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Science initiatives and research progress in the U.S. MARGINS Program

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Introduction Commencing in 1997, a series of community wide workshops and planning meetings led to the development of four science initiatives within the U.S. MARGINS Program: the Seismogenic Zone Experiment (SEIZE), the Subduction Factory (SubFac); Rifting of Continental Lithosphere (RCL) and Sedimentation from Source to Sink (S2S). All four initiatives center on integrated, interdisciplinary studies of active processes at plate margins, and necessitate research that crosses the shoreline. Research funded by the National Science Foundation includes observational, analytical, theoretical and experimental studies of key regions and processes. The specific research projects are buttressed by a series of synthesis workshops and Theoretical and Experimental Institutes that engage a larger community than those funded by NSF-MARGINS. Results of research and meetings are widely disseminated via the MARGINS website (www.margins.wustl.edu) and published books. The Initiatives The first initiative established, SEIZE focuses on the seismogenic zone, that part of the subduction zone where earthquakes occur on the interface between the upper and downgoing plates at ca. 10-40 km depth. These are the regions where the Earth's most dangerous earthquakes and tsunamis typically occur. In detail, the depth, abundance and magnitude of seismicity can vary dramatically in seismogenic zones around the world. SEIZE asks: 1) what controls the characteristic depth of the seismogenic zone in both its updip and downdip limits; 2) what controls the speed of rupture during an earthquake; 3) what are the temporal variations in stress, deformation and fluid pressure and composition through the seismic cycle and what are their effects on seismicity; and 4) what conditions lead to tsunamigenic earthquakes? SEIZE research focuses on the Nankai region of Japan and Central America (including the Osa Peninsula), where the seismogenic zone is shallow enough that riser drilling may penetrate

the interface within, or very near to, the up-dip limit of the seismogenic zone. The talk will show research to date in the two focus areas, including seismology, geodesy, heat and fluid flow and fluid chemistry, and laboratory studies of material properties along the seismogenic zone. SubFac studies the subduction of oceanic lithosphere (crust and mantle) and overlying sediments, together with their associated volatiles, from trench to rear-arc and into the deep mantle. In addition to earthquakes and explosive volcanism, this process also leads to the growth of the continents and formation of ore deposits, support of a subduction zone biosphere, and changing composition of the atmosphere as well as the deep mantle. SubFac addresses three primary foci: 1) how do variations in subduction parameters (e.g. convergence rate, plate age, sediment dynamics, thickness of the overlying plate lithosphere) control the production and composition of fluids and melts across the width of the subduction factory; 2) how does the cycle of water and CO2 affect biological, physical and chemical processes from trench to deep mantle; and 3) how do subduction and volcanism affect continental growth and evolution? Focus areas for SubFac are the Izu-Bonin-Mariana arc, where old cold plate is subducting, and Central America, where a young, warm slab is subducting, along with its carbonate sediments. Research to date includes seismic studies of crustal structure and mantle velocity, geodesy, magnetotellurics, geochronology, petrology and geochemistry, studies of water in subduction zone fluids and serpentinites, in arc lavas and in experimentally determined melting processes, and theoretical studies of mantle melting, convection and melt migration. RCL provided much of the original impetus for the development of a MARGINS program and approach. RCL focuses on the major factors that control lithospheric deformation leading to continental break-up and the formation of new oceans, and includes societally relevant aspects such as oil and gas deposits. With strong integration between theorists and observationalists, RCL investigates:1) the driving forces of rift initiation, continuation and propagation; 2) variation in lithospheric deformation in time and space and the controls on rift architecture; 3) the physical, thermal, rheological and chemical evolution of the crust and upper mantle as rifting proceeds to seafloor spreading; and 4) the distribution, composition, volume and melting depth of magma associated with continental extension. Focus areas are the Gulf of California/Salton Trough (GOC/ST) and the Gulf of Suez/Red Sea (GoS/RS), areas of orogenic and cratonic crust, respectively, where transition from rifting to spreading along strike serves as a proxy for temporal variation in the development of the margin. Progress has been affected by marine mammal issues in the GoC/ST and politics in the GoS/RS. Nevertheless, research to date includes seismic and geodetic studies of the Gulf of California, for crust and upper mantle structure, along with potential field studies, swath bathymetry and field and lab studies. In the Red Sea region, geodetic studies and thermochronological and structural studies are being carried out. The most recently established, Source

to Sink (S2S) focuses on the transfer of sediment from its source in continental uplands, through intermediate storage basins to its sink on continental margins, and the role S2S processes play in Earth's carbon cycle, in ecosystem change due to global change and sea-level rise, and in resource management of soils, wetlands, groundwater and hydrocarbons. Geomorphologists, sedimentologists seismic stratigraphers, hydrologists, and water chemists, both theoretical and observational, work together to address three major themes: 1) how do tectonics, climate and sea-level change regulate the production, transfer and storage of sediments and solutes from source to sink; 2) what processes initiation erosion and sediment transfer and what feedbacks link the processes; and 3) how do variations in sedimentary processes and fluxes interact with tectonics and sea level to build the stratigraphic record, with its history of global changes. Focus areas are the Gulf of Papua (an active foreland basin, tropical, mixed siliciclastic-carbonate system with relatively constant drainage and little anthropomorphic perturbation) and the Waipaoa region of New Zealand (sub-tropical to temperate, siliciclastic system, strong seasonal variations in discharge and from cyclonic events, and strong anthropomorphic impact in last 100 years). Research to date in the Gulf of Papua focuses on clinoform development, sediment dispersal processes, environmental change and floodplain sediment deposition, siliciclastic and carbonate sediment fluxes, and biogeochemical cycling and authigenic mineral formation. In Waipaoa, the initial proposals have just been funded to investigate sediment transport, storage and generation along the actively deforming continental slope. The MARGINS Program was recently reviewed by an NSF blue ribbon committee. Material prepared for that review (summarizing research accomplishments, research gaps, MARGINS Office activities and priorities) and comments from the review committee are available at www.marginsreview.wustl.edu. The committee recommended greater emphasis on education and outreach, increasing event response as scientific opportunities arose, vigorous pursuit of integration within and between the initiatives, and preparation of a plan for a next decade of the US MARGINS program.