From the MARGINS Chair – Spring 2009
Geoff Abers, Lamont-Doherty Earth Observatory

For the last several months, the dominant issue facing MARGINS has been the Decadal Review, which has led to much thinking about a successor program. The Decadal Review Committee met February 2-3 at NSF, with visiting experts in each Initiative and the Chair providing information. The Committee’s Report was completed in a month, and at a March 19-20 MARGINS Steering Committee (MSC) meeting we drafted a response to it. The Report, the MSC Response, and NSF’s encouragement to work toward a new Science Plan are all available on line, along with extensive material prepared in advance of the review (www.nsf-margins.org/Review2009). The Report’s Summary is included in a box below, as is a slightly-abbreviated MSC Response.

This process went very well, thanks to considerable scientific achievement and the hard work of many people, and we are now taking steps towards a MARGINS successor program. The Report commends MARGINS for its many accomplishments, and also argues that a successor program had great merit. As a result, NSF has invited us to organize a large community workshop to develop consensus on the scientific goals and structure of a successor program. This workshop will lead to a draft Science Plan. After NSF has evaluated the plan we should know if a successor will emerge and what form it will take. In the mean time, keep an eye out for announcements regarding the planning workshop – we expect a late-winter 2010 date and a warm-climate venue – and for other opportunities to provide input, at other meetings, through discussion with MSC members, and through on-line forms.

MSC Response to Decadal Review Report
MARGINS Steering Committee, March 2009

The MARGINS Steering Committee met at NSF on March 19 and 20, providing the opportunity to discuss the Decadal Review Committee (DRC) Report and NSF’s initial reactions to it. Overall, we are pleased with the DRC report, and excited for the opportunity to help shape a successor program should NSF follow the report’s recommendations. We appreciate that a successor is likely to look different in many ways from the current MARGINS Program. While we will build on MARGINS past successes, a primary topic for the next several months will be to identify the outstanding new scientific questions that will guide future research. In this context, we would like to highlight several new scientific opportunities, some of which were discussed only briefly in the DRC Report but in which we see great potential for transformative discovery.

**Projecting MARGINS successes into a successor program**

The Review recognized the success of several core approaches of the current MARGINS Program: the broad approach to community building, the importance of crossing the shoreline, the use of focus sites; the added value in cultivating international partnerships, and the importance of integrating computational and experimental research with field observation. The DRC also recognized that such activities could not have succeeded without a science program separate from core funding. We concur with this assessment and would like to build upon these achievements in a successor to MARGINS.

As a guiding statement, the Steering Committee envisions a successor program that will investigate the coupled geodynamic, surficial, and climatic processes that build and modify continental margins over a wide range of timescales (from s to My). Such a program will have applications to margin evolution and dynamics, construction of stratigraphic architecture, and implications for accumulation of economic resources, associated geologic hazards, climate change and environmental management. Addressing such complex coupled systems requires an integrated approach, and we envision a broad range of studies combining field research in structure and tectonics, geo-
chemistry, geophysics, sedimentology and stratigraphy, but also incorporating experimental, analytical and numerical modeling investigations.

Both the Steering Committee and DRC have recognized that the breadth, energy, and synergy within and between the current initiatives provide an excellent template for thinking broadly about the future, and give a certain advantage to those emphases. Therefore, planning for a successor program can build upon the successful parts of MARGINS, while considering broadly new opportunities and program structure during the community workshop: what separate initiatives to have, if any; the role of focus sites, if any; whether and how to better include industry participation; and how better to address resource, hazards, climate, and management objectives while retaining an emphasis on solid earth dynamics. Unquestionably, new opportunities exist for a MARGINS successor to interface more closely with other NSF facilities including EarthScope, Ocean Drilling and cyberinfrastructure initiatives such as CIG. These opportunities will lead to integrative transformative discoveries, while further growing the MARGINS community.

With NSF’s encouragement, we will submit a proposal for a community-wide planning workshop to identify the critical scientific opportunities that require a successor program, outline a program organization, and lay the groundwork for a draft science plan for NSF to consider. This workshop will be planned for early 2010, and will be open to all interested participants, with emphasis on early career scientists who can help to steer the next generation of MARGINS science. Even prior to this community-wide meeting, initial planning activities are underway within the existing MARGINS initiatives. Two Initiative Synthesis and planning workshops take place this Spring (S2S in April and RCL in early May), during which we have reserved time to discuss a successor program and initiative priorities. We have invited additional participants to each workshop who can provide links between the sediment and rifting communities. Likewise, a Theoretical and Experimental Institute on Volatiles in Subduction (September 2009) will include planning discussions. We also plan to solicit proposals for small, focused workshops to explore specific scientific opportunities prior to the community-wide workshop. By taking such a proactive approach, we expect to be able to submit a draft Science Plan to NSF by early- or mid-2010, allowing consideration of a successor program by FY 2011. During this transition period, we will maintain the central MARGINS office as well as ongoing education and outreach programs, in order to facilitate planning and minimize the effects of any hiatus.

Subduction Initiatives

The DRC spoke highly of the successes of the two subduction initiatives, SEIZE and SubFac, and their recommendations for the future closely parallel those outlined in the MARGINS review documents. Cascadia and the Alaska-Aleutian margin are already

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Summary of DRC Recommendations

The Decadal Review Committee met February 2-3, 2009, to evaluate the MARGINS program over its lifetime. The full report can be found at www.nsf-margins.org/1_DRCrep09.pdf; the closing summary recommendations are listed here.

- That the NSF set up a new themed program, MARGINS-2010, to follow on from the existing MARGINS program.
- That the new program is not restricted to active margins, but also addresses passive margins in the context of understanding how these margins are formed.
- That the new program continues to build on the focus site concept, but is flexible such that old sites can be wound down and new ones brought in as the science dictates.
- That the new program builds on the strengths of MARGINS and incorporates its SEIZE and SubFac initiatives and a new initiative which we dub a Rifts, Sediments and Fluids initiative (RSF).
- That the S2S initiative is not a standalone entity within MARGINS-2010, but is integrated explicitly into the SubFac and RSF initiatives.
- That large-scale computer modeling, laboratory experimental studies and studies of margin analogues in the rock record continue to be important elements of MARGINS-2010.
- That MARGINS-2010 continue to work productively with other large-scale NSF facilities and programs such as EarthScope, OOI, IODP and the new R/V Marcus G. Langseth.
- That the new program highlights links with societal issues such as climate, sea-level and environmental change, geo-hazards and energy and resources.
- That a new committee, the Steering and Oversight Committee, be set up to manage MARGINS-2010 which is dominated by academics, but includes representatives of the industry and the state/national surveys.
- That the Distinguished Lecture Program is expanded to include a highly visible, videoed, Public and University Lecture Series which is held in international institutions, especially those who will be collaborating in MARGINS-2010 research.
- That the current 5-year review timescale of MARGINS be retained in MARGINS-2010.
Allied sites in both current initiatives for clear scientific reasons (warm and sediment-rich endmembers, history of great earthquakes, etc.). The presence of EarthScope and potentially OOI facilities makes these sites even more attractive, and a successor program that complements EarthScope will promote greater scientific participation from the EAR scientific community. Nonetheless, the community will need to decide which focus site(s) will best address the key questions that will guide the next Science Plan (if the Focus Site concept is to continue), and will need to critically evaluate all feasible alternatives.

One point of discussion could be the integration of SEIZE and SubFac into a single subduction initiative, addressing integrated studies at common focus sites. Certainly, the co-location of the two initiatives at the Central America focus site offered intellectual and logistical advantages that led to discoveries that have transformed our understanding of subduction processes. Similar synergies are likely in the future. Perhaps more importantly, the key processes investigated within SEIZE and SubFac are proving to be increasingly interrelated, and a future joint subduction initiative could entice those working at the transitions. Counterarguments exist to retain the separation between Initiatives, and the topic should be discussed by the community during the planning process.

**Rifts**

The DRC report recommends a significant restructuring of a future rifting initiative relative to the current Rupturing Continental Lithosphere (RCL) Initiative. The DRC report recommended that a new initiative contain a more robust sedimentological component to better extract the sedimentary record of rifting, as well as the influence of sediments on rift evolution. Similar discussions have been initiated already within the community, and a small workshop was held in April 2008 at LDEO, generating 3 mini-whitepapers that identified exciting future directions for such a rifting initiative (included in the online Review Material). These mini-whitepapers also highlight the fundamental role of magmatism and 4D evolution of lithospheric strain as key components of a future program, in addition to sedimentation. While we agree with the DRC that many exciting opportunities exist for studying the interplay between rifting and the sedimentary record, we feel that a full rift system model must incorporate these other processes as well. In particular, recent studies in the Gulf of California (and elsewhere) show that there are direct links between sedimentation, magmatism, and the timing of breakup. Thus, a successor program that will fundamentally advance our understanding of rift evolution must include studies that focus on both surface and mantle processes, as well as the linkages between them. We suggest that planning for a future rifting initiative include consideration of these topics, and that discussions would also evaluate the benefits of extending MARGINS beyond active rifts to sites where rifting is complete. In anticipation of this discussion, the program for the early May RCL Synthesis workshop includes some time to address these issues.

**Sedimentary Process**

There has been much discussion of the DRC’s recommendation to fold studies of sedimentary processes into other initiatives in a manner that emphasizes continental evolution, rather than continue Source-to-Sink (S2S) independently. Most Steering Committee members reluctantly accept the recommendation. We reiterate evidence from the Review documents that, despite the late start of S2S, important progress has been made that lays the basis for continued work on active sedimentary processes along continental margins. As the DRC recognized, the approaches taken by the S2S community are substantially different from those needed to interpret continental evolution from the sedimentary record, so the proposed reorganization could result in a significant change in the research community involved, and will probably require significant rebuilding of the community. It seems worthwhile at this juncture to think as broadly as possible about the role of earth surface studies (erosion, sediment transport, stratigraphy, etc.) in all of the MARGINS initiatives, beyond the controls on basin stratigraphy. In particular, we would like to seek ways in which the process-oriented approach championed by the S2S community could be best integrated into related studies. Quantitative approaches to sedimentary and erosional systems are rapidly developing, and it seems very possible for the community to identify new directions that differ substantially from those envisioned by the DRC. We hope for extensive discussions of these issues at the upcoming workshops, including the April S2S Synthesis Workshop.

**Program structure, societal relevance, education**

We generally agree with the Review Committee’s assessment of the opportunities for greater societal relevance, ways to usefully restructure the program management, and suggestions to improve the education program. We look forward to continued dialog with NSF and the community on these issues, and expect to use the DRC Report along with the review documents we provided as a basis for structuring these aspects of the program. As a first step, the Education Advisory Committee meets in late May, to consider the future development of the education program. Once the scientific agenda for a successor program becomes clear, decisions about these programmatic aspects should develop rapidly.

In summary, the Steering Committee views this review very positively, and sees many opportunities to transform the science through a successor program. While we recognize that a successor cannot be authorized by NSF until a Science Plan is submitted, the fact that we are being asked to develop one represents a very positive outcome of the review process. It reflects confidence that integrated approaches to studying the evolution of continental margins will provide transformative breakthroughs over the coming decade, and that these systems will have increasing societal relevance.
MARGINS Decadal Review Committee (DRC) convened by NSF met on February 2nd and 3rd 2009. They were charged to review the Program’s accomplishments, future plans and management structure and make recommendations to the Foundation about its continuation. Their work was greatly facilitated by the substantive documentation produced by MARGINS Steering Committee (MSC) and the community in preparation for the review. The DRC was very appreciative of the hard work and considerable thought that went into producing the documentation, especially the nuggets comprising summaries of the projects funded under MARGINS umbrella.

NSF has accepted the DRC report in principle. However, its recommendations require further discussions within the Foundation and with the Geosciences community at large. To facilitate the community’s involvement in determining the direction of future margins-related research, the Foundation has encouraged the MSC to plan a broad-based workshop to deliberate the science as well as the management structure and produce a draft science plan for a potential successor program to MARGINS by mid 2010. This will ensure that the community has the opportunity to consider the DRC report in detail and reconsider the program in its entirety. The decision to continue MARGINS as a special program will hinge on the acceptance of the science plans by the Foundation.

In the meantime FY 2010 (which starts in October 2009) is seen as a period of transition for the MARGINS Program. Because of this transition, for the next proposal submittal deadline (July 1, 2009) MARGINS program at NSF encourages the community to submit proposals for workshops and integrative/synthesis activities under the current MARGINS Program. Proposals for new data collection efforts should be limited to short-duration efforts critical to the completion of such integration and synthesis goals. In addition to these, there are a number of field projects on which funding decisions were made during the last MARGINS competition and these could still be partially or wholly funded from FY 2010 funds.

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For MARGINS Program
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Call for Future-Looking MARGINS Mini-workshop Proposals

In addition to the regular call for interdisciplinary MARGINS mini-workshops (see box on page 14), the MARGINS Office (MO) and Steering Committee aim to specifically support efforts that help shape the scientific objectives of a possible MARGINS successor program.

To this end, MO offers to help investigators organise and fund future-looking mini-workshops. Ideally, these would take place in conjunction with major national meetings. But, where a critical need can be shown, proposals for a small, stand-alone mini-workshop that is focussed upon future-looking goals will be considered. In this case, travel support for up to 20 participants as well as the cost of the meeting room, presentation equipment and non-alcoholic refreshments would be met by MO. The Office would also help meeting convenors with logistical arrangements.

If you are interested in convening a focussed, future-looking working group either in conjunction with a national meeting or as a stand-alone event, please follow the general guidelines for the regular mini-workshop proposal (see box on page 14) and send your 1-2 page meeting plan outline to the Office and Chair:

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Introduction

In the past decade, the earth science community has greatly expanded our understanding of subduction zone megathrust behavior to include a wider continuum of strain release than previously realized. We have made a huge advance in moving from the classic definitions of coseismic slip and creep to a wide range of behaviors that includes silent earthquakes, episodic tremor and slip (ETS), low frequency earthquakes (LFE), and very low frequency earthquakes (VLF). Recent focused field campaigns conducted as part of the MARGINS SEIZE program in Nankai and Central America have played a key role in expanding our view of subduction zone behavior and the transitions between these behaviors. Laboratory and theoretical studies have elucidated links between fault rock rheology and the mechanics of fault slip. However, important recent progress has also emerged from allied studies at non-focus sites and through new techniques and strategies applied outside MARGINS. Future progress for SEIZE requires exploring our current status and assessing potential future directions.

On September 23-26, 2008, eighty scientists from around the world gathered at Timberline Lodge on Mt. Hood, Oregon to present results from recent progress on the MARGINS SEIZE initiative and discuss future directions for SEIZE. The workshop was sponsored by the National Science Foundation through the MARGINS program. Geoff Abers and the MARGINS Office staff including Niva Ranjeet, Andrew Goodwillie, and Kristen Woodford assisted the workshop conveners Nathan Bangs, Demian Saffer, Susan Schwartz and Don Reed in organizing and running the workshop.

Workshop Goals

The workshop came at the end of the current MARGINS program, immediately prior to the decadal program review and 5 years after the most recent SEIZE meeting, a Theoretical and Experimental Institute (TEI) held in March 2003. We designed a series of science presentations to: (1) assess the progress made in the last decade on major SEIZE projects and science objectives at the focus sites; (2) identify new fundamental questions about subduction seismogenesis that have emerged from MARGINS and related field, laboratory, and theoretical studies; and (3) define any critical gaps or unanswered questions from the existing SEIZE science plan.

In addition to these goals, we addressed four specific questions about the structure of the SEIZE program to feed directly into shaping a potential descendant program in the next decade of MARGINS. We discussed: (1) the need for new facilities and technological developments to address the core science questions; (2) the relative merits of retaining the current SEIZE focus sites, adding new ones, or moving away from the focus site model altogether and instead switch to a thematic-based initiative; (3) the need for a dedicated program at NSF to adequately address remaining and emerging SEIZE science objectives; and (4) how the SEIZE initiative could be broadened to more fully incorporate societally relevant objectives, and to reach...
out to other geoscience communities to strengthen the initiative and increase participation.

The workshop was organized as a series of sessions with oral presentations on recent results from focus sites, studies of key processes from settings outside focus sites, new and emerging questions and discoveries, and new techniques and facilities. The workshop agenda was structured to include plenary discussions following each of the main sessions. In addition, a series of separate breakout sessions addressed each of the four topics related to initiative structure noted above. Poster presentations provided added details and were available for viewing during most of the meeting. In this report, we present a brief synopsis of key results reported in the science sessions, and summarize some of the discussion of the four programmatic issues. Additional information about the meeting, including the agenda, list of participants, abstracts, and powerpoint presentations, is available at: http://www.nsf-margins.org/SEIZE/2008/index.html

Recent Results and SEIZE-Related Developments

**Nankai Trough Focus Site**

The major developments at the Nankai focus site include the first stage of NanTroSEIZE IODP drilling, and the acquisition and processing of a 3-D seismic survey over the margin, extending from the trench across the updip terminus of coseismic rupture [G. Moore et al., 2007]. From September, 2007, through February, 2008, IODP Expeditions 314, 315, and 316 were carried out as a unified program of drilling collectively known as Stage 1 of NanTroSEIZE. A transect of eight sites was selected for riserless drilling to target the frontal thrust region, the midslope mega-splay fault region, and the Kumano forearc basin region. Two of these sites are preparatory pilot holes for the planned deep riser drilling operations, while the others targeted fault zone material in the shallow, presumed aseismic zone at both the frontal thrust near the trench and a major out-of-sequence thrust fault (termed the "mega-splay"), which is implicated in coseismic rupture [G. Moore et al., 2007; Kinoshita et al., 2008]. Expedition 314 was dedicated to in situ measurement of physical properties and borehole imaging through logging-while-drilling (LWD) in holes dedicated to that purpose. Expedition 315 was devoted to core sampling and downhole temperature measurements at a site in the mega-splay region and one in the forearc basin. Expedition 316 targeted the frontal and out-of-sequence mega-splay fault region in the mid-slope environment.

Core recovery and logging identified zones of shearing on the scale of meters and clearly identified an age reversal from 2.4 Ma to 1.6 Ma across a pair of fault zones that comprise the shallow mega-splay (Figure 2). Recent faulting overthrusts accreted sediment onto slump deposits and slope apron sediments, with horizontal displacement of up to ~1,000 m [e.g., G. Moore et al., 2007]. From the newly-acquired 3-D seismic images, these faults can be seen to merge at depth to the deep splay fault branches, which then connect to the main plate boundary detachment beneath the inner wedge below the Kumano forearc basin (Figure 2). It now appears that the plate-boundary detachment also branches into the decollement beneath the outer wedge and remains ~ 1 km above the top of the subducting crust, connecting seaward to the youngest outer wedge in-sequence thrusts at the deformation front. Deep riser drilling in future phases of NanTroSEIZE will target the plate boundary fault system and underthrusting sediment and basaltic basement at a depth of ~6 km bsf, within a zone of high coseismic slip.

One key result from Stage 1 drilling was the observation that the shallow stress regime changes dramatically between the inner and outer wedge, over a short distance [Kinoshita et al., 2008], as inferred from borehole breakouts and structural analysis of recovered cores. The forearc basin and uppermost ~400 m of the older underlying accretionary wedge is currently in NW-SE extension, whereas the outer wedge is dominantly in NW-SE compression and nearly subparallel to the plate convergence direction. Deeper drilling in future stages of NanTroSEIZE will help to assess whether the stress field reorients at depth in the inner accretionary wedge to be consistent with thrust faulting on the megathrust. Thrust focal mechanisms are also observed for VLF earthquakes inferred to occur across both the inner and outer wedge [Ito and Obara, 2006] (Figure 3).
Central America Focus Site

Slip along the Central America margin varies widely along strike, as inferred from patterns of seismicity and geodetic motions. Old, smooth crust of the subducting plate beneath Nicaragua is weakly coupled and slips frequently in moderate-sized earthquakes (M~5) and rare large events that are characterized by slow rupture velocities and larger than expected tsunami. To the south along the Nicoya peninsula, increased interplate coupling develops into a locked zone that generates large earthquakes (M~7.7) and has disproportionately fewer moderate-sized events during interseismic periods. Silent slip or slow slip events have been detected or inferred beneath the Nicoya peninsula based on onshore GPS data and offshore correlated fluid flow transients. These are interpreted to originate both updip and downdip of the currently locked zone [Norabuena et al., 2004]. The Nicoya region differs from other settings in which silent slip events appear to originate only at the downdip edge of the seismogenic zone on a transitionally locked portion of the megathrust [e.g., Dragert et al., 2001]. Non-volcanic tremor (NVT) has been detected in Costa Rica in OBSs positioned offshore near the toe of the accretionary prism and linked to hydrologic transients observed at the seafloor and in borehole observatories near the trench [Brown et al., 2005; Davis et al., 2006]. NVT has also been recorded on land seismometers during a GPS detected slow slip event. Elsewhere, deep NVT has been attributed to fluid generated by dehydration processes in the slab [Obara, 2002] or swarms of small low frequency earthquakes and either or both mechanisms may be operating offshore Nicoya as well [Schwartz and DeShon, 2007]. South of Nicoya, frequent, regular rupture of large events (M~7) coincides with relatively younger subducting crust that is populated with numerous seamounts. Seamounts are believed to reduce the coupling area leading to small asperities and the distinctive slip behavior [e.g., Bilek et al. 2003].

Similar to other subduction zones, the updip and downdip limits of the seismogenic zone, as defined by microseismicity, appear to be thermally controlled. For example, along the Nicoya peninsula, the initiation depth of the seismicity clearly correlates with heat flow on the incoming plate, suggesting a thermal influence on the onset of the microseismicity [Schwartz and DeShon, 2007]. Although correlated with inferred temperature, the precise process(es) and mechanism(s) controlling this transition in slip behavior are still not known [e.g., Harris and Wang, 2002; Spinelli and Saffer, 2004; Saffer and Marone, 2003]. Furthermore, recent geodetic data indicate that the locations of the seismogenic zone defined by microseismicity and that defined by interseismic geodetic locking may not coincide; this is a critical finding because it suggests that different processes may operate to cause multiple transitions in fault slip behavior at different depths.

The intriguing correlation between the shallow NVT and hydrologic transients observed by Brown et al. [2005] and Davis et al. [2006] (noted above), has been modeled as a poro-elastic response to propagating slow slip along the plate interface near the up-dip limit of the seismogenic zone [Brown et al., 2005]. Links between hydrologic processes and fault slip have also been inferred from recent allied studies of seep sites and mud mounds on the lower continental slope offshore Costa Rica. Here venting fluids are believed to source from the plate interface near the updip limit of seismogenesis, on the basis of observed pore water freshening, presence of thermogenic hydrocarbons, and other geochemical indicators of a high-T (~80-150 C) source [Hensen et al., 2004; Ranero et al., 2008]. The exhaustion of bound and pore fluid with increasing temperature and progressive consolidation may play a critical role in the evolution of mechanical properties along the subducting plate interface, and potentially in causing the transition from stable sliding to stick slip behavior at this non-accretionary margin [e.g., Moore and Saffer, 2001; Saffer and Marone, 2003; Klauke et al., 2008; Ranero et al., 2008].

Non-Focus Sites

The fundamental SEIZE science goals have also been advanced significantly by recent observations from non-focus sites, and via laboratory and theoretical studies. Perhaps the most visible example is the December 26, 2004 Sumatra megathrust event. The rupture length (>1300 km) and duration (> 10 min) of this event are the largest for any earthquake recorded by modern instrumentation. Thus the spatial and temporal distributions of slip, including coseismic and post-seismic slip phenomena, have been characterized in unprecedented detail, providing an opportunity to better understand deformational processes occurring during the earthquake cycle [Ammon et al., 2005; Chlieh et al., 2008]. Three asperities ruptured during the 2004 earthquake, with a

Figure 3. Cross section from 3D seismic imaging (Moore et al., 2007) through preliminary NonTroSEIZE drilling sites (orange) showing Phase 1 penetration (solid) and penetration planned for later phases (unfilled). Focal mechanisms of VLF earthquakes (after Ito and Obara, 2006) are superposed to show their shallow extent.
maximum of 15–20 m of horizontal and 5 m of vertical displacement. A large fraction of the total slip (~30%) occurred as aseismic afterslip within 30 days following the earthquake. Since then, three additional major earthquakes have occurred sequentially along this margin, providing strong evidence for stress transfer. The slip patterns of these ruptured segments correlate directly with interseismically locked zones, and exhibited substantial afterslip both updip and downdip from the main coseismic rupture area.

Another key discovery from both focus and non-focus sites relates to strain release on active fault zones. We now recognize a much wider range of fault slip behaviors and rates than previously imagined, forcing a fundamental change in thinking about the nature and definition of the seismogenic zone from classic division of slip behavior into coseismic slip and creep, to a wider spectrum of behaviors that includes silent earthquakes, SSE, ETS, LFE, and VLF earthquakes. A key question is how these slower time constant events fit with the coseismic release during normal earthquakes, or if these slow events comprise an entirely new class of seismic moment release, fundamentally different from normal earthquakes [Ide et al., 2007]. Cascadia and Japan are the “type locations” for these events based on the early observations [e.g., Heki et al., 1997; Dragert et al., 2001; Obara, 2002], although new datasets document similar events in many other subduction zones (Mexico, Alaska, Costa Rica, New Zealand) and along strike slip (San Andreas) and other (Hawaii) fault zones. NVT has been explained as continuous low frequency earthquakes, thus linking the tremor and slow slip as a single process occurring on the subduction megathrust [Shelly et al., 2007], although as mentioned previously, others have linked the tremor to fluid processes [e.g., Obara, 2002].

Allied studies undertaken at on-land exposures of exhumed seismogenic fault systems, such as the Ghost Rocks mélangé exposed along Kodiak Island, AK, and the Shimanto Belt in coastal Japan, have also served to elucidate key fault zone processes through documentation of fault architecture, composition, and deformation mechanisms [J.C. Moore et al., 2007; Rowe et al., 2005]. These field studies have documented the potential role of melting and fluidization during seismogenic slip [e.g., Brodsky et al., 2009], and have given rise to the new hypothesis that quartz cementation and pressure solution act as an underlying processes to control the upper aseismic-seismic transition [J.C. Moore et al., 2007].

**New Method Developments**

In August 2008, a continuous GPS-Acoustic buoy/seafloor transponder system was deployed offshore San Diego to test continuous monitoring of seafloor vertical and horizontal motions (Figure 4). The goal was to provide continuous cm-scale resolution geodetic monitoring offshore, to complement onshore stations. Existing on-land stations have been critical for unraveling plate motions in the forearc related to strain accumulation during the seismic cycle, yet have been severely limited to small areas of subareal exposure, and lack the resolution to constrain deformation in the outer forearc and near the up-dip limit of the seismogenic zone. Thus, offshore monitoring with resolution comparable to on-land stations will be a major breakthrough for SEIZE, particularly when combined with continuous monitoring in boreholes, such as seafloor flux meters, pore pressure sensors, strainmeters, and seismometers [e.g., Davis et al., 2006]. Offshore networks will enable accurate records of small offshore earthquakes and other slow slip events, critical for characterizing the full continuum of slip. Fluid pressure events coincide with strain events through a wide range of seismic responses. These can now be measured in boreholes using CORKS down to small scales (0.5 Pa) and frequencies of up to
1 Hz and offer promising new ways to measure strain within hydrologically isolated formations, especially where they can be tied to cabled networks and monitored for extended periods in real time. Ultimately, buoy systems will complement permanent cabled network systems that will provide similar data for long-term focused studies, such as the DONET system scheduled to come on line in 2010 in the NanTroSEIZE study area and the NEPTUNE system offshore Cascadia.

**Shaping the future of SEIZE**

**What new strategies or technologies are needed?**

A combination of new strategies and technologies will contribute to future SEIZE directions. First, a broader application of existing technologies is needed. For example, the recent studies at the Costa Rica SEIZE focus site have made direct connections between fluid flow and seismic activity from a campaign of deploying new instrumentation to measure fluid flow and seismicity simultaneously [Brown et al., 2005]. It is ripe for broader application. Similarly, paleoseismo logical studies have delineated rupture history and segmentation in great detail along the Cascadia margin [Goldfinger et al., 2003] and could be broadly applied to define long-term rupture patterns in other settings. Second, new technologies and facilities need to be developed for direct measurements of stress/strain across the seismogenic zone from the trench to shore. Instruments and techniques for submarine geodesy require further development by improving submarine GPS measurements [Chadwell et al., 2005], to accurately measure accumulating strain offshore in a large number of locations that can be used in coordination with GPS campaigns on land and SAR interferometry. Third, strategies employing combinations of short-term campaign style, longer-term buoy deployments, and long-term cabled installations, will provide flexibility to make co-located observations over a wide-variety of spatial and temporal scales to characterize seismic, stress/strain, and other related properties. Lastly, coordination and collaboration of facilities and technologies between ongoing, complementary programs, such as long-term observatory efforts with OOI, SAFOD and others, will be key component of future efforts to span the shoreline and expand the range of observations.

**Emerging and new questions**

One key outcome of the workshop was the definition of a new generation of core science questions that have evolved via major advances and emerging questions from the last decade of SEIZE-related research:

1. What controls the observed wide spectrum of fault slip behaviors, specifically their spatial distribution and variation through the seismic cycle?
2. What controls along-strike variations in moment release in great earthquakes, and similar variations in interseismic locking?
3. What is the role of fluids in controlling fault rheology?
4. What are the state of stress and absolute strength of subduction faults and wall rock?
5. What is the geology of the seismogenic zone and its transitions?

**Program Structure**

**Focus Sites vs. Theme-based initiatives**

Significant discussion and debate centered on the issue of whether future SEIZE efforts should continue with focus sites (whether the existing sites or new ones), or instead adopting a theme-based strategy. For this discussion we divided into four smaller groups to allow more intimate discussion, and then reconvened in a plenary session. The outcomes were: (1) a common recognition that continued co-located cross-disciplinary and complementary studies at the current focus sites are critical to address existing and new SEIZE science questions (noted above); and (2) to adequately address these questions will also require branch ing out to new locations and adapting new strategies. For example, one of the key emerging science questions is to understand underlying controls on the observed spectrum of fault slip behaviors, including creep, afterslip, ETS, VLF events, tsunami earthquakes, and “normal” earthquakes. No single site exhibits all of these behaviors; notably, many important and relevant datasets have come from studies outside the current focus sites, such as Cascadia and Sumatra, and from laboratory and theoretical studies. Similarly, addressing the causes of observed temporal variations in seismogenic zone behavior can be addressed only through studying multiple systems at various stages in the seismic cycle, and by examining along-strike variations at individual margins.

**Concluding remarks and Future Questions/Directions**

During this workshop we saw the preliminary results from the first of the four phases of the NanTroSEIZE program, a small taste of the shallow drilling. Results from the deep drilling, which is truly uncharted territory, are still to come. We also saw a subset of recent work completed in Central America, and more is on the way with major new programs, like CRISP, still ahead. The current momentum on SEIZE focus sites and the potential to explore new thematic directions, such as the broader range of slip behavior, are emerging opportunities. There are also many sites outside the focus areas that offer broader opportunities to examine all forms of slip and examine slip at different phases of the seismic cycle. We look forward to an exciting future for SEIZE.

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Apply for the NSF MARGINS Post-Doctoral Program

Applications due at the regular July 1 NSF deadline

For details, see the NSF program announcement and http://www.nsf-margins.org/PostDoc.html

Congratulations to the 2009 recipient, Dr. Christie Rowe! Dr. Rowe’s award details are described in the awards section on page 26
Introduction

Among the most beautifully geometric features of Planet Earth is the string of volcanoes and parallel subduction furrow draped between the facing nations of Russia and the United States. This beauty, carpeted in emerald-green tundra, is both mysterious and dangerous: the Aleutian arc is among the most seismically and volcanically active but poorly understood regions of the two countries. Indeed, the American segment was the site of the world’s largest eruption and second largest earthquake in the 20th century. Despite this circumstance, the Aleutian subduction zone (SZ) has not been a particularly active area for NSF-funded research and has only recently been subject to extensive volcano monitoring by the U.S. Geological Survey (USGS).

The Aleutians are, in fact, a birthplace of the subduction paradigm [Coats, 1962; Stauder, 1968, Plafker, 1965] wherein an oceanic megathrust gives rise to andesitic volcanism. Although cited as a “strategic region for focused study” because of “high magma production rates and volcanic hazards to U.S. citizens and planes flying in U.S. airspace”, the MARGINS 2004 Science Plan concluded that “too little is known to frame such a study.” But lack of knowledge should not continue to be a rationale for lack of gaining knowledge. The purpose of this report is to urge an international, multihazards and integrated science approach, one in which MARGINS would logically play an important role.

Background

The Aleutian region has been an important human pathway and natural resource since early Holocene time. The Aleuts developed sophisticated technologies in seafaring, hunting, and clothing to survive in its challenging environment and access its rich banquet of food - a banquet that in modern times accounts for more than 50% of US seafood production. Europeans began sailing Aleutian waters in 1741 with the Alaska discovery voyages of Alexander Chirikov and Vitus Bering, leading to colonization by Russia. The United States purchased Alaska along with 80% of the arc shortly after the Civil War. The transaction was derided in Russia as a sellout of part of the country and in America as “Seward’s Icebox”, a waste of money. The intriguing western Aleutians, the Commander Islands where Bering died in attempting to return to Kamchatka, remain Russian.

The region surfaced in American consciousness during World War II when Japan occupied some of the islands, establishing a seaplane and submarine base on Kiska. The sad history of the Aleuts, some captured by the Japanese and others harshly relocated by the Americans, is a depressing and cautionary tale in human relations. Shortly after WWII, an eruption near a military airstrip caused the then U.S. War Department to request the USGS to prepare a report on the threat of volcanic activity along the arc. Investigations that followed culminated in the first geologic study of the Aleutian Ridge and the seminal notion that subduction was the underlying cause of arc volcanism everywhere. Strategic importance of the region continued with the Cold War and attendant military presence and nuclear testing, but made a bilateral pan-Aleutian study impossible.

In 1971, as the plate tectonic para-
Aleutian Subduction

digm was being tested, the first drill cores documenting rates of trench fill sedimentation were recovered from the Aleutian Trench axis off Kodiak (DSDP Leg 18). They confirmed rates of axial sedimentation consistent with plate convergence rather than the much slower rates from sparse conventional sampling. Seismic images showed the subduction of lower trench sediment and accretion of upper turbidite layers.

In response to oil shortages of the 1970s, the USGS conducted extensive offshore investigations of the Aleutian SZ [Scholl et al., 1987]. With 1983’s declaration of the U.S. Exclusive Economic Zone, much of the area of the Aleutian-Alaska offshore was imaged by GLORIA sidescan technology. Later, the one-line TACT and EDGE deep seismic studies of the Alaska forearc significantly advanced knowledge of the evolution of this sector, revealing rapid expulsion of pore fluids from the frontal accretionary prism [Moore et al., 1991, Fuis et al., 2007]. In the west, Russia’s R/V Volcanolog and other research vessels plied Aleutian waters during many expeditions, discovering the submerged and active backarc Pipp Volcano and conducting bathymetric and seismic surveys and dredging [e.g., Gainanov et al., 1970; Ustinov and Volk, 1985].

The end of the Cold War opened scientific opportunities, but did not mitigate the logistical challenges of scientific research in the Aleutian environment. Some important discoveries were made, nonetheless; for example, the 1995 findings of ODP Leg 145 correlating a late Cenozoic episode of vigorous Kamchatka and Aleutian volcanism with Northern Hemisphere glaciation [Rea et al., 1995]. Among explorations of arc structure and history by occasional NSF-, GEO-MAR-, and NOAA-sponsored cruises was discovery of a plethora of adakitic submarine vents in pull-apart basins west of the most western of Aleutian subaerial edifices.

As with the Magellan probe to Venus, SAR satellites provided the first clear views of many of the cloud-shrouded subaerial Aleutian volcanoes. SAR imagery now allows successful tracking of pre- and syneruptive deformation. The advent of GPS instrumentation revealed the complexity of the broader deformation field, including verification that the Commander Islands sector of the Aleutian Ridge is moving with the Pacific plate, placing the present plate boundary on the Bering-Kresta shear zone.

A near-fatal encounter with an eruptive ash cloud by a passenger Boeing 747 aircraft over Alaska in 1989 led to ambitious expansion of volcano monitoring in the Aleutian arc over the next 15 years through growth of the Alaska Volcano Observatory (AVO), a partnership among the University of Alaska Fairbanks, the State of Alaska, and the USGS. AVO is arguably the first pan-arc volcano observatory, monitoring seismically in real time 33 of the 42 historically active arc volcanoes, stretching 2000 km eastward from Little Sitkin near Amchitka to Mount Spurr near Anchorage.

With parallel growth of volcano and earthquake monitoring and research developments in the Russian Far East and Japan, the Japan-Kamchatka-Alaska Subduction Processes (JKASP) consortium formed to advance scientific collaboration in the region. Multi-disciplinary workshops have been held approximately biennially in Sapporo, Petropavlovsk-Kamchatsky, and Fairbanks since 1998 (http://gps.alaska.edu/JKASP/), yielding collaborative efforts including a volume focusing on Kamchatka subduction and its Aleutian junction [Eichelberger et al., 2007].

Evolution of Aleutian subduction

Scholl [2007] summarized evidence that the oceanic portion of the offshore Aleutian Arc, or Aleutian Ridge, arose about 50 Ma [Jicha et al., 2006] when the Koryak SZ at the northwestern-most corner of the Pacific basin choked on an accreting arc massif. New subduction was forced to propagate westward from the tip of the Alaska Peninsula, turning as it did to align with Pacific plate motion. An initial Alaska Peninsula – Koryak tear in the Pacific slab gradually became the Bering-Kresta tear of today. Seaward jump of subduction entrapped a piece of Pacific plate as the oceanic realm of the present Bering Sea Basin and microplate.

With westward-increasing obliquity of the angle of plate convergence, progressive coupling of the arc with the Pacific plate occurs. Central Aleutian blocks of the arc massif are being frittered from the Bering microplate and rotated clockwise. The far west Commander Islands sector is completely locked to the Pacific plate. Further still, Cape Kamchatka Peninsula records orthogonal collisions of Aleutian arc blocks with Kamchatka. This corner, subduction’s sharpest cusp, ranks as an area of prodigious volcanic output, with ~5-km-high Kliuchevskoi Volcano of the massive Kliuchevskaya group and Aleutian-like Shiveluch in nearly constant eruption. Together, these centers account for a significant portion of the ash clouds that invade the North Pacific air corridor. Yogodzinski et al [2001] attributed geochemistry of volcanism here to exposure of the edge of the Pacific slab to hot mantle.

At the opposite end of the arc, late Cenozoic plunge of the Yakutat block, a continent fragment transported northward along the British Columbia margin, gave birth to Earth’s highest coastal mountain system, hosting the planet’s third largest ice mass. Exceptional uplift rates and 5 Myr of alpine glaciation delivered massive quantities of turbiditic sediment to the Aleutian Trench, which slopes downward to the west. As a consequence, the trench as far west as Attu was flooded with continental sediment, most of which is subducted. Sediment ingestion is one of the factors for the Aleutian SZ to repeatedly nucleate high-magnitude megathrust earthquakes.

The human consequences of Aleutian subduction in the 20th century are fabled. Hapless Kodiak City, 160 km downwind of Novarupta, received 30 cm of ash from the 3-day, 30 km$^2$ eruption...
of 1912, as well as a tsunami from the Mw 9.2 earthquake in 1964. The latter event left nothing of Valdez and swept southward to take lives at Crescent City, CA. Trans-Pacific tsunamis launched by the Aleutian subduction zone in 1948 and 1957 wreaked havoc and destruction at Hilo, Hawaii, and island and coastal communities far to the south.

The long-term effect of Aleutian subduction on circulation in the ocean and atmosphere has been profound. The Aleutian Ridge restricts flow of warm Pacific waters into the Bering Sea and onward to the Arctic Ocean. The only deep channel (~4 km) between the Pacific and Bering is Kamchatka Pass between the Commander Islands and Kamchatka, and this feature is likely ephemeral on the scale of arc lifetime. To the east, the rise of the Alaska and St. Elias Ranges blocked the flow of warm, moist Pacific air into the interior of Alaska and North America respectively. Thus has Aleutian subduction contributed to the thermal isolation of the Arctic and changed the climate of North America.

Superimposed on this long-term climate effect are the consequences of large eruptions. The smallest of the Holocene caldera-forming events, Katmai 1912, had a demonstrable but short-term impact in the Northern Hemisphere. The effects of much larger eruptions, such as the two Okmoks, Fisher, and Aniakchak calderas were probably global. More severe were the local effects to critical ecosystems. The ~1645 BC Aniakchak eruption may have created a trans-Alaska Peninsula dead zone, for a time separating animal and human populations. On a smaller scale, the unexpected and catastrophic eruption of Kasatochi volcano on August 7, 2008 obliterated an island ecosystem that had been carefully monitored by the US Fish and Wildlife Service for decades.

Relevance to national needs

The Aleutian Islands are of considerable importance to both Russia and the United States, and for similar reasons. As in early Holocene time, they are an important transportation corridor. With future opening of the Arctic Ocean, ship traffic will flow between north and south as well as east and west. The Aleutian-Bering Sea region remains one of the few healthy fisheries on Earth, supplying a considerable portion of needs of Russians and Americans and beyond. As such, sustainability and resilience of the region’s communities and their environment is an issue.

The contiguous Aleutian and Alaska sectors of the Aleutian SZ represent, in combination, one of the most geohazardous segments of the Pacific Rim. This is true with respect to explosive arc volcanism, repeated nucleation of giant-magnitude earthquakes (5 since 1899 of 24 globally), and subsequent launching of destructive local and trans-oceanic tsunamis.

Other issues are local, but not necessarily minor, concerns. Examples of the latter include Aleut interest in the integrity of the Amchitka nuclear test site in a great earthquake, and the need of villages to have sustainable, environmentally benign energy sources. A multi-agency alliance in Aleutian studies on the American side would permit application of resources in basic geoscience; hazard, energy and ecosystem concerns; and airborne and satellite-based remote sensing.

Opportunities for illuminating the Subduction Factory

Among the scientific lures of Aleutian subduction are prominent lateral changes in a number of forcing factors and boundary conditions. Along its 4000 km reach are 90° rotation of the angle of convergence, changes of sediment input type and thickness, crossing of Pacific Fracture Zones, breakout of backarc volcanism, changes in position of the arc magmatic front, and the transition between ocean-continent and intra-oceanic convergence. These changes provide valuable tests of how subduction parameters affect melt generation and other factory products.

Because the Aleutian Ridge is deeply dissected by offshore fault scarps, most spectacularly in the Commander Islands, and its summit deeply (4-6 km) denuded by subaerial and wave-base erosion, onshore and offshore mapping and sampling investigation can be mounted to resolve the history of arc magmatic additions.

Finally, there are the “end effects”, with an exposed slab at the Russian western end and jammed subduction at the eastern end.

A binational enterprise would remind Russians and Americans that we are neighbors, despite both having national capitals a third of the world away from the Aleutian arc and a third of a world away from each other.

Acknowledgements

The authors’ brief synopsis contains important contributions from S. Kirby (USGS), R. von Huene (USGS), J. Freymueller (University of Alaska Fairbanks), and others.

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**Call for Interdisciplinary MARGINS Mini-workshop Proposals**

The MARGINS Office (MO) and Steering Committee aim to support efforts that expedite synthesis of results from MARGINS science in the various focus areas and initiatives. To this end, MO offers to help MARGINS-funded investigators organize and fund Mini-workshops held at national meetings for the purpose of bringing together a group of multi-disciplinary investigators to synthesize results to date. Such Mini-workshops can be associated with GSA, AGU, or other national meetings at which your research area is well represented. They can be 2-4 hour workshops one evening after sessions, or half-day sessions before or after the meeting. They can bring together multiple investigators from a single focus site or from both focus sites within an initiative, or can address a theme that transcends initiatives, according to what makes the most scientific sense and where there is the greatest need.

If you are interested in hosting a Mini-workshop, coordinate with your colleagues, and then send the MARGINS Office a 1-2 page outline of your meeting plan as soon as possible (margins@nsf-margins.org). Requests should generally come not later than 3 months ahead of the meeting. The MARGINS Steering Committee (MSC) will review the submitted proposal. Proposals are due by Sept. 1 for events during Fall AGU Mini-workshop. Your write-up should include:

- Scientific rationale for the meeting and reasons for its timeliness.
- Evidence that a wide group of interdisciplinary researchers would be able to attend.
- A draft scientific program for the Mini-workshop.
- The national meeting with which the Mini-workshop would be associated.
- The format (evening, half-day or full day, pre- or post-meeting) desired and acceptable dates
- Size of meeting envisioned.
- Anticipated cost items (meeting space, refreshments, A/V equipment, etc.). Note that a detailed budget for these costs is not initially required, and travel or lodging costs for participants cannot be provided.

There are some ground rules intended to maximize the benefit of such workshops to a larger scientific community and emphasize opportunities for interdisciplinary integration. A number of arrangements will be made upon approval of a Mini-workshop proposal: MO will provide the cost of a meeting room, presentation equipment and non-alcoholic refreshments, and will assist the meeting conveners in the logistical arrangements. Conveners are responsible for developing the science program and communicating with workshop participants on scientific matters. Any MO supported Mini-workshop will be open to all interested parties and will be advertised via the MARGINS mailing list and website. Workshop conveners will provide brief write-up of the major results of the meeting for dissemination via MARGINS website and newsletter.

**The MARGINS Office and Steering Committee**

(Visit [http://www.nsf-margins.org](http://www.nsf-margins.org) for more information)
Computational Infrastructure for Geodynamics

Michael Gurnis
California Institute for Technology

The Computational Infrastructure for Geodynamics (CIG) is a facility that NSF supports for software development and maintenance in the geosciences. The resources provided by CIG are particularly useful for the MARGINS community given the goal of enhancing our understanding of plate margin processes through an interdisciplinary approach.

As a community-governed organization, administered by Caltech, CIG has a small team of software engineers which provides software services to the community in terms of programming, documentation, training, and support. Guidance for the programmers comes from a Science Steering Committee.

With a high level of community participation, CIG has leveraged the state of the art in scientific computing into a suite of open-source tools and codes. Many of the problems addressed generally in geodynamics are computationally challenging, often involving processes occurring over a wide range of time and spatial scales. Since existing solution methods are often not sufficiently robust to solve these problems, CIG has pursued a strategy of partnering with the larger world of computational science. In some cases, scalable, robust methods have yet to be discovered and new research is needed while in other cases methods can be imported from allied disciplines. CIG software is being developed collaboratively with investigators from national labs, software companies, and academics in applied mathematics.

The software is developed and maintained for problems ranging widely from mantle dynamics, crustal and earthquake dynamics, magma migration, seismology, and related topics, key components of the SEIZE, RCL, and SubFac initiatives. CIG has been able to introduce a number of important stand-alone codes that can be used in research, such as CitcomS for thermal-chemical convection, PyLith for the entire earthquake cycle from tectonic loading and unloading to dynamic rupture, and Gale for the spontaneous initiation and evolution of faulted rift and compressional margins. In all cases, we have attempted to balance the needs of respecting the three-dimensional geometry of the geological environment and the strong variations in material properties that occur in tectonic problems, with the need to scale efficiently from desktops to the most massively parallel supercomputers available.

In other cases, CIG has opted not to pursue the development of single stand-alone codes, such as in magma migration because the community has not been able to agree on the equations governing the underlying physics. In the case of magma migration, we have developed benchmarks and developed a test suite of codes for solving them.

One of the underlying computational challenges spanning nearly all of geodynamics is the need to resolve fine-scale features (such as faults or the sharp boundary of a rising mantle plume) embedded in a larger domain (such as a plate or the mantle). The computational challenge is the need to resolve the fine features as they form, evolve and entirely disappear. Often, the fine-scale features...
are associated with strong variations in materials properties (such as jumps in viscosity over many orders of magnitude) making the problems highly ill-conditioned. CIG has pursued a multiple approach to bring useful software to the community. The first is a collaboration with the developers of deal.II, a finite element library with a wide range of functionality in Adaptive Mesh Refinement (AMR), through the creation of a geodynamics AMR test suite. We currently have tutorials for Stokes flow and mantle convection but will soon release examples in magma migration and viscoelastic deformation. We have also pursued a research strategy with the Institute of Computational Science and Engineering (ICES) at the University of Texas, Austin through which we have recently demonstrated global mantle convection problems having resolutions as fine as 1 km while scaling on tens of thousands of computational cores (processors). In terms of resolution and scalability, the applications are far-reaching for all of geodynamics.

An entirely different strategy that CIG has pursued for the community has been the development and maintenance of Science Gateways to allow users to initiate and monitor simulations on the TeraGrid (the current incarnation of the NSF supercomputer centers and a powerful resource that is under-utilized by the geosciences community). One portal applicable to the MARGINS community is CIG’s computational seismology gateway in which users can simulate seismic wave propagation in fully three-dimensional earth models using the versatile Specfem3D code. On the web, users can select the seismic sources and stations (with the data automatically retrieved), select the earth model, start the simulation on a remote parallel computer, and later download the results in the popular SAC format. A beta version allows users to upload their own 3D earth model.

The MARGINS community is encouraged to use CIG software, interact with the developers and oversight communities, and join a working group. We hold several specialized training workshops for both the geodynamics and larger earth science communities. The stand-alone codes can be downloaded as tar files by users to build on their own cluster or as executable binaries that run on a desktop for training and testing. If users do not have a large computer, our major codes are preinstalled on the NSF TeraGrid and CIG has a large community allocation of computational cycles that we can reallocate. Advanced users can download the latest versions of software from our repository or browse our code line by line through the web. Detailed user manuals with technical background, tutorials and benchmarks are available for all codes. For those wanting to actively participate, we have working groups for the subdisciplines of geodynamics, a wide variety of list-servs, and we sponsor several workshops per year. All of the material described here is available through our web site at http://geodynamics.org.

CSDMS and What it Means in the MARGINS context

James Syvitski1, Rudy Slingerland2

1Executive Director of CSDMS, U. Colorado—Boulder; 2Chair of the CSDMS Steering Committee, Penn State

CSDMS, pronounced “Systems”, stands for the Community Surface Dynamics Modeling System. CSDMS deals with the Earth’s surface—the dynamic interface between the lithosphere, hydrosphere, cryosphere, and atmosphere. CSDMS is the virtual home for a diverse community of experts who foster and promote the modeling of earth surface processes, with emphasis on the movement of fluids, sediment and solutes in landscapes, seascapes and their sedimentary basins. In essence CSDMS is about glaciers, floods, deltas, coastal erosion, climate impacts, underwater avalanches, tropical reefs, ocean storms, and much more.

CSDMS includes an open library or repository of useful, vetted, surface dynamic models, along with appropriate databases and numerical tools. The growing library provides access and information on more than 100 models, along with their metadata. The CSDMS Integration Facility in Boulder presently offers 200,000 lines of code. CSDMS’s data repository deals with model initializations and boundary conditions; benchmarking data for stand-alone models; and data structures for system framework validation.

CSDMS Integration Facility as supported by the Cyberinformatics and Numerics Working Group provides the “Middleware” to couple models and data systems. CSDMS uses the “Common Component Architecture” to allow components to be combined and integrated for enhanced functionality on high-performance computing systems. “BABEL” is used as the language interoperability compiler that automatically generates the glue code that is necessary for components written in different open-source languages to communicate, including C, C++, Fortran (all years), Java and Python. CSDMS uses as its Interface Standard “OpenMI”, to define the rules and supporting infrastructure for how a component must be written or refactored in order for it to more easily exchange data with other components that adhere to the same standard. The OpenMI Standard supports two-way links where the involved models mutually depend on calculation results from each other, allowing models to run asynchronously, and represent data on different geometries (grids).

CSDMS offers software products of interest to academia, government and industry, through its Education and Knowledge Transfer Working Group, that in turn is supported by an Industrial Consortium involving energy and environmental companies, and a CSDMS Interagency...
Committee with representatives from NSF, ARO, ACE, ONR, NASA, NOAA, USGS, USDA, EPA, NPS, and DOE/INL. This knowledge transfer effort closely follows the products developed by each of the Environmental Working Groups (Terrestrial; Coastal; Marine) and Focus Research Groups (Chesapeake; Hydrology; Carbonate). Together the CSDMS “virtual” community includes 250 experts (as of Feb 1, 2009) from 22 countries who are advancing the field of Quantitative Geoscience.

CSDMS also provides a concerted effort to help the surface dynamic disciplines take advantage of High Performance Computing (HPC). The CSDMS chain of HPC clusters includes a dedicated Tier 3 CSDMS cluster (512 cores, >6 Tflops), connected to Tier 2 Front Range HPC (7000 cores, >100 Tflops), with plans for linkage to a regional Tier 1 Petascale (>100,000 cores, 2-4 Pflops) system.

As a community effort, CSDMS: 1) ensures continuity and project robustness beyond individual projects; 2) cuts redundancy since open-source models can be built upon on already existing concepts, algorithms and code; 3) allows scientists to engage with software engineers, helping to bridge the cultural and, often, institutional gap between these teams; and 4) offers transparency that promotes user participation, better testing, more robust models and more acceptance of the results.

CSDMS addresses the challenging problems of surface-dynamic systems: self-organization, localization, thresholds, strong linkages across environments, scale invariance, and interwoven biology and geochemistry. CSDMS supports the following imperatives in Earth Science research:

1. discovery, use, and conservation of natural resources;
2. characterization and mitigation of natural hazards;
3. geotechnical support of commercial and infrastructure development;
4. stewardship of the environment; and
5. terrestrial surveillance for global security.

CSDMS partners with related computational and scientific programs to eliminate duplication of effort and to provide an intellectually stimulating environment. To date, partners on the computational side include: ESMF, CCA, OpenMI, CSTMS, CCMP, OMS (Object Modeling System); and with the following observational or field programs: MARGINS, Taiwan CSTS, CCMP, CZO, CUHISI, NCED, LOICZ, NEON, NOPP, NCALM, Carbonate FRG, RCEM. While this alphabet soup seems daunting, each of these large programs commands infrastructure that supports focused research teams that claim with good evidence to be transformative to national interests within their research disciplines.

To date, CSDMS has focused its attention to the MARGINS Source-to-Sink Initiative. The S2S focus on how “tectonics, climate, sea level and human disturbances regulate the production, transfer and storage of sediment and solutes from their sources to their sinks” is completely in line with the grand challenges of CSDMS. The S2S interests in sediment budgets, canyons, shoreline migration, organic fluxes, incised valleys, clinoforms, and siliciclastic-carbonate interactions, are all aspects that the CSDMS community is helping to address through integrated models and the CSDMS Working Groups or Focus Research Groups. S2S offers CSDMS the potential of an integrated database from which to validate coupled models working through the CSDMS framework. CSDMS needs environmentally integrated databases that involve gridded data that represent a time-dependent multidimensional parameter space, from which 1D, 2D and 3D simulations can be validated.

A community challenge is to ensure good cross-fertilization of ideas and needs. A modeling study might require a CSDMS field program to sample in a prescribed manner, so as to best exercise the model’s predictive capabilities in both time and space. S2S field-based studies might otherwise work to economize their research funds and thus sample in a manner to maximize the information needed to uncover the geological history of their area of interest. The two sampling approaches might be very different in where or when observations are made. Indeed the field sites themselves might be different, chosen to reflect the unique criteria of each community. Yet even with little consensus, both communities offer much to the other and strongly support the efforts of one another. As extension of the MARGINS program is discussed this support will undoubtedly be tapped.

**Enhance Your Broader Impacts**

A range of programs and resources is available to help investigators enhance the impact and educational reach of their MARGINS-funded research.

- MARGINS Post-Doctoral program: Entrain early-career scientists in your research (see box on page 10)
- Participate in the MARGINS mini-lesson program: Use and evaluate a broad range of teacher-ready MARGINS mini-lessons in your undergraduate classroom ([http://serc.carleton.edu/margins/topic.html](http://serc.carleton.edu/margins/topic.html))
- Encourage your students to enter the MARGINS Student Prize ([http://www.nsf-margins.org/AGU2008/PastPres.html](http://www.nsf-margins.org/AGU2008/PastPres.html))

MARGINS Education and Outreach

MARGINS Steering Committee Highlights, Fall 2008

October 27-28, 2008, Lamont-Doherty Earth Observatory, Palisades, NY

Edited by Andrew Goodwillie

1. Geoff Abers, MARGINS Chairman, welcomed new committee members Mike Gurnis and Danny Stockli, thanked everyone for their efforts on the MARGINS Decadal Review (see items 10 and 11), and summarised recent activities of the MARGINS Office. Last summer, the Office solicited one-page Nuggets highlighting results of science done under the MARGINS program. The nuggets are on line (http://www.nsf-margins.org/Nuggets_Public/nuggets_public.html). MARGINS-related activities at AGU were outlined.

2. Bilal Haq, NSF Program Director, presented an NSF update.
   - The new Assistant Director for Geosciences is Tim Killeen (NCAR). Bob Detrick (WHOI) becomes Division Director for EAR, with Bob Houtman (ONR) as Section Head for IPS/Ship Ops. Candace Major became program director in OCE. IPAs are Rick Carlson (MGG) in charge of the Ridge 2000 program, and Debbie Smith (ODP).
   - An 11-member independent advisory MARGINS Review committee is in place, chaired by Tony Watts. It will meet in February 2009, and report directly to AD/GEO. The coming year is going to be a period of transition for MARGINS.
   - The FY2009 MARGINS Panel saw a record pool of proposals (40).
   - The 2009 budget is expected to be flat. NSF hopes to fund 10-12 proposals from FY09 funds, plus some from FY10 funds.
   - The FY2010 budget is also expected to be flat. Awards will include funding for synthesis work, deferred field programs, and community workshops.
   - MARGINS data policy compliance is being viewed closely within NSF. PIs will be reminded of compliance commitments. Final Reports will not be approved without satisfactory data compliance and future funding will be affected. NSF expects modelers to submit their code as part of the data compliance.
   - MSC reviewed the MARGINS post-doc proposal process and improvement.

3. Workshop Report
   - Nathan Bangs summarised the successful SEIZE workshop (Sept, 2008). See report on page 5-10.
   - Demian Saffer outlined NanTroSEIZE developments. Stage 2 drilling is slated for May-Sept 2009 with observatory instrument installation probably in 2010. Ways to access down-hole observatories data in real-time using the Japanese DONET infrastructure are being investigated.

4. Upcoming meetings
   - S2S and RCL synthesis workshops are to be held in April and May 2009. See MARGINS web page. The S2S meeting will be in New Zealand to promote further collaborations with New Zealand colleagues.
   - A SubFac Magma Volatiles TEI is scheduled for September 2009 (see page 20).

5. Education Updates
   - Monthly conference calls are helping move the MARGINS CCLI mini-lessons project to its next stage of formal evaluation. A new mini-lessons workshop is planned for May 2009.
   - The next round of the highly successful MARGINS Distinguished Lecture Program will see six speakers visiting 24 schools between Feb-Apr 2009.

6. Göran Ekström, Chairman of the EarthScope Steering Committee, presented an EarthScope update. The construction phase of this NSF-EAR funded facility experiment ended in September, and EarthScope is working with IRIS and UNAVCO to promote integrative science. The EarthScope Office will move every three years and significant Office resources are dedicated to Education and Outreach. Synergies between EarthScope and MARGINS were encouraged.

7. Data Management:
   - Suzanne Carbotte, MGDS PI, summarised MARGINS database accomplishments. There are now entries for 62 field programs covering a diverse suite of marine and terrestrial data types. The MARGINS data portal (http://www.marine-geo.org/portals/margins/) has been improved and data sets can be searched using award number and publications. A GeoMapApp-based 3-D virtual globe, called Virtual Ocean (www.virtualocean.org), is being developed. Community awareness is increasing through workshops and demonstrations. Partnerships with national repositories including IRIS, UNAVCO, NGDC and EarthChem continue to improve MARGINS data services. Future plans include serving more derived MARGINS data products.

8. R/V Langseth update:
   - Steve Holbrook, chairman of the Langseth Science Oversight Committee, and Suzanne Carbotte outlined the first four cruises on the new academic seismic vessel Langseth, and discussed longer-term funding issues. The initial cruises were deemed successful. Langseth’s full operating schedule is about 250 days/year. For 2009, NSF will provide 75% funding with the remainder coming through work for the Taiwanese government.
   - The high-quality airgun source unexpectedly revealed that finer sampling rates can be used.
   - Source-receiver positioning is within industry specifications.
• Brute stacks are created in near real-time.
• The Simrad EM120 multibeam swath system works well.

9. Industry-supported drilling Proposal: Greg Mountain summarised plans for the Ocean Drilling Consortium (ODC) – an academic-industry partnership aiming to plug the 4 months/year funding gap for the refurbished drilling vessel JOIDES Resolution.

• Three industry-preferred investigations emerged from a summer 2008 workshop: (1) Structure and evolution of deep-water basins, (2) Deep Sea reservoirs, (3) Source rocks.
• If funding is approved, the first drilling will be at high northern latitudes for the eight-month block from June 2010 – January 2011. The second block of ship time would be in June 2011-January 2012.
• Scientists from academia would sail on these expeditions. A plan for data access and drill core availability was laid out.

10. Decadal Review Initiative Report summary:
• S2S (Kuehl): In the Waipaoa Focus Site, attention is turning to organic carbon in the system and the role played by human deforestation. A major result from PNG is that development of clinoforms has been documented from multiple sediment sources. Carbon in the floodplain system is an exciting new direction. The CSDMS modelling effort will help bring results together.
• RCL (Ebinger): Major successes of the RCL initiative include recognition of the changing styles of Gulf of CA rifting, and the important roles of magmatism, sedimentation and plate rheology. Looking forward, should RCL be restricted to active margins or expanded to include extinct margins?
• SubFac (Ryan): Key cross-cutting discoveries have been highlighted. MARGINS results have prompted studies on other arcs, and all arcs are found to have water content of 2-6%. Temperatures involved in wet melting are found to be about 200°C lower than previously thought (about 800°C now) and the role of hydrated mineral phases such as serpentine is being examined. So-called tonalite, an intermediate-velocity component, was found under IBM arcs although the bulk composition is gabbroic. MARGINS work also found that geochemical fluxes correlate with seismological attenuation variations and that crustal thickness varies with arc characteristics. Synthesis and modelling work has produced better estimates of slab interface temperatures.
• SEIZE (Bangs): Our view of seismogenic zones and the nature of slip has changed dramatically. Geodesy and seismology give differing estimates of the locked zone. Long-term co-located measurements offer tremendous opportunity. Studies of ETS and VLF are new – from data within the last five years.

11. Decadal Review Documentation: The remaining third of the MSC meeting was spent on the critical task of discussing, writing and finalising MARGINS Decadal Review documentation. Documents have a deadline with both NSF and the Decadal Review Committee of the 7th of November. Important discussions covered uniformity of sections describing each of the four initiatives, the tone and presentation of the initiative review section, how best to highlight the many successes of the MARGINS program, and the importance of a list of high-impact forward-looking questions for each initiative. The question-summary format was also decided for each initiative summary. Writers and editors were identified amongst MSC members for other unfinished sections, and final editorial decisions were made. Throughout, links between initiatives were emphasised. The chairman is most grateful for these invaluable efforts.

MARGINS Database

http://www.marine-geo.org/margins/

Download data! Get field program information!

Visit the MARGINS database to find information on over seventy MARGINS-funded and related terrestrial and marine field programs in the six Focus Sites.

Search for Data (http://www.marine-geo.org/tools/search/) – search by keyword such as investigator, Focus Site, data type, cruise ID.

GeoMapApp (http://www.geomapapp.org/) – explore and visualize data. Import grids, spreadsheets, and shape files. Create custom maps and grids. Export grids, images, and data. Connect seamlessly to partner databases including PetDB, SedDB, UNAVCO, IRIS, NGDC.

Virtual Ocean (http://www.virtualocean.org/) – provides GeoMapApp functionality in 3-D. Import data tables and spreadsheets.

The MARGINS database is a free community resource. For more information about the MARGINS database, please contact info@marine-geo.org or the MARGINS Office.
MARGINS TEI: Volatiles in the Subduction Factory  
Mount Hood, Oregon, September 28-October 1, 2009

Conveners:  
E. Hauri (hauri@dtm.ciw.edu), P. Van Keken (keken@umich.edu),  
K. Fischer (Karen_Fischer@brown.edu), C. Manning (manning@ess.ucla.edu), G. Gaetani (ggaetani@whoi.edu) 

Applications Due: June 1, 2009

The MARGINS Office is pleased to announce a 4-day Theoretical and Experimental Institute (TEI) focused on the behavior, mass-balance, and influence of volatiles in subduction zones. The scope of the meeting will encompass the range of research topics within the MARGINS SubFac (Subduction Factory), SEIZE (Seismogenic Zone Experiment) and RCL (Rupturing Continental Lithosphere) initiatives that are directly influenced by subduction-related fluids. This multidisciplinary meeting, to be held Sept. 28-Oct. 1 2009 at Timberline Lodge, Oregon, will bring together geochemists, geophysicists and modelers to critically examine and discuss the current state of our knowledge on the budgets of H$_2$O, CO$_2$, N, F, S, Cl, noble gases and hydrocarbons in the two SubFac focus sites (Izu-Bonin-Mariana and Central America), to compare and contrast the focus sites, and to deepen our understanding of the influence of volatile elements on issues of importance fundamental to our understanding of subduction zones, including:

- mass-balance of volatile and non-volatile elements into and through the Subduction Factory  
- flux and composition of fluids emanating from fore-arc and the role of serpentine in modulating fluid flow and composition, fault slip, and H$_2$O transport to deeper levels  
- devolatilization reactions in the slab from the trench to the transition zone  
- the composition and mass transfer of fluids from slab to the mantle wedge and arc crust  
- the influence of fluids in earthquake generation and slab and mantle rheology  
- the role of volatiles in the interpretation of seismic observables (e.g. velocities, anisotropy, attenuation) in IBM and Central America  
- magma and volatile fluxes in the IBM and Central American arcs  
- the influence of water on magma generation  
- the effect of arc volatile emissions on volcanic hazards and global climate

The last day of the Volatiles TEI will be devoted to summarizing major unresolved questions regarding volatiles in subduction zones, and using this information to formulate future research directions for the next decadal MARGINS science plan.

Approximately 90 participants can be accommodated. Selected participants will be provided with full or partial funding for travel, accommodation and meals. We encourage applications from young investigators, graduate students, and members of under-represented groups. A record of successful past MARGINS funding is not a prerequisite. Applicants should prepare a short CV, abstract, and brief (half-page) statement of interest. Detailed instructions are included on the web application form which can be accessed from the TEI web page: www.nsf-margins.org/SF/2009/

Applications close on June 1, 2009. Inquiries should be directed to the conveners (e-mail above). 

Applications can be submitted online at:  
The MARGINS database group (www.marine-geo.org/portals/margins) would like to thank the following investigators for contributing information and data since the last newsletter report for a number of MARGINS-funded field programs.

In the IBM focus site, Doug Wiens and Sara Pozgay provided information on terrestrial seismometer station operations during 2003. Data from these land-based instruments as well as from the related OBS studies, formed the core of the Multi-Scale Seismic Imaging MARIANA project. Adam Kent made available geochemistry data for rock samples collected during 2003 from Izu arc volcanoes. Toby Fischer, Dave Hilton and Eric Hauri contributed information on their 2004-2005 field sampling expedition to Marianas-Izu islands.

For the Red Sea Ancillary Site, information is now available for Danny Stockli’s multi-year thermochronology sampling/analysis project.

The Central America focus site also saw updates. The 2006 NicLakes seismic survey (Kirk McIntosh and Paul Mann) and sediment coring program (Robert Dull and Sabine Wulf) for Lake Managua and Lake Nicaragua was added to the database. The 1999-2008 seismic and geodetic CRSEIZE and Nicoya projects of Susan Schwartz and Tim Dixon were expanded.

In the Alaska allied region, rock sampling information for Casey Moore’s summer field programs was added.

For the southern end of the Gulf of California focus site, field program information was submitted for the 2008 neotectonics CHIRP/sidescan cruise of Paul Umhoefer, Neal Driscoll and Graham Kent. For the northern end of the gulf, expedition information for Joann Stock’s 2008 MARGINS-related field mapping program is now available.

Web page updates

New-look MARGINS portal web pages (www.marine-geo.org/portals/margins/) were released. These include an enhanced Search For Data page. In addition to allowing key word searches on scientific name, data and device type, field program or cruise ID, Focus Site, date ranges and geographical bounds, users can now search for entries associated with specific MARGINS NSF awards and references. A Google Maps™-based interactive map viewer shows ship survey tracks, stations and samples from MARGINS-funded expeditions within each of the focus sites. Clicking on a track or station invokes an information bubble with links to the associated data sets and full field program information. Statistics on data file downloads are now being compiled annually to be sent to the contributing scientists.

Education and Outreach

At the Fall 2008 AGU meeting, we ran an information booth in the exhibit hall at which we gave demonstrations of MARGINS database resources. These resources were also highlighted during an Earth2Class workshop held at Lamont for high school teachers.

MediaBank (media.marine-geo.org), a new database resource, provides ready access to a range of MARGINS-related images in a gallery format. Almost 30 images are currently available in the MARGINS album, including photos of IBM volcanoes from Dave Hilton, focus site maps, and images from a number of MARGINS decadal review nuggets. We welcome more contributions.

GeoMapApp and Virtual Ocean

Functionality of GeoMapApp (www.geomapapp.org), the free map-based data exploration and visualisation tool, continues to broaden, and MARGINS-related content has been expanded. In the Central America focus site, Jim Walker’s geochemical analyses were added for his 2004 Guatamalan volcanic samples and can be plotted and graphed, with symbols scaled and coloured for selected geochemical parameters. Through an ongoing international collaboration with JAMSTEC, more grids of processed multibeam bathymetry in waters around Japan and the western Pacific have been added. Multimedia tutorials for GeoMapApp are available on the GeoMapApp web page.

Virtual Ocean (www.virtualocean.org), offers GeoMapApp capabilities in 3-D and continues to draw new users. A wide range of built-in data sets is available. Data tables can be imported and manipulated, custom maps can be generated.

The Global Multi-Resolution Topography synthesis (GMRT) which is the base map for GeoMapApp and Virtual Ocean was updated with multibeam data from a number of MARGINS-funded cruises: Andy Fisher’s 2002 TicoFlux II cruise to the Costa Rican margin, and ten Melville Source-to-Sink cruises to the Papua New Guinea focus site. In addition, more than 150 multibeam cruises from the Scripps archives, primarily for the Pacific Ocean, have been added to GMRT.

We welcome new contributions of data and information from your MARGINS-funded work: please contact us at www.marine-geo.org/about/contact.php.

Participate in Mini-Lessons!
serc.carleton.edu/margins/topic.html
Assessment and in-class trials needed.
The MARGINS Office announces the fifth annual MARGINS Distinguished Lectureship Program for academic year 2009-2010 with an outstanding line-up of speakers. Distinguished scientists involved with MARGINS science and planning are available to visit American colleges and universities to present technical talks and public lectures on subjects related to the four MARGINS science initiatives (www.nsf-margins.org).

**Speakers from last year extend their tour.**

The MARGINS Office is glad to announce that half of the speakers from the 2008-2009 lectureship program have graciously accepted to participate on another round of lecture series for the current program. Farewell and thanks to Greg Hirth, Patricia Wiberg, John Hopper, David Mohrig, and Peter Kelemen for their past two years of contribution to the lectureship program!

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**The MARGINS Speakers and Lecture Themes**

### The Subduction Factory

**Simon Klemperer**

Simon is a Professor of Geophysics, and by courtesy of Geological and Environmental Sciences, at Stanford University.

**Technical lecture**: Crustal structure and evolution of the Mariana intra-oceanic island arc.

**Public Lecture**: The volatile story of subduction zone volcanism

### Katherine Kelley

Katie is an Assistant Professor of Geological Oceanography at the Graduate School of Oceanography, University of Rhode Island.

**Public Lecture**: The role of water in mantle melting and mass transfer processes at subduction zones.

### Chris Goldfinger

Dr. Chris Goldfinger is a marine geologist and geophysicist with a focus on great earthquakes and structure of subduction zones around the world.

**Public Lecture**: Great Submarine Earthquakes, the Riddle of the Sands

**Technical**: Earthquake Recurrence, Segmentation, and Stress Triggering on the Cascadia Margin.

### Source-to-Sink

**Rudy Slingerland**

Rudy Slingerland is a Professor of Geology in the Department of Geosciences at the Pennsylvania State University, University Park, PA.

**Public Lecture**: How River Deltas Work: The Patterns and Dynamics of Distributive Fluvial Systems.

**Technical**: Building a Continental Shelf One Grain at a Time.

### Rupturing Continental Lithosphere

**Donna Shillington**

Donna is a Doherty Associate Research Scientist at Lamont-Doherty Earth Observatory.

**Public Lecture**: Recipe(s) for continental breakup;

**Technical**: An abrupt along-strike transition from magma-poor to magma-rich rifting in the eastern Black Sea.

### Becky Dorsey

Becky is a professor in the Department of Geological Sciences at the University of Oregon.

**Public Lecture**: Stratigraphic record of transform-rift tectonics, southern California and NW Mexico

**Technical**: Crustal recycling along an oblique-divergent plate boundary: from the Colorado Plateau to the Salton Trough and Gulf of California.

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**Interested in hosting a speaker?**

Any college or university wishing to invite a MARGINS speaker may apply via the MARGINS Office website: www.nsf-margins.org/DLProgram. Applications are due July 1, 2009. Invitations from institutions that are not currently involved with MARGINS research are strongly encouraged to apply, including those granting undergraduate or masters degrees, as well as those with Ph.D. programs. Institutions may request a technical and/or public lecture.

The MARGINS Office will cover airfares for speakers’ travel and will coordinate travel and off-site logistics. Host institutions are responsible for local living costs for the duration of the visit.
Biographies of MARGINS New Speakers

(www.nsf-margins.org/DLProgram/)

Katherine Kelley uses geochemical methods to examine the processes of magma formation and evolution in a variety of tectonic settings. She utilizes and develops micro-analytical techniques in geochemistry to probe the compositions of natural glasses and mineral inclusions. Her research currently focuses on constraining the importance of volatile species (esp. water) to mantle and magmatic processes at subduction zones and mid-ocean ridges, developing geochemical tracers of material cycling through subduction zones, and modeling the long-term effects of subduction on the geochemical evolution of the earth’s interior. She has worked on volcanoes from the Mariana islands, the Philippines and Indonesia, ODP drill sites 801 and 1149 in the Pacific plate, and a global sampling of submarine spreading ridges.

Chris Goldfinger has experience with deep submersibles, sidescan sonar, seismic reflection, and other marine geophysical tools on over 30 oceanographic cruises over the last 20 years. He is currently working on great subduction earthquakes along the Cascadia and Sumatran margins, as well as the Northern San Andreas Fault off northern California using the evidence for earthquakes found in deep-sea sediments. Goldfinger is an Associate Professor of Marine Geology and received his PhD from Oregon State University in 1994.

Rudy Slingerland’s research group studies the evolution of morphodynamic systems such as deltas, rivers, and shallow marine shelves by coupling theory, often in the form of dynamical models, with observations in the field and subsurface. Our ultimate goal is develop predictive theories for the behavior of these systems and the stratigraphic record of their deposits.

Becky Dorsey studies the stratigraphic record of basin development at tectonically active continental margins. Becky and her students combine field data with collaborative studies of geochronology, paleomagnetism, geochemistry, and paleontology to assess the tectonic, climatic, and eustatic controls on deposition in ancient sedimentary basins. Current work in southern California and NW Mexico is aimed at understanding the timing, rates, and processes of oblique rifting and continental rupture along the Pacific-North America plate boundary.

Biographies of MARGINS Continuing Speakers

Simon Klemperer uses seismic methods to image lithospheric structure, and to understand the growth, composition and tectonic evolution of continental crust. His research emphasises acquisition of new datasets to explore “natural laboratories”: key regions of earth that exemplify important active processes. A key “Subduction Factory” experiment within the MARGINS initiative has been to measure the crustal volumes and compositions created above the intra-oceanic Mariana subduction zone. Other recent foci of Klemperer’s research in continental tectonics have been Tibet and the Himalaya, the East African Rift, and the Basin-and-Range province of western North America.

Tim Dixon uses space geodetic techniques such as GPS and InSAR (Interferometric Synthetic Aperture Radar) to study motion and deformation of Earth’s surface due to faulting, earthquakes, volcanic activity and coastal subsidence.

Donna Shillington examines the processes associated with continental rupture and initial seafloor spreading using seismic reflection and refraction data in combination with other geophysical/geological data and quantitative techniques, such as subsidence analysis. She has studied these processes at extensional systems such as the Newfoundland-Iberia conjugate margins and the Black Sea. She is also interested in magmatic processes in island arcs and in characterizing variations in pore-pressure and pore-fluid content in sediments.
We are also grateful to AGU for their cooperation and assistance with logistics before, during and after the meeting.

MARGINS Student Prize for Outstanding Presentations
2008 AGU Fall Meeting, Dec 10-14, San Francisco

Congratulations to all those that entered our annual student competition, which took place at the AGU 2008 Fall Meeting. As in previous years, the judges were impressed by the quality and diversity of all entries. We recognize here the outstanding entries that received the highest scores by our judges. The MARGINS Prize accepted entries from students in any nation who could establish a link between their research and a stated aim of a MARGINS Program Initiative. The winners and honorable mentions reflect the breadth of the field, representing several countries, gender diversity and the four MARGINS initiatives.

Our thanks go to the Judges and to the students who entered. Together, it is their efforts that make the MARGINS Student Prize possible. We are also grateful to AGU for their cooperation and assistance with logistics before, during and after the meeting.

Oral Presentation Winner:

Andy Frassetto, University of Arizona, AZ

Student’s Comment: “Thank you for this honor! It’s energizing to be recognized by a community as diverse and respected as MARGINS. I look forward to actively pursuing future MARGINS related research.”

From the Judges:
Andy presented important and interesting data and provided a clear and believable interpretation. A strong presentation. I really enjoyed the talk.

Title of Abstract:
Seismic character of the crust and upper mantle beneath the Sierra Nevada (S32B-05)

Co-Authors: H Gilbert, G Zandt, T J Owens, C Jones

Honorable Mentions:

Mike Krawczynski, Massachusetts Institute of Technology, MA

Student’s Comment:
“Thank you very much for the consideration of my research for this award. I am happy to be considered among the top of the diverse and competitive field that MARGINS supports. I look forward to doing more subduction related research in my career.”

From the Judges:
“Clear, effective delivery. Well backed up conclusion of great importance to Subfac geoscientists. Fantastic Talk.”

Title of Abstract:
Magma processing in the lower crust as recorded in mafic inclusions from Mt. Shasta, CA (V22A-04)

Co-Authors: T L Grove

Poster Presentation Winner:

Justin Brown, Stanford University, CA

Student’s Comment:
“It is a true honor to receive this award from an outstanding community of earth scientists. A special thanks goes to NSF and MARGINS for showcasing student research at AGU. I look forward to continuing my research on MARGINS related initiatives.”

From the Judges:
Justin presented state of the art work. The research is conclusive and high quality. Very well spoken concerning his research and his work has significant impact.

Title of Abstract:
Comparing Observations of Low Frequency Earthquakes From Tremor at Three Subduction Zones (U33A-0023)

Co-Authors: G C Beroza, S Ide, D R Shelly, H Kao, S Y Schwartz

Lepolt Linkimer, The University of Arizona, AZ

Student’s Comment:
“Thank you for this recognition. I hope the MARGINS program continues to benefit and recognize Costa Rican students as well as students from all the Focus Site regions.”

From the Judges:
Lepolt has done an outstanding job in analyzing and error-checking. He clearly had a state-of-the-art understanding of the subject matter. A very strong contribution.

Title of Abstract:
Vp/Vs Ratio and Depth to Moho and the Subducting Cocos Slab across Northern Costa Rica estimated from Receiver Function Analysis (T23B-2036)

Co-Authors: S Beck, S Schwartz, G Zandt, V Levin

Linda Chernak, Brown University, RI

Student’s Comment:
“I am honored that my research has been recognized by MARGINS. I have really enjoyed getting to know the MARGINS community and look forward to future research that contributes to the goals of the MARGINS program.”

From the Judges:
Very clear presentation of an interesting mineralogical/rheological issue. Poster nicely started with big picture motivation and was laid out clearly. Excellent work, well designed and executed.

Title of Abstract:
Experimental Constraints on the Strength of Antigorite Deformed at High Temperature and Pressure (T53C-1966)

Co-Authors: G Hirth

Laurel Childress, North Carolina State University, NC

Student’s Comment:
“I am deeply grateful to have been recognized by the MARGINS program. Thank you to all members of the MARGINS office and community, who make it possible for me and other students to participate in this important research.”

From the Judges:
Well laid out, logical poster. Presentation was very clear, student was engaged and knowledgeable. Effective presentation.

Title of Abstract:
Use of Carbon and Nitrogen Stable Isotopes to Study Late Pleistocene to Holocene Environmental Change in the Waipaoa Sedimentary System, New Zealand (OS11B-1135)

Co-Authors: E L Leithold, N E Blair, B R Brulet
MARGINS-NSF Awards 2009

This is a preliminary list of the funded MARGINS Proposals for the fiscal year 2009. Because of the late budget resolution, NSF spending for FY09 in not finalized as of the printing of this Newsletter. If additional awards are announced, they will be listed in the next Newsletter and we will add the details to the MARGINS Awards web page <www.nsf-margins.org/Mawards.html>.

NSF Award 0840848

MARGINS: The Sr-Nd-Pb-Hf Isotope Evolution of the Mariana Island Arc
Susanne Straub
Lamont-Doherty Earth Observatory of Columbia University

The chemical outflux of volcanic arcs is a compositional blend of the contributing crust, slab and mantle reservoirs. Consequently, variations in the arc outflux over the life of arcs (~20-100 million years) must be coupled to secular changes of the Earth’s surface and mantle reservoirs. In this project, we will investigate the causes of the variable outflux of the Mariana arc that initiated ~49 million years ago as part of the Izu Bonin-Mariana (IBM) subduction zone in the northwest Pacific. The Mariana arc shows a variable K$_{40}$ outflux (K$_{2}O$ normalized to 4 wt% MgO) that increases and fluctuates with time. In order to understand what forces these ‘fluctuations’, we will characterize the time-precise and temporally highly resolved Mariana tephra record from the last 30 million years by major and trace elements and high-quality Sr-Nd-Pb-Hf isotope ratios. The new data will fill an important gap in the overall evolution of the IBM system. On a global scale, the understanding of causal linkages between the arc fluxes and long-term environmental change will be promoted.

NSF Award 0840862

MARGINS: Mariana Forearc Geology and Early Arc Volcanism
Mark Reagan, William McClelland, David Peate
University of Iowa

Funding is requested to carry out geochemical analyses of early subduction-related volcanic rocks from the Izu–Bonin–Mariana (IBM) arc collected via recent Shinkai 6500 diving or on-land investigations by the lead PI near Guam. The goal is to develop a comprehensive understanding of the early evolution of the southern portion of this arc system so that magma sources and melting processes can be compared through time and space, spanning from a proto-arc to a fully developed volcanic arc. Analyses will include major element, trace element, and Sr-Nd-Pb-Hf isotope compositions of whole rocks and pillow glasses, and major, trace, and volatile element concentrations in glassy melt inclusions from olivine and other minerals. The ages of eruption will be constrained by $^{40}$Ar/$^{39}$Ar and U-Pb geochronology.

For subaerial proto-arc samples volatile element contents can be determined by analysis of mineral-hosted glass inclusions. Submarine igneous rocks collected deepest and closest to the trench southeast of Guam comprise fine-grained gabbroic rocks and quench textured basalts. These lavas are resemble mid-ocean ridge basalts, but have geochemical signatures suggesting that they are subduction-related. These forearc basalts are overlain in turn by low-Ca boninite and magnesian andesites. Major element, trace element, and Sr-Nd-Pb isotope analyses are complete for all three rock types. Still needed are Hf isotope analyses. The andesites have been dated at 30-32 Ma, which places their eruption at about the same time as the original IBM arc rifted. The ages of the older rocks, however, are presently only constrained by stratigraphy and comparison to ages of similar rocks from elsewhere in the IBM arc. Further diving will be done in this region during July, 2008. Most of the funds requested here will be used to analyze rocks from these dives, and to complete the geochemical analyses and radiometric age dating. Based on the work accomplished to date, it is postulated that the forearc basalts are the first volcanic rocks to erupt after subduction begins. Their genesis largely involved decompression melting of upwelling mantle as it ascended to fill space left by the catastrophic initial sinking of the slab. It is further hypothesized that continued melting of this now-shallow harzburgitic mantle residue in the presence of a robust flux of water-rich slab-derived fluid resulted in the genesis of the boninites. Beginning with the 45-46 Ma rhyolites on Saipan and 41-42 Ma arc tholeiites on Guam, lavas with relatively normal arc signatures started being generated. Thus the changeover from proto-arc mantle upwelling to first-arc mantle counterflow appears to take 4-7 Ma depending on location. The research is potentially transformative because it could redefine the succession of magmas resulting from subduction initiation, which will contribute to an understanding of why subduction starts and how the mantle responds to the sinking slab. This work will provide improved estimates for mass fluxes of elements from the slab to the surface over the life of the arc.

NSF Awards 0840908, 0841022, and 0841040

Collaborative Research: Defining locations and patch sizes for slow earthquake ruptures in subduction zones
Susan Bilek$^1$, Heather DeShon$^2$, E.Robert Engdahl$^3$

$^1$New Mexico Institute of Mining and Technology; $^2$University of Memphis; $^3$University of Colorado at Boulder

The work proposed is to relocate and examine the focal mechanisms of mid to large size earthquakes along the circum-Pacific subduction zones. Assuming that along-strike variations in rupture processes within the subduction zone reflect fault zone conditions, the PIs will address the following: 1) whether slow earthquakes occur in known tsunami generating areas; 2) whether areas with slow earthquakes have certain characteristics which might make them prone for generating tsunamis; and 3) whether there are spatial correlations between slow slip events and deep episodic tremor and aseismic slip.
NSF Award 0840977

MARGINS FELLOWSHIP: Fluidization of Very Thick Granular Layers in Ancient Thrust Faults

Emily Brodsky
University of California-Santa Cruz

Seismogenic faults - that is, faults that generate earthquakes of significant magnitude, are of particular interest because the earthquakes they produce can cause appreciable damage and loss of life. It is thus very important to understand the mechanisms by which they fail in the brittle regime - i.e., by fracture as opposed to flow. Granular layers are ubiquitous features of faults that form in the brittle regime, and their evolution and behavior have been shown to be critically related to strength and strain rate relationships. In the laboratory, the behavior of both synthetic and natural samples has been shown to be affected by a variety of factors, such as grain size and size distribution, layer thickness, and fluid saturation. Theoretical mechanisms for dynamic weakening of these materials have been proposed and explored, but not examined in the field. Field observations of faults suggest that granular layers fluidize or deform as a suspension that behaves like a viscous fluid. It is therefore essential to examine the role of these factors in natural fault settings and constrain these parameters with observations of in situ granular layers in faults. This study by two female researchers will compare two large, mature brittle faults (one in Alaska, and one in Africa) that contain very thick fluidized granular layers that contain evidence for significant flow during fault activity. The structure of fluidized granular layers has the potential to elucidate the rate at which the fault slipped, as well as the changes in overall strength of faults during the seismic cycle. Among its broader impacts, this study will advance the career development of a young female researcher, Dr. Christie Rowe, including her reintegration into the US academic community. In addition, there will be significant international collaboration with South African and Namibian scientists. The project has high societal relevance in that it addresses the causes of earthquake risk.

MARGINS: Collaborative Research: The Oxidation State of Mariana Arc Magmas and its Relationship to Subduction Volatile and Mass Cycling

Katherine Kelley¹, Elizabeth Cottrell²
¹University of Rhode Island; ²Smithsonian Institution

Geochemical exchange between the earth’s interior and exterior via subduction has modified the composition of both the surface and interior reservoirs through time. The oceanic crust becomes progressively oxidized and hydrated as it ages, linking water and oxidation state in the subducting plate. Oxidized or oxidizing components from the subducted slab may subsequently modify mantle and magmatic oxidation states, thereby influencing element partitioning, magmatic differentiation and degassing, and the long-term evolution of oxygen availability in the mantle. Several recent studies of various proxies for oxidation state have yielded contradictory views of mantle oxidation state in modern tectonic settings and throughout earth history. Modern subduction zones provide an ideal setting to investigate if and how redox conditions of the mantle and hydrosphere have co-evolved. This study will develop a synchrotron-based microbeam technique (micro-XANES) for non-destructive, in situ measurement of the redox-sensitive Fe⁴+ /ΣFe ratio in glasses, which will be directly related to major, volatile, and trace element composition in natural basaltic melts and experimental glasses. Both natural glasses from along and across the Mariana arc/trough system and synthetic glasses from analog piston-cylinder experiments will be analyzed, with the goals of (1) testing magmatic Fe⁴+ /ΣFe ratios against alternative proxies of melt and mantle oxidation state (2) evaluating the role of magmatic processes, volatiles, and slab-derived components in influencing oxidation state, and (3) modeling the effects of the subduction cycle on the long-term evolution of redox conditions in the earth’s interior.

Collaborative Research: Geomorphodynamic Modulation of Biogeochemical Fluxes and Basin Stratigraphy of the Fly River

Marc Spiegelman¹, Peter van Keken²
¹Columbia University; ²University of Michigan Ann Arbor

The work proposed is to develop quantitative tools to model fluid flow and magmatism at subduction zones. The focus of the work will be on the top of the downgoing slab where fluids are released by metamorphic dehydration reactions, and the mantle wedge where fluids interact with high temperature solids to form magma. The work will start with 2-D models and extend to more challenging 3-D models.

NSF Award 0841077

Imaging 3D Seismic Velocity and Attenuation Heterogeneity Along the Seismogenic Zone of Costa Rica and Nicaragua

Heather DeShon
University of Memphis

The work proposed is to integrate existing national and international seismic data sets to provide insight into seismogenic zone processes at the subduction zone offset of Costa Rica and Nicaragua. This subduction zone generates large and tsunami earthquakes.

NSF Awards 0841061 and 0841091

Collaborative Research: A Plate Boundary Observatory on the Nicoya Peninsula, Costa Rica

Timothy Dixon¹, Susan Schwartz²
¹University of Miami Rosenstiel School of Marine & Atmospheric Sci; ²University of California-Santa Cruz

The work proposed is to augment, upgrade and extend the monitoring period of an existing network of GPS and seismic instrumentation on the Nicoya Peninsula, Costa Rica. The questions to be addressed by the data collected include: 1) What is the relationship between slow slip, tremor, strain accumulation and interplate earthquakes? 2) What is the role of temperature and fluids in tremor and slip generation? 3) Is the occurrence of fast and slow slip tremor spatially and/or temporally separated? The answers to these questions have important implications for understanding seismic processes at subduction zones.

NSF Awards 0841079 and 0841075

Neptune System, Boundary Observatory on the Nicoya Peninsula, Costa Rica. This subduction zone generates large and tsunami earthquakes.

NSF Award 0841077

NSF Awards 0841108 and 0841006
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Upcoming MARGINS Meeting:

Volatile TEI
Mount Hood, Oregon, September 28-October 1, 2009
Applications Due June 1, 2009
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NSF-MARGINS Proposal and Postdoctoral Fellowship Deadline:
July 1, 2009.