MARGINS 2009 Review

6. Other Impacts

6.1 Building an Interdisciplinary Community

MARGINS has succeeded at building a large, interdisciplinary and growing community over its decade. The program has funded 181 proposals (94 distinct projects) to 120 individual PIs, spanning many geosciences disciplines. A total of 908 different scientists have attended the 23 MARGINS-sponsored workshops since 2000, and 1360 receive the Newsletter worldwide. MARGINS groups organize special sessions at international meetings such as Fall AGU, where in 2006 MARGINS-related special sections made up 25% of all Tectonophysics submissions. The database of MARGINS-funded research articles exceeds **250** in peer-reviewed journals, with MARGINS-related research many times more. While much of the larger community is funded by other programs in the US and abroad, and many scientific questions have multiple roots, the MARGINS program has significant intellectual contribution to this major new, interdisciplinary community.

Workshops. Since the inauguration of the MARGINS Program in 1999, MARGINS has sponsored conferences to build a broad, interdisciplinary scientific community. A complete summary is given in the Supplementary Documents, and major ones are enumerated in the Table on the next page. *The Theoretical and Experimental Institutes* (TEIs; flagged in table) provide broad education across disciplines similar to short courses; one has taken place for each Initiative as shown in the Table. A TEI is designed to cross-educate diverse groups of scientists about controversies, approaches, techniques, and problems in a spectrum of disciplines relevant to the problem at hand. TEIs have led to new collaborations and multidisciplinary proposals, have entrained many scientists not previously working within MARGINS, and have trained a generation of young scientists to approach problems in an interdisciplinary manner. TEIs have been complemented by a variety of *Thematic Workshops* to address specific problems of interest to a number of MARGINS investigators, and *Focus Site Workshops* that have defined and (more recently) synthesized the work done at the workshops. In 2008 a series of *Synthesis Workshops* began, to summarize the MARGINS decade.

Since 2000, when the program funding began, 23 major and minor workshops were held, following 8 earlier planning workshops. The meetings served between 27 and 133 participants each. In nearly all cases, meetings are widely advertised (Eos, MARGINS listserv and newsletter, etc.), with a fraction of spaces reserved for students and post-docs. All are reported in a subsequent MARGINS newsletter. A web page is established for nearly all workshops (see Supplementary Documents for list), and remains on-line indefinitely, including presentation material from most speakers.

Most MARGINS Offices have kept records of workshop attendees, providing some insight into the broad spectrum of scientists enlisted to MARGINS workshops. Remarkably, a total of 908 different scientists, students, and other attendees have participated in the MARGINS workshops for which records exist (all since 2000); each of these attendees has attended on average 1.49 MARGINS workshops. Because all MARGINS Focus Sites lie abroad and major international partnerships shape the program, nearly 40% of all workshop participants come from countries other than the United States. Approximately 35% of attendees are graduate students or post-docs at the time of attendance. NSF-funded researchers also receive funding from a wide array of Ocean Sciences and Earth Sciences panels. Overall, this diverse group attests to a healthy, growing community.

Table: Summary of MARGINS-sponsored Workshops and TEIs

1988 (Irvine) Margins: A research initiative for Interdisciplinary Studies… [75]
1991 (Irvine): Mechanics of Lithospheric Deformation
1993 (Austin): Magmatism and Mass Fluxes at Continental Margins [42]
1993 (Palisades): Sedimentation and the Stratigraphic Record
1995 (Japan): ILP SEIZE workshop
1996 (Palisades), MARGINS Initial Science Plan [~50]
1997 (Kona), The Seismogenic Zone Experiment [~50]
1998 (La Jolla), The Subduction Factory [65]
1999 (Lake Quinault), Source-to-Sink [50]
2000 (Snowbird) TEI: Rheology and deformation of the lithosphere at continental margins (RCL) [99]
2000 (Eugene), TEI: Inside the Subduction Factory [95]
2000 (Tahoe), Source-to-Sink [80]
2000 (Puerto Vallarta) Rupturing of continental lithosphere in the Gulf of Calif. region [87]
2001 (Sharm el-Sheikh) Rupturing of continental lithosphere in the Red Sea / Gulf of Suez [61]
2001 (Heredia, Costa Rica), Central America Seismogenic Zone and Subduction Factory [118]
2002 (Boulder) , Building a community sediment model [60]
2002 (Honolulu), Izu-Bonin-Mariana subduction system [61]
2002 (Ann Arbor), Subduction zone dynamics and thermal structure [30]
2003 (Snowbird), TEI: The Seismogenic Zone Revisited [78]
2003 (Gisborne) Waipaoa focus area (Source to Sink) [35]
2003 (Costa Rica, Nicaragua), Field Workshop: Chemistry and flux of volcanic volatiles [80]
2003 (Kiel, Germany) Costa Rica Seismogenesis Project (CRISP)
2004 (Pontresina), InterMARGINS: Modeling the extensional deformation of the lithosphere [46]
2006 (Ensenada): Lithospheric rupture in the Gulf of California – Salton Trough region [75]
2006 (Woods Hole), Interpreting Upper Mantle Images [61]
2006 (Eel River), TEI: Teleconnections between source and sink in sediment dispersal systems [79]
2007 (Monterey), Integrated MARGINS/EarthScope Collaborations [77]
2007 (Arlington) Education: Bringing MARGINS science to the classroom [27]
2007 (Kiel) Building a global data network [82]
2007 (Heredia), Integration of SubFac and SEIZE studies in Central America [133]
2007 (Honolulu), Subduction Factory studies in the Izu-Bonin-Mariana arc [104]
2008 (Mt Hood), The next decade of the Seismogenic Zone Experiment [80]

Number of participants, where known, in [square brackets]. Details in Supplementary Documents.

Newsletter, listserv and web page. The MARGINS Newsletter is delivered twice yearly, reaching 1360 subscribers worldwide. Approximately 38% of subscribers are outside the U.S. Content includes workshop summaries, short contributed articles on new technologies or datasets of MARGINS interest, notifications of upcoming workshops and special volumes, lists of recent awards, special sessions at AGU and Ocean Sciences of MARGINS interest, profiles of MARGINS Post-docs and Student Prize winners, regular reports from the Chair, Program Manager and Steering Committee highlights, and any other information of interest to the community. The Listserv also relays information to the community, about a wide variety of events, opportunities and timely communications – the emails reach about 1200 subscribers.

The Web Page serves as a repository and link to a wide variety of programmatic, research and educational resources (*www.nsf-margins.org*). The page houses over 5 Gb of program-related data, including Science Plans, site- and initiative-specific data, policy statements, and meeting-related documents including presentation materials. It is currently run on a commercial server (*bluehost.org*), providing stability, security and transferability through Office moves. Bluehost reports 2700-4000 unique visitors per month to the MARGINS pages, visiting between 10700 and 17800 pages for monthly bandwidth of 3.3-4.1 Gb (obvious web crawlers and robots not included). Most popular pages are the

Forum on MARGINS Future, and past Newsletters. These statistics indicate that the web page serves a variety of community-building needs.

Data Sharing. Early in the program's history, the rapid and open dissemination of information was seen as a necessary requirement. It allows different research groups to take advantage of each other's results, and makes integration of disparate data possible. The MARGINS Data Policy (see Appendix) requires greater accountability and shorter "restricted" times than standard NSF policies. Metadata must be provided to the MARGINS data portal within 60 days of the end of a field program, and all data must be made available within 2 years. The Data Portal (*www.marine-geo.org/portals/margins*) provides infrastructure for metadata and some types of raw data archival, and provides direct access to other pre-existing data centers (e.g., IRIS, EarthChem, etc.). The Data group also builds and maintains intuitive interactive tools that sample much of these data, including the popular GeoMapApp application (*www.geomapapp.org*). These facilities are more fully described in the Program Management chapter of this Report.

6.2 Geohazards

The MARGINS research community has proven to be uniquely positioned to identify, address, and respond to natural hazards. This arises in large part from the scientific focus and understanding of active margins that generate such hazards, but also from very strong international collaborations that allow researchers to mobilize on-shore and off-shore resources around the world, often immediately following an event.

An excellent example of this capability lies in the sudden eruption of Anatahan in 2003. MARGINS researchers (e.g., Wiens et al. Nugget – see chapter 10) happened to be on site and made initial observations, and shortly thereafter other MARGINS scientists (Fischer et al. Nugget) and their international colleagues working in the Izu-Bonin-Marianas area were able to respond, visiting the island to measure and sample volcanic products, deploy seismometers, and carry out follow-up studies over months to years. Researchers worked directly with the USGS, as well as local authorities, (i.e., the Emergency Management office in Saipan) to evaluate the risks associated with the eruption. Webcast reporting from the field has been used by teachers to educate students on how scientists conduct such field operations. A special volume of *J. Volc. Geotherm. Res.* includes 14 publications on the Anatahan eruption (enumerated in Supplementary Documents), placing the event in geologic context, thereby providing critical data to interpret all future activity and assess the hazards that this volcano still poses today.

More broadly, MARGINS SubFac investigations in both the IBM site and Central America have unraveled the eruptive histories of volcanoes and constrained the geochemical evolution that might influence eruptive behavior. Integration of these results with deep geophysical surveys has provided unique insights into the origins of spatial variations in eruptive compositions, which can now be tested in other settings subject to explosive eruptions (see SubFac Initiative Summary).

Numerous other examples of relevant MARGINS-related research also exist. Many of the specific objectives of the Seismogenic Zone (SEIZE) initiative, i.e., understanding the physical nature of fault asperities, the temporal and spatial variations and relationships among stress, strain, and pore fluids throughout the seismic cycle, and the nature of tsunamigenic earthquake zones, have been directly addressed, at least in part (see SEIZE Initiative summary in chapter 3). Although fault rocks from active subduction megathrust zones have not yet been recovered, laboratory experiments on fault rock lithologies have evaluated some of the factors likely to influence fault stability and earthquake rupture extent. Direct measurements and sampling are planned within the current NanTroSEIZE drilling program, and will further address the complex interplay of structural, compositional, and stress conditions that influence fault zone rheology.

Seismic surveys across active subduction zones have also provided new insights into tsunamigenesis. A 3D survey offshore of Japan's Kii Peninusla shows that a large offset splay fault likely ruptures to the seafloor, possibly accounting for tsunami generation during large earthquakes. Deep seismic surveys over the Nicaraguan forearc revealed a large block with high seismic velocities that may influence the potential of megathrust earthquakes along this margin to produce tsunami earthquakes as they did in 1992. MARGINS researchers also participated in international seismic and bathymetric surveys following the great Sumatra earthquake and tsunami of 2004, to identify the key structures, geometries, and surface ruptures that might have produced the tsunami. New efforts are underway to carry out the necessary site surveys at this ancillary MARGINS site in preparation for potential IODP drilling along the active margin.

Characterizing evolving fault behavior and associated ground motions is crucial to constraining to where a particular margin lies within the seismic cycle. Onshore-offshore OBS and geodetic studies along the Central American margin have defined the spatial distribution of seismicity and ground motions consistent with offshore locking of the seismogenic zone beneath the Nicoya Peninsula. In this location, earthquake recurrence is on the order of 50 years, raising serious concerns about fault rupture in the near term. MARGINS scientists and their collaborators are uniquely poised to capture this event in real time, and thus clarifying the full earthquake rupture process. In fact, the risks associated with Nicoya, and the geophysical data that constrain them, have been included in lesson plans and textbooks of Costa Rican students. Informing the local population about the scientific basis for hazard assessment has proven to be one of the most successful approaches to hazard mitigation.

Within the RCL Initiative, both on-land field studies and offshore geophysical surveys in and around the Gulf of California have clarified the fault activity and interconnections within this oblique rift environment (see RCL Initiative summary). Paleoseismologic investigations in Baja California have provided basic knowledge of active fault hazards within a major urbanizing tourist destination. Importantly, the integration of onshore and offshore studies enabled through MARGINS have offered the rare opportunity to connect paleoseismology of exposed faults with offshore structures resolved through marine seismic studies. MARGINS researchers also have engaged national and international organizations in the assessment of local earthquake hazards, and scientific exchanges (e.g., through PI visits, student and postdoc support, and field activities), thus contributing to the broader education of the scientific community.

Source-to-Sink (S2S) activities, focused on the Fly River that enters the Gulf of Papua, and Waipaoa River system in New Zealand, have examined a unique set of interconnected processes under different climatic and land-use conditions part (see S2S Initiative summary). The tropical Fly River system is largely unaffected by human land use, but is subject to long-term ENSO-related changes in climatic conditions. In contrast, the Waipaoa River system is strongly affected by seasonal changes in discharge, and also at least 100 yrs of European land-use patterns. Marine investigations in this setting have demonstrated how changing land use practices can dramatically affect the flux and fate of terrestrial sediments and organic carbon (e.g., through erosion and flooding) on the continental margin, with implications for modeling of margin development, the global carbon cycle, and coastal and nearshore ecosystems. Collaborative MARGINS studies with local and international scientists are contributing to our understanding of how both long- and short-term changes are recorded in the offshore sedimentary record, with applications to interpreting their effects on the local populations.

6.3 International Collaborations

All MARGINS Focus Sites lie outside the U.S., at least in part, and at several sites, other major international programs exist. As a result, MARGINS has been at the center of several programmatic collaborations, which have greatly enhanced scientific discovery in several ways. First, the pooling of national programs has led to much greater diversity and availability of resources, greatly increasing the observations made. Second, new scientific collaborations have emerged, in several cases leading to new discovery. As a demonstration, the several recent Science and Nature papers to emerge from the program all have multi-national authorship lists (e.g., Hoernle et al., 2008; Moore et al., 2007; Lizarralde et al., 2007). Third, in several host countries, MARGINS-funded scientists have participated in a range of in-country training and education efforts. These range from training in modern analytical methods to short courses and training visits to the U.S.; several of these are listed in the Education and Outreach chapter of this document. In at least one case, MARGINS science formed a case study in a revised Costa Rican 5th grade science textbook (the SEIZE experiment in Central America).

These collaborations fall into three categories. Many are with host-country groups, where MARGINS may bring focus to some part of national efforts, help national groups achieve observational programs not otherwise possible, and provide training or education. Another category is partnerships with national programs in other countries who chose similar Focus Sites and goals as MARGINS – the German "Volatiles and Fluids in Subduction Zones" initiative in Central America is one example, the Japanese JAMSTEC/IFREE programs in Nankai and in Izu-Bonin are others. Finally, many other smaller groups of PIs from other countries have formed MARGINS collaborations. These are some prominent collaborators:

- ***Gulf of California, Mexico***
  Centro de Investigación Cientifica y de Educación Superior de Ensenada (CICESE)
  Centro de Geociencias, Juriquilla
  Universidad Autónoma de Baja California Sur
  Utrecht University *(NARS-Baja array)*
  Munich Ludwig-Maximilians University *(GPS programs)*

- ***Red Sea***
  King Saud University, Geology Department and Seismic Studies Center
  King Abdulaziz City for Science and Technology Riyadh
  Saudi Geological Survey
  Sana'a University, Faculty of Science
  Asmara University, Egypt

- ***Fly River, Papua New Guinea***
  University of Papua New Guinea, Port Moresby
  Ok Tedi Mining *(logistical support)*

- ***Waipaoa, New Zealand***
  GNS Science
  Nat. Inst. Water & Atmos. Res. (NIWA)
  University of Victoria (Wellington)
  Massey University
  University of Otago
  Gisborne District Council

- ***Central America***
  GEOMAR (Kiel, Germany) & Collaborative Research Center
  SFB-574 "Volatiles and Fluids in Subduction Zones"
  University of Kiel
  Observatorio Vulcanológico y Sismológico de Costa Rica
  (OVSICORI), Universidad Nacional (UNA)
  Universidad de Costa Rica (UCR)
  Instituto Costarricense de Electricidad (ICE), Costa Rica
  Instituto Nicaragüense de Estudios Territoriales (INETER),
  Nicaragua

- ***Izu-Bonin-Mariana***
  Institute for Frontier Research on Earth Evolution (IFREE)
  of Japan Agency for Marine-Earth Science and Technology
  (JAMSTEC)
  Commonwealth of the Northern Mariana Islands (CNMI) Disaster
  Management

- ***Nankai***
  IODP-MI
  Japan Agency for Marine-Earth Science and Technology
  (JAMSTEC): Center for Deep Earth Exploration (CDEX)
  Japan Agency for Marine-Earth Science and Technology
  (JAMSTEC): Institute for Frontier Research on Earth
  Evolution (IFREE)
  Universität Bremen

6.4 Relationship to major NSF-supported facilities

MARGINS has made significant use of major infrastructure investments supported by NSF (OCE and EAR), and has potential to do much more in the future. MARGINS can provide intellectual framework for many uses of these MREFC and other major investments.

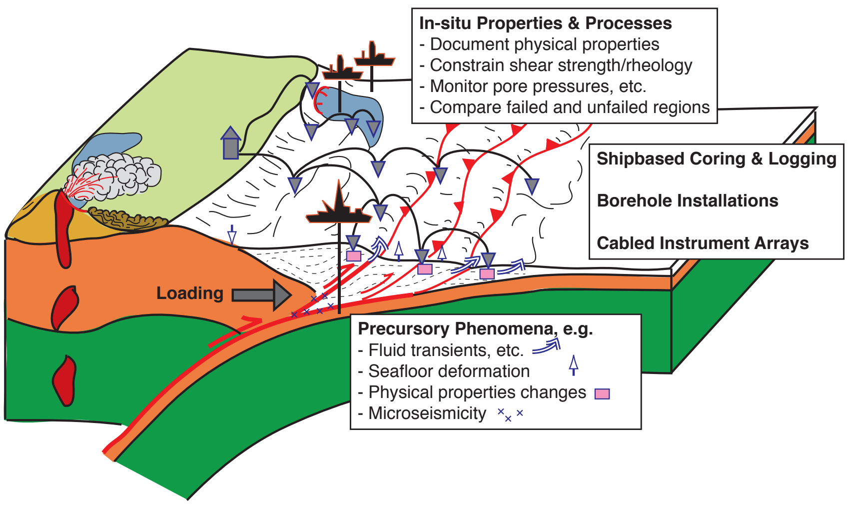

Figure: Direct observation, monitoring, and sampling of actively deforming regions can provide critical in-situ physical properties and mechanical conditions, and can reveal transient phenomena that may be precursory to failure (Modified from Morgan et al., 2008).

UNOLS fleet. Marine components of MARGINS have made extensive use of a wide array of shipboard facilities, ranging from sea floor sampling, attending to long-term observatories, heat flow, swath bathymetry, OBS and magnetotelluric station servicing, among many others. MARGINS supported directly the first science cruise on R/V Marcus Langseth, the new seismic acquisition platform, to image the Costa Rica crust with state-of-the-art capability.

IODP/ODP. Many MARGINS initiatives have ocean drilling as a major target. This has been best realized by the inauguration of NanTroSEIZE, the program to drill through the seismogenic zone at Nankai and the first major academic riser-drilling program. The NanTroSEIZE concept is in many ways a by-product of the SEIZE initiative. Drilling proposals are also circulating for projects offshore Costa Rica and the IBM arc system, among others. A proposed industry-supported drilling program for the U.S. vessel could provide critical data for both the studies of rifted margins, and of offshore sediment process, currently within the RCL and S2S initiatives.

EarthScope. EarthScope provides unprecedented infrastructure for deep seismic imaging and measuring strain events in North America. Some co-funding and data exchange has taken place between MARGINS and EarthScope, at the Salton Trough/Gulf of California site. Workshops have identified several targets of future collaboration between these two programs, specifically in the Cascadia subduction system (the youngest subducting plate to be associated with a volcanic arc), perhaps the Alaska/Aleutian system, and perhaps the Atlantic rifted margin. All are places where MARGINS could extend EarthScope-type observations offshore, and provide a vehicle for geochemical, geological and marine sciences to integrate with the facility.

OOI. The possibility of a cabled observatory system across the Juan de Fuca plate provides many potential opportunities for MARGINS-type research in Cascadia. The planned "subduction" node provides an opportunity for a variety of long-term observation, and when integrated with Canadian efforts should greatly improve the understanding of strain, fluid flow, fluid chemistry, and seismicity in the offshore region.

OBSIP, IRIS, UNAVCO. These major geophysical facilities have provided instrumentation to MARGINS-supported researchers on a number of occasions. As well, complementary efforts in subduction zones and rifts worldwide have been supported by these facilities, through other NSF programs, leading to some natural comparative projects that greatly extend MARGINS science beyond the focus sites.

Geochemical facilities. NSF has supported major instrumentation at many labs across the country, which have provided a comprehensive data set for much of the geochemistry supported by MARGINS. For example, the quantum leap in volatile measurements over the last decade, a key to SubFac's success, has been in part due to the development of a new generation of geochemical instrumentation.

6.5 MARGINS and the National Computational Infrastructure

While high-performance computing (HPC) has played a role in MARGINS research, we believe that its potential as a tool for integrative studies will grow significantly. MARGINS could benefit by strengthening linkages and interaction with existing HPC efforts both within the geosciences and those that exist more broadly as national facilities. MARGINS HPC covers both the science-specific software as well as the computational hardware. NSF has made investments in both areas that have closely aligned objectives with ours. On the software side, NSF supports CSDMS (Community Surface Dynamics Modeling System) and CIG (Computational Infrastructure for Geodynamics).

CSDMS offers a new paradigm dealing with the Earth's surface - the ever-changing, dynamic interface between lithosphere, hydrosphere, cryosphere, and atmosphere. CSDMS is a diverse community of experts promoting the modeling of earth surface processes by developing, supporting, and disseminating integrated software modules that predict the movement of fluids, and the flux (production, erosion, transport, and deposition) of sediment and solutes in landscapes and their sedimentary basins. Models combining land-surface dynamics, basin evolution, and distributed transport (such as spatially-distributed hydrologic and fluvial landscape evolution models, ice-sheet dynamic models, and coastal dynamic models) are similar in complexity to atmosphere and ocean models in that the time evolution of several spatial grids is modeled for one or more vertical layers by solving a set of coupled partial differential equations. However, the physically-important spatial scales are much smaller than those of coupled ocean–atmosphere models, where 5 m to 100 m grid cells (vs. 1 km to 100 km cells) are required to resolve surface dynamic processes. In addition, coupled land-surface and subsurface processes are often integrated at different time scales, from seconds - minutes for channelized surface flow, to hours - days for overland and subsurface flows.

CIG is also a community-organized NSF Center that has been developing computational tools for solid earth geodynamics, such as several packages that can address MARGINS science goals, especially those within SEIZE, SubFac, and RCL. CIG's development and release of two finite element pages (*PyLith and Gale*) that scale well on large parallel computers, such as the TeraGrid, are notable. *PyLith* was specially designed to address the multiple time and space scales associated with the earthquake cycle (tectonic loading, earthquake rupture, post seismic relaxation) within geometrically and mechanically complex plate boundaries such as the Nankai Trough. *Gale* was specially designed to simulate the crust and lithosphere over millions of years as faults and shear zones form and grow. As such, *Gale* is an ideal tool for following the initial rupture of continental lithosphere and the growth of faults as passive margins evolve. By nurturing the Magma Dynamics Development Suite, CIG has brought the magma dynamics community together in the first steps to develop open source software in areas of research vital to the goals of SubFac and RCL.

Both CSDMS and CIG provide coordinated development together with a distribution of community software tools, and represent a major advance in the approach to computational problems taken within the geosciences community. NSF has also invested significant resources in the hardware on the TeraGrid. The growing integration between MARGINS scientists and modelers who interact with the computational initiatives provides efficient leveraging of NSF-sponsored programs.