a U.S. MARGINS Town Meeting on the Nankai Seismogenic Zone Experiment during the AGU Meeting in San Francisco next December. A meeting of the representatives of the member countries is planned to take place during the 21-26 April 2002 European Geophysical Society General Assembly in Nice, France.

The European MARGINS Program — EUROMARGINS — is becoming operational, and the deadline for the first call for proposals expired on October 15th, 2001. In response to this call for proposals, the European Science Foundation (ESF) received 61 outline proposals, which are being processed as this is written. More information on EUROMARGINS can be found on ESF’s web site: http://www.esf.org
Since April, 2001 the MARGINS Office has been tracking the visits to the MARGINS web site, in order to realistically assess the profile of our visitors, and how often the web site is used. Some of the statistics collected are shown in the diagrams in Figure 1A-D.

The total number of hits on the web site varies considerably with time, but the average is not as high as we hoped. We would like to increase this by improving the web site to optimize its usefulness. To this end, a permanent user survey has been posted on the web site. If you have any suggestions on how to make the web site more useful, and how to attract more users, please take this survey, or e-mail your suggestions to Olaf Svenningsen (olafs@ldeo.columbia.edu).

The statistics presented here are not 100% reliable, since they depend on what information any web site visitor is releasing (knowingly or not...) through his/her computer’s operating system and web browser. For example, to demonstrate that the MARGINS web site is used all over the world, not just by U.S. researchers, this would be indicated by either the number of hits by countries/domains, or by languages of the operating systems. However, these two numbers differ, in an apparent contradiction. The following languages were registered (ordered according to decreasing number of hits): English (85%), Japanese, Italian, Spanish, French, German, Swedish, Arabic, Dutch, Korean, Portuguese, Turkish, Interlingue (an international language constructed in the early 20th century), and Norwegian (see Fig. 1 for countries/domains).

Another interesting note, is that web browsers older than version 4 of Netscape and MS Internet Explorer are almost completely phased out, opening new technical possibilities for the future development of the web site.

A period of more noticeable change lies ahead for the MARGINS web site. For example, enhanced within-site navigation, a clearer overall structure, and some new sections (perhaps most notably a data repository) will be added. The changes will be gradually introduced over the coming months. The entire MARGINS community is invited to act as testers, and it is much appreciated if any errors or idiosyncracies are reported to the Office.

The second, integral component of the MARGINS Office’s web services is the electronic mailing list. It presently has c. 1,200 subscribers, but this slowly growing number changes on a daily basis. The user survey on the web site also covers the mailing list, but any comments or suggestions are welcome. Please remember that the mailing list relies almost completely on input from the community. There is no formal procedure to submit a contribution, if you have any item you wish to post, e-mail it to: olafs@ldeo.columbia.edu. As a member of the MARGINS community, please help us to spread the word of what great and useful resources the MARGINS mailing list and web site are.

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**Figure 1.** Graphs showing selected access statistics for the MARGINS web site (http://www.ldeo.columbia.edu/margins). A shows hits per month from May to November 15th, 2001. In spite of the variability, the trend (if any) is of a slowly growing number of hits. B shows the operating systems of the visitors, and C shows what type and version of web browser that was used. Finally, diagram D shows from which domain the web site was visited. Note that the data in D depends on whether or not this information was provided by the remote server.
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