Report on the MARGINS Source-to-Sink Theoretical Institute: Teleconnections Between Source and Sink in Sediment Dispersal Systems

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Introduction

MARGINS Source-to-Sink (S2S) is an NSF initiative to develop a quantitative understanding of margin sediment dispersal systems and associated stratigraphy. It aims to answer three overarching questions:

1. What processes control the rate of sediment and solute production in a dispersal system;
2. How does transport through the system alter the magnitude, character, and delivery rate to sediment sinks; and
3. How are variabilities in sediment production, transport, and accumulation in a dispersal system preserved in the stratigraphic record?

At the start of the initiative two focus sites were chosen by the community for detailed study: the Gulf of Papua (GoP) Sedimentary System, Papua New Guinea, and the Waipaoa Sedimentary System of the North Island, New Zealand. Research efforts were initiated in the GoP focus site in 2002 and in the Waipaoa in 2004. To date there have been 20 funded Source to Sink projects, including 12 field studies in the GoP and 5 field studies in the Waipaoa.

Here we report on a recent Theoretical and Experimental Institute (TEI) held on September 17-23, 2006 to foster stronger interaction among observationalists, experimentalists, and theoreticians interested in MARGINS Source-to-Sink problems, with particular emphasis on the two focus areas. The objectives of the institute, entitled "Teleconnections Between Source & Sink in Sediment Dispersal Systems", were

1. to identify key field or experimental observations, theory, and syntheses required to address significant unsolved problems in the S2S system;
2. to facilitate discussion among experimentalists, modelers, and field practitioners involved in studying S2S systems;
3. to consider possible questions for future S2S research; and

4. to educate the community of researchers in the advantages and methodologies of integrating numerical and physical modeling into field studies of the S2S system.

Seventy-nine scientists and student researchers met in northern California for five days of presentations, poster sessions, group discussions, and field trips; 23 remained for a sixth day in which ideas were summarized and future plans discussed in greater detail. Of particular interest was the large number of students (19) and post-doctoral researchers (7) who attended the meeting. Appendix I contains the names of the participants and Appendix II contains the program.

Current S2S Successes

Beyond the personal knowledge gained, the meeting produced a consensus among attendees as to some notable successes that the MARGINS S2S Program has achieved to date. These include:

1. **Collection and archiving of large comprehensive datasets** now available to the entire community at http://www.marine-geo.org/margins/;
2. **Development of S2S system knowledge** that allows NSF core-program studies to succeed where they otherwise might not have been conceived;
3. **Education of graduate students** in new techniques and broader scientific concepts in a learning environment of diverse yet integrated research;
4. **Fostering of a community surface dynamics modeling effort;**
5. **Recognition that timing of river & ocean events** is key to understanding margin sediment dynamics;
6. **Refinement of Recent and Holocene sediment budgets** at both focus sites, at least in a first-order spatial and temporal sense;
7. **At the Waipaoa focus site:**
    a. **successful prediction of the Waipaoa sediment rating curve by Hydrotrend**, and extending it over the past 3000 years;
    b. **recognition that knickpoints along the river provide a key control of signal propagation upstream;**
    c. **recognition of rapid delivery of terrigenous sediment from various sources** to deep water;
    d. **development of a conceptual understanding of the shelf depocenters and sediment fluxes;**
    e. delineation and mapping of a key surface that spans the terrestrial-marine boundary;
8. **At the GoP focus site:**
    a. **progress on a number of river issues,** including decadal and 100 year sediment budgets for the Fly and Strickland rivers showing 40% loss on the Fly floodplain; development of a 1-D model of Fly and Strickland response to sea level change pointing to a topographic barrier;
    b. **identification of multiple sources** in both shelf and deep-water sediments;

c. **realization that the Fly has a more profound effect on global carbon cycle** than anticipated;
d. **first 3-D clinothem characterization** revealing shifting, onlapping lobe deposits;
e. **development of an improved understanding of clinoform dynamics,** including the role of longitudinal flow in growing self-similar clinothems, quantification of the role of tidal and wave-induced gravity mud flows, recognition of the role of tidal dynamics in inner topset sediment processing, and the possibility of condensed horizons as indicators of El Nino conditions; and
f. **recognition of stepwise sea level rise** and its manifestation in clinothem and mixed carbonate/clastic basin stratigraphy.

Current Gaps in S2S Concepts and Research

In the course of discussions, TEI attendees also recognized significant gaps. Objectives identified in the science plan towards which little progress has been made include:

1. **An improved theory and testing of whole-system behavior** in response to various climatic, base level, and anthropogenic forcings. For example, we need to develop theories for signal transfer among system components and for stratigraphy generation;
2. **Better prediction of sediment texture and composition** delivered to a coast under various geomorphic and climatic regimes;
3. **Better process physics and model validation of:**
    a. sand/mud mixtures;
    b. consolidation/ hardening theory for bed erodibility;
    c. gravity flow models (wave-driven and also tide-driven);
    d. sediment routing and storage through tidal reaches;
    e. aggregation dynamics of particles in rivers, estuaries, and the coastal ocean;
    f. dynamics of moving boundaries in margins systems;
    g. floodplain deposition, especially for distal reaches; and
    h. the role of biota in sediment dynamics;
4. **Improved paleohydrologic predictions** of how climate change translates into changing discharge;
5. R**econciliation of short-term and long-term estimates of sediment accumulation rates.** For example, to what extent does the Sadler Effect dictate differences in ^{210}Pb and ^{14}C rates?
6. B**etter gauging of fluxes during extreme events,** both in rivers and the coastal ocean;
7. **More source studies at both focus sites**; and
8. **Better estimates of neritic carbonate production and export processes**, as functions of climate and sea level.

Current S2S Opportunities

TEI attendees noted that since the present S2S Science Plan was written, the development of new technologies and methodologies has expanded opportunities in the understanding of S2S systems. These include:

1. Emerging applications of **radionuclides, organic carbon, luminescence, and other tracers** to track and sediments through the S2S system;
2. **Lidar to delineate geomorphic change;**
3. **Next-generation long cores, thereby allowing us to better understand early Quaternary development of sedimentary sequences;**
4. **Orion, Venus** (Victoria Experimental Network under the Sea) data/equipment for quantitatively documenting the magnitude and impact of events;
5. **Opportunities to develop rapid response infrastructure** and capabilities to monitor sediment dispersal through major events, which would serve model development;
6. **Opportunities to leverage industry interests and resources** if the program were packaged in broader temporal and spatial frameworks; and
7. **Exploit the environmental record of lake sediments** on the floodplains at the focus sites in order to gain, for example, better insights into climatic change and the impact of episodic events.

Summary

The MARGINS Source to Sink program represents one of the first integrated attempts to understand a sedimentary system from the sediment's origin to its ultimate deposition. Over the past four years S2S researchers have recognized new linkages across the system that S2S working models and hypotheses now routinely take into account. A new generation of S2S-inspired fluvial-coastal models demonstrates just how counterintuitive coupled behaviors of this system can be. Older 2-D models of sediment dispersal on shelves are now recognized as inaccurate. An obvious example is clinotherm development, which is now seen to be not a simple 2-D progradation but rather a complex interlinking of sedimentary lobes controlled by global (e.g. sea-level transgression) and local (e.g. river dominance) processes. These successes have arisen because observationalists and theorists in geomorphology, sedimentary geology, marine geology, and paleoceanography are working together as never before. The MARGINS Source-to-Sink Theoretical Institute: Teleconnections Between Source and Sink in Sediment Dispersal Systems provided a valuable opportunity for this community to continue this collaboration by sharing its goals, accomplishments, and evolving concepts regarding processes and products in the Gulf of Papua and Waipaoa S2S systems.

Appendix I. Names of Participants and Affiliation

First Name	Last Name	Institution
Rolf	Aalto	University of Washington
Geoff	Abers	Boston University
Clark	Alexander	Skidaway Institute of Oceanography
Sam	Bentley	Memorial University of Newfoundland
Kelvin	Berryman	GNS Science (New Zealand)
Meredith	Berwick	Washington University in St. Louis
Neal	Blair	North Carolina State University
Mike	Blum	Louisiana State University
Benjamin	Crosby	Idaho State University
Angela	Dickens	Woods Hole Oceanographic Institution
Bill	Dietrich	University of California - Berkeley
Tina	Drexler	University of Washington
Neal	Driscoll	Scripps Institution of Oceanography
Andre	Droxler	Rice University
Thomas	Dunne	University of California - Santa Barbara
Doug*	Edmonds	Pennsylvania State University
Sergio	Fagherazzi	Florida State University
Katherine	Farnsworth	USGS
Kevin	Furlong	Pennsylvania State University
Lila	Gerald	Virginia Institute of Marine Science
Thomas	Gerber	Duke University
Steven	Goldsmith	The Ohio State
Basil	Gomez	Indiana State University
Miguel	Goni	Oregon State University
Steven	Goodbred	Vanderbilt University
Bilal	Haq	National Science Foundation
Courtney	Harris	Virginia Institute of Marine Science
Jenna	Hill	Scripps Institution of Oceanography
Leah	Hogarth	Scripps Institution of Oceanography
Chih-An	Huh	Academia Sinica (Taiwan)
John	Jaeger	University of Florida
Douglas	Jerolmack	MIT
Elizabeth	Johnstone	Scripps Institution of Oceanography
Cary	Kandel	Boston University
Shuh-Ji	Kao	Academia Sinica (Taiwan)
Harvey	Kelsey	Humboldt State University
Albert	Kettner	Technical University Delft
Goran	Kniewald	Rudjer Boskovic Institute (Croatia)
Alexander	Kolker	Stony Brook University
Andrew	Kurtz	Boston University
Elana	Leithold	North Carolina State University
Saulwood	Lin	National Taiwan University

Gwyn	Lintern	Natural Resources Canada
Tom	Lisle	Humboldt State University
Paul	Liu	North Carolina State University
Ben	Mackey	University of Oregon
Kathleen	Marsaglia	California State University - Northridge
Dennis	Martin	University of Washington
Kerry	McCarney	University of South Carolina
Bob	Meade	USGS (Emeritus)
Andrea	Miller	Virginia Institute of Marine Science
John	Milliman	Virginia Institute of Marine Science
Neil	Mitchell	Cardiff University
Frank	Nitsche	Lamont-Doherty Earth Observatory
Chuck	Nittrouer	University of Washington
Jeffrey	Nittrouer	University of Texas
Damian	O'Grady	ExxonMobil
Andrea	Ogston	University of Washington
Irina	Overeem	Technical University Delft
Cindy	Palinkas	University of Maryland
Taylor	Perron	University of California - Berkeley
Lincoln	Pratson	Duke University
Jim	Selegean	U.S. Army Corps of Engineers
Rudy	Slingerland	Pennsylvania State University
John	Swenson	University of Minnesota - Duluth
James	Syvitski	University of Colorado
Catherine	Thompson	North Carolina State University
Amy	Weislogel	Stanford University
Rob	Wheatcroft	Oregon State University
Peter	Whiting	Case Western Reserve University
Patricia	Wiberg	University of Virginia
Matthew	Wolinsky	University of Minnesota
Jill	Womack	Louisiana State University
Paul	Wyer	Washington University in St. Louis
Kehui	Xu	Virginia Institute of Marine Science
Zuo	Xue	North Carolina State University
Penny	Youngs	Stony Brook University
Ho-Shing	Yu	National Taiwan University
Janet	Yun	Chevron Energy Technology Company