SOURCE TO SINK STUDIES

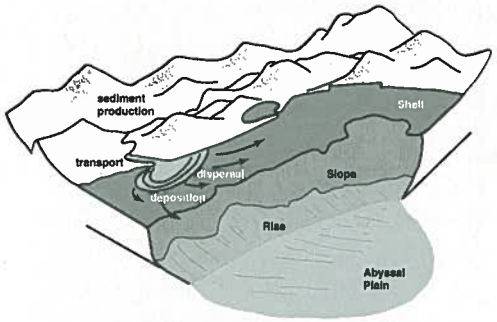
contributed by Charles Nittrouer and Neal Driscoll

Continental margins—including the sediment dispersal systems that traverse and shape them—are inhabited by a significant portion of the world's population. In the United States alone, some 80% of the population is estimated to live within 100 km of the coastline. Yet pollution and coastal erosion threaten sustainable development in these key areas, which also contain important resources such as hydrocarbon fuels, groundwater and agricultural lands as well as coastal wetlands, fisheries and marine algae. In addition, these diverse regions are subject to various environmental hazards such as earthquakes, tsunamis, floods, and landslides.

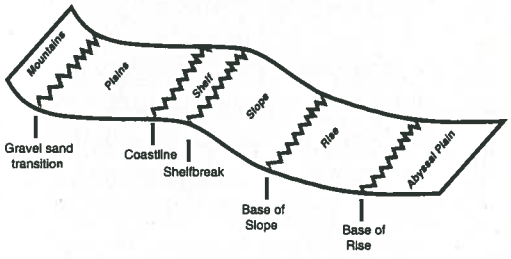
The material dispersal systems of margins convey water, sediment, and associated chemicals from the continent to the sea via rivers, mass movements, and turbidity currents. Typically, on a geological time scale, all the components of the system are in a state of change. The temporal and spatial evolution of margins involves strong interactions among the zones of the sediment dispersal system (Figure 1). Understanding and predicting these changes requires empirical knowledge of the links and feedbacks among the components. At present, we have some understanding of the individual units constituting margins, but we have little ability to link them in a quantitative and predictive way. The MARGINS Source to Sink Initiative was conceived upon the premise that significant improvements in both our understanding and predictive ability can be obtained by studying the links. A ten-year program of concerted research, with a holistic philosophy fully integrating field, experimental, and modeling elements, should produce a major breakthrough toward achieving predictive ability. The intertwining of sediment flux, morphodynamics, and stratigraphy offers an unprecedented opportunity for research synergism.

Fig. 1: "Source to Sink"

Sediment production, transport, and accumulation



(Modified from Hedges and Keil, Marine Chemistry, 49, 81-115, 1995)



The program's research goal is to discern the relationships among margins processes—relevant to sediment production, transport, accumulation, and preservation—on multiple temporal scales (turbulence to tectonics) and spacial, scales (from sedimentary fabric to sequence stratigraphy and basin analysis). An expected outgrowth of the program is an improved ability to quantitatively interpret the stratigraphic record of change in both terrestrial and submarine settings. This approach should extend the existing record of environmental changes over time that have affected human populations and ecosystems along continental margins.

A Source to Sink Workshop—funded by NSF and JOI/USSSP—was held at Lake Quinault, WA, from September 28 to October 1, 1999. The purpose of the workshop, which was convened by Chuck Nittrouer and Neal Driscoll, was to create the science plan for the MARGINS sedimentology and stratigraphy community. This plan suggests important directions for future research; recommends strategies for accomplishing this research; and considers candidate sites for detailed interdisciplinary studies. This plan provides a blueprint for taking geomorphologic, sedimentary, and stratigraphic processes to a substantially higher level of understanding.

MARGINS SOURCE TO SINK STRATEGY

The MARGINS effort encapsulates several conceptual innovations. The first of these is the recognition of margins as entities extending from a sediment source to sediment sink. This idea is best illustrated as a physiographic curve, extending from eroding continental highlands to the portions of the oceans that constitute the ultimate sediment sink (Figure 1). The second conceptual innovation divides this curve into five discrete units separated by four discrete boundaries that are dynamic and shift in response to perturbations. These are delineated below.

Unit	Boundary
Continental uplands	
	Transition from gravel-bed to sand-bed streams
Continental plains	
	Coast (estuaries, lagoons, deltas and shoreline)
Continental shelf	
	Shelf-slope break
Continental slope	
	Slope base
Continental rise and beyond	

Thus, margins, as conceived here, contain two terrestrial units and three submarine units, as well as four boundaries. One of these boundaries, the plains-shelf boundary, contains considerable internal structure. Each of the units may contain subunits, such

as bedrock and alluvial subunits, within the continental uplands zone. Also, each unit may produce sediment through erosion and/or act as a sediment sink through deposition, either temporarily or permanently. The zones are linked by the flux of sediment through the boundaries.

The third, and perhaps most important, of the innovations is the recognition that all of the boundaries are dynamic and shift in response to climatic, tectonic, and anthropogenic perturbations. This motion is perhaps most dramatically illustrated in the major changes to shoreline position in response to sea-level change. For example, the shoreline of the U.S. East Coast has migrated over 100 km landward since the end of the last glaciation. It is essential to understand, however, that every other boundary is also dynamic. For example, the shelf-slope break migrates seaward due to clinoform progradation and the gravel-sand transition migrates downstream in response to tectonically driven inputs of coarse sediment.

Each unit has a characteristic morphology which interacts with sediment flux through the laws of morphodynamics. Wherever there is net deposition within a unit, a stratigraphic section records this interaction. The units "talk" to each other by communicating sediment across the moving boundaries. The "solution" to how each unit responds to perturbation is intimately linked with the "solution" of boundary migration. Thus, at the scales of interest to the MARGINS program, no unit can be viewed in isolation, rather the units must be examined as part of a linked system. Central to the goal of MARGINS is the dynamic quantification of unit interaction in response to the triad of forcing functions: climate change, tectonics, and eustasy.

The linking of the five units allows for even the most distal components to interact with each other — albeit with time lags and filtering of the signal as it propagates through the intermediate units. Thus, rejuvenated tectonism in the continental uplands may ultimately result in increased sedimentation on submarine fans. On the other hand, the increase in sediment supply generated by tectonism may not cause a submarine response if there is sufficient accommodation created by subsidence on the continental plain. Conversely, rapid base-level drop can cause knickpoint migration up bedrock streams on the continental uplands, but only if the effect can propagate through the coastal plain.

The fourth conceptual innovation of the MARGINS program recognizes the power of the analogy between the subaerial and submarine world. The continental uplands are in many ways loosely analogous with the submarine continental slope. The continental plains are likewise loosely analogous to the submarine fans found at and below the continental rise. More specifically the following analog structures stand out.

Subaerial	Subaqueous
Incised bedrock channels	Submarine canyons
Alluvial fans	Submarine fans
Meandering rivers	Meandering channels on fans
Subaerial debris flows	Submarine debris flows
Deltaic tributary channels	Channel networks on submarine fans

In no case is the analogy perfect. The degree of similarity, however, is sufficient to suggest that they represent different expressions of the same set of physical laws. The pursuit of these analogies links the terrestrial and submarine worlds, and goes beyond the already powerful link of sediment transport across moving, dynamic boundaries. The MARGINS program is unique in viewing subaerial and submarine processes, morphology, and stratigraphy as linked pieces of the same fundamental unit, and viewing each unit, subaerial, or submarine, as one realization of a unified underlying structure.

This unified conceptualization demands an interdisciplinary approach to studying margins. Field research provides the baseline empirical base and the overall perspective. Experimental research allows for the testing of hypotheses that cannot be directly tested in the field. Theoretical and numerical research builds the basis for predictive capabilities. This framework requires cooperation among geomorphologists, stratigraphers, and oceanographers, and requires them to cross the shoreline between the terrestrial and submarine environment. There is unprecedented potential for synergism between communities that are not typically in close communication. This is why it is essential to involve both terrestrial and marine earth scientists in the MARGINS Source to Sink Initiative.

Ocean Drilling

One of the major objectives of the Source to Sink Initiative is to assess the morphologic and stratigraphic response of continental margins to a number of environmental forcing functions acting over a variety of scales. To understand the links between fundamental physical processes and the evolution of landscapes and seascapes requires sampling and imaging strategies spanning entire margins, from the mountain tops to the deep sea. Rapid advances in technology have greatly improved the accuracy and precision with which we can image the Earth, both the subaerial and submarine environments. However, marine coring technology available to the research community has not kept pace with geophysical advances, especially in shallow-water environments. Hole stability in, and core recovery of, unconsolidated sediments remains poor, which greatly limits groundtruthing/correlating capability. Addressing fundamental questions about the development and evolution of dispersal systems on continental margins requires platforms for shallow-water drilling (<100 m) that complement the strengths and capabilities of the *JOIDES Resolution*. New coring and downhole logging technology developed for industry offers exciting prospects for continuously coring and logging unconsolidated sediments in diverse environments (e.g., continental shelf and slope). The MARGINS program views ocean drilling, which optimizes drilling and recovery capabilities and develops additional platforms to drill shallow-

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and everyone hopes that the funding for ODP/IODP can increase regularly for the next 6-8 years. The additional funds will be used to fund U.S. science programs related to the drilling program, but not operations. The NSF is understandably reluctant to have its contribution to the international program exceed the current level, approximately 66% (not counting the cost ($6M) of the recent refit which was borne entirely by U.S. funds).

There are remaining concerns about the length of the drilling hiatus between ODP and IODP and the impact on US science planning. However, in a recent letter from Bruce Malfait to Ted Moore (Chair of IPSC), an ambitious program for the transition timing was reiterated. The letter states in part:

> "Funding permitting, it is NSF's intent to begin the selection process for the non-riser vessel, and operator in January of 2002, and make an award for vessel acquisition/modification/conversion by October 2003. Conversion would occur in fiscal year 2004, and the vessel would, hopefully, be available to commence international operations no later than early fiscal year 2005."

Given that ODP drilling will extend to approximately September 2003, the hiatus presently anticipated could be as short as a year, but not as long as 18 months. Peggy Delaney and the U.S. Science Advisory Committee (USSAC) have recently completed a report on the future non-riser drilling platform through the Conceptual Design Committee. The committee found a wide variety of suitable, existing ships, which meet the community's criteria. The report is on-line at:www.joi-odp.org/usssp/cdc/. See page 8 of this newsletter for additional information.

During the coming months, Orcutt will continue to meet with those with a stake in the transition from the ODP to IODP in an effort to develop a transition plan prior to the EXCOM meeting in late June. He will continue to update the community on progress and urges those in the community with questions, concerns, and suggestions about this transition to contact him via email at jorcutt@igpp.ucsd.edu or by telephone at (858) 534-2887.

Source to Sink Workshop, continued from page 17

water environments, as an essential tool for the success of MARGINS science, especially the Source to Sink Initiative.

Fall Education and Planning Workshop

A MARGINS Source to Sink Education and Planning Workshop will be held September 11-15, 2000, at Lake Tahoe. Participants in the workshop will examine the relationships among processes relevant to sediment production, transport, accumulation, and preservation on margins across a large range of temporal and spatial scales. Experts will be invited to speak about various aspects of the selected focus and allied study sites (e.g., New Zealand, New Guinea, and SE Alaska). This approach will provide an opportunity for scientists to submit competitive proposals to the MARGINS January 15, 2001 RFP, even if they were not familiar with the originally selected study sites.

The four-day workshop will begin with an overview of the study sites focusing on processes that affect landscape and seascape evolution. Day 2 will be devoted to examining the interaction and feedback among these processes along the path from the eroding continental highlands to the deep sea. The agenda for days 3 and 4 will accelerate progress on the Source to Sink theme by developing interdisciplinary approaches to research in the focus areas and by implementing a research strategy that maximizes synergy and use of facilities while minimizing dilution of effort. Applications to attend the workshop should be submitted to the MARGINS Office by June 15, 2000. Funds to cover lodging and meals, and to defray partial travel costs, of U.S. participants are available. Applicants should send a one-page email message to margins@soest.hawaii.edu containing (1) address and contact information and (2) a brief description of research interests. Inquiries may be addressed to the MARGINS Office (www.soest.hawaii.edu/margins) or to the convenors care of Chuck Nittrouer (cnittrouer@ocean.washington.edu) or Neal Driscoll (ndriscoll@whoi.edu).

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