



Source to Sink Systems Around the World and Through Time



American Geophysical Union Chapman Conference

Oxnard, California, USA

24-27 January 2011

AGU Chapman Conference on Source to Sink Systems Around the World and Through Time

Oxnard, California, USA
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Cover photo

View of Santa Clara River looking northeastward from the Pacific Ocean sink toward the San Gabriel Mountain source.

David Pu'u, photographer, Santa Barbara, California

AGU Chapman Conference on Source to Sink Systems Around the World and Through Time

Meeting At A Glance

Sunday, 23 January 2011

1800h-1930h Conference Icebreaker

Monday, 24 January 2011

0800h-0820h Welcome and Introductory Comments
0820h-0955h Monday Session (including morning discussion)
0955h-1025h Break
1025h-1145h Monday Session Resumes
1145h-1200h Post-Session Discussion
1200h-1220h Poster Previews
1220h-1230h Presentation of Afternoon Plans
1230h-1400h Lunch (communal)
1400h-1530h Breakout Groups
1530h-1600h Plenary Discussion of Breakout Group Progress
1600h-1800h Monday Poster Session and Evening Reception

Tuesday, 25 January 2011

0800h-1020h Tuesday Session (including morning discussion)
1020h-1050h Break
1050h-1150h Tuesday Session Resumes
1150h-1200h Post-Session Discussion
1200h-1220h Poster Previews
1220h-1230h Presentation of Afternoon Plans
1230h-1400h Lunch (communal)
1400h-1530h Breakout Groups
1530h-1600h Plenary Discussion of Breakout Group Progress
1600h-1800h Tuesday Poster Session and Evening Reception
1900h-2100h Conference Banquet
1900h-1945h Field Trip Presentations at Conference Banquet

Wednesday, 26 January 2011

0800h-1020h Wednesday Session (including morning discussion)
1020h-1050h Break
1050h-1150h Wednesday Session Resumes
1150h-1200h Post-Session Discussion
1200h-1220h Poster Previews
1220h-1230h Presentation of Afternoon Plans
1230h-1400h Lunch (communal)
1400h-1530h Breakout Groups
1530h-1600h Plenary Discussion of Breakout Group Progress
1600h-1800h Wednesday Poster Session and Evening Reception

Thursday, 27 January 2011

0800h-1020h Thursday Session (including morning discussion)
1020h-1050h Break
1050h-1150h Thursday Session Resumes
1150h-1200h Post-Session Discussion
1200h-1230h Final Comments
1300h-1800h Santa Clara River Basin Field Trip

SCIENTIFIC PROGRAM

SUNDAY, 23 JANUARY

1800h – 1930h **Conference Icebreaker**

MONDAY, 24 JANUARY

Welcome and Introductory Comments

Presiding: Chuck Nittrouer, Steve Kuehl
Mandalay A

Monday Session

Mandalay A

- 0820h – 0840h **Niels Hovius** | Sediment Production, Mobilization, Storage and Remobilization in Uplands
- 0840h – 0900h **Joshua J. Roering** | Hillslope form, function, and sediment contribution
- 0900h – 0920h **William E. Dietrich** | Sediment Supply to Rivers: Rates, Controls and Predictability
- 0920h – 0940h **Rudy L. Slingerland** | Modification of Sediment Fluxes by the Transfer Fluvial System
- 0940h – 0955h Discussion
- 0955h – 1025h Break
- 1025h – 1045h **Yoshiki Saito** | Monsoon control of sediment discharge and dispersal in Asia: Examples from a steep river/narrow shelf and a large river/wide shelf
- 1045h – 1105h **David Mohrig** | Connecting the Flow and Sediment-Transport in Coastal Rivers to Short- and Long-Term Patterns of Delta Sedimentation
- 1105h – 1125h **Gail C. Kineke** | The Role of High Concentration Suspensions in Dispersal of River Sediment
- 1125h – 1145h **Gary Parker** | Turbidity Currents and Submarine Debris Flows: Mechanisms for the Dispersal of Sediment from the Nearshore Zone to Deep Water
- 1145h – 1200h Discussion
- 1200h – 1220h Poster Previews
- 1220h – 1230h Presentation of Afternoon Plans

1230h – 1400h Lunch
1400h – 1530h Breakout Groups
1530h – 1600h Plenary Discussion of Breakout Group Progress

1600h – 1800h **Monday Poster Session**
Mandalay B

- M-1 **James T. Liu** | From the Highest to the Deepest: A River-Sea Dispersal System on the NE Edge of the South China Sea
- M-2 **Chih-An Huh** | Magnetic Properties as Source-to-Sink Tracers of Sediments: A Case Study in the Taiwan Strait
- M-3 **Jyh-Jaan Huang** | Mega-flooding and Human Settlement Abandonment Over the Past Millennium in the Lan-Yang River's S2S System
- M-4 **Rick Yang** | The temporal variability of particle composition in the river plume of a small mountainous river
- M-5 **Kristen Ross** | Active Seismic and Tectonic Events Recorded in the Rapid Accumulated Sediments between the Taiwan Lanyang River and South Okinawa Trough
- M-6 **Ray T. Hsu** | Variations of Bulk Flocc Density and Porosity of Different Sizes in Suspended Particles Corresponding to Organic Carbon in the Gaoping River Plume in Southern Taiwan
- M-7 **Carrie Bender** | Evaluating sediment routing from source-to-sink: South Island, New Zealand
- M-8 **Phaedra Upton** | Modeling Source-to-Sink systems in New Zealand: The Waipaoa and the Waitaki catchments
- M-9 **Eric Bilderback** | Timing and magnitude of latest Pleistocene and Holocene deep-seated landslides in the Waipaoa Sedimentary System, New Zealand
- M-10 **Lila E. Rose** | Sediment Records Holocene Transgression in a Tectonically Controlled Shelf Environment, Waipaoa Sedimentary System, New Zealand
- M-11 **Kathleen M. Marsaglia** | Using Sand Composition as a Tracer to Establish Linkages and Disconnects Between Onshore and Offshore Segments of the Waipaoa Sedimentary System
- M-12 **Richard P. Hale** | Sediment-Gravity Flows on the Poverty Bay Continental Shelf, New Zealand
- M-13 **Nicola J. Litchfield** | Tectonic controls on Source to Sink Systems and the interplay with sea level change: examples from northeastern New Zealand
- M-14 **Jean-Noël Proust** | Controls on Relief and Sediment Fluxes of Active Margins at 10 ka to 1 Ma Timescales: The Hawke Bay Forearc Domain Example From New Zealand

- M-15 **Elana L. Leithold** | The use of continental margin organic geochemical stratigraphy to reconstruct watershed history—Lessons from the Waipaoa Sedimentary System, New Zealand
- M-16 **Aaron J. Bever** | The influence of the geometry of Poverty Bay on sediment deposition, dispersal, and sorting within the Waipaoa Sedimentary System, New Zealand: numerical model investigations comparing present-day, 2 kya, and 7 kya configurations
- M-17 **Julia M. Moriarty** | Wave- and Current- Induced Bed Stress on the Waipaoa Shelf, New Zealand: Variations in Time and Space
- M-18 **John P. Walsh** | Strata Development on the Poverty Bay Margin: Insights from Sedimentological, Radiochemical and Geophysical Data
- M-19 **Clark Alexander** | Timing, Magnitude and Extent of Sediment Distribution and Redistribution on the Poverty Continental Margin, North New Zealand
- M-20 **Geert-Jan Vis** | From floodplain to abyssal plain: depocentre migration of a large European river
- M-21 **Alessandro Amorosi** | Heavy metals as indicators of source-to-sink sediment transfer from the Apennines to the Adriatic Sea: the example of the Po Plain
- M-22 **Hans Middelkoop** | The Rhine Delta: A Record Of Sediment Trapping Over Various Time Scales
- M-23 **Pere Puig** | Contemporary Off-shelf Sediment Transport on the Ebro Margin (COSTEM)
- M-24 **David Amblas** | Canyon development on prograding continental margins: an example from the NW Mediterranean
- M-25 **Albert Palanques** | CANYON AND OPEN SLOPE AS SOURCES OF SUSPENDED SEDIMENT TRANSPORT IN THE MARGIN AND BASIN OF THE WESTERN GULF OF LIONS
- M-26 **W R. Geyer** | How hyperpycnal?
- M-27 **Peter T. Harris** | Global distribution of large submarine canyons based on GIS analysis of ETOPO1 bathymetry
- M-28 **Matthew A. Wolinsky** | Source to Sink Sediment Dynamics: Making Models Talk to Data
- M-29 **Shih-Nan Chen** | A numerical investigation of the dynamics of hyperpycnal river plume on sloping continental shelves
- M-30 **Remo Cossu** | Coriolis forces influence the secondary circulation of gravity currents flowing in large scale sinuous submarine channel systems
- M-31 **Som Dutta** | Turbulence Modulation due to Stratification in Turbidity Currents: Numerical Modeling and Implications for Turbidites

- M-32 **Paul Liu** | Fates of River-Derived Sediments to the Sea: Longshore v.s. cross-shelf transport at passive and active margins with high or low energy shelf environments
- M-33 **Tian-Jian Hsu** | The trapping and delivery of fine sediment in the coastal environment

TUESDAY, 25 JANUARY

Tuesday Session

Mandalay A

- 0800h – 0820h **Neal E. Blair** | The Role of Watershed Storage on Exported Riverine Organic Carbon Signatures
- 0820h – 0840h **Brent McKee** | Variable Geochemical Supply to the Ocean
- 0840h – 0900h **Robert C. Aller** | Source to sink serial reactors and the critical importance of energetic topsets in biogeochemical cycling
- 0900h – 0910h Discussion
- 0910h – 0930h **Michele N. Koppes** | On The Rate Of Production And Transfer Of Sediment From Glaciated Terrains
- 0930h – 0950h **Ellen A. Cowan** | Fjord Sedimentation from Tidewater Glaciers
- 0950h – 1010h **John M. Jaeger** | Cross-Margin Signal Transfer in a Glacial Source-To-Sink Sedimentary System, Southern Alaska
- 1010h – 1020h Discussion
- 1020h – 1050h Break
- 1050h – 1110h **Patricia L. Wiberg** | Mechanisms for Entrapment of Sediment Reaching the Coastal Ocean
- 1110h – 1130h **Andrea S. Ogston** | Contrasts in sediment delivery and dispersal from river mouth to modern accumulation zones in high sediment load systems: Fly River, Papua New Guinea and Waipaoa River, New Zealand
- 1130h – 1150h **Andre W. Droxler** | Plio-Pleistocene Evolution of Barrier Reefs along Mixed Continental Shelf Edges
- 1150h – 1200h Discussion
- 1200h – 1220h Poster Previews
- 1220h – 1230h Presentation of Afternoon Plans
- 1230h – 1400h Lunch
- 1400h – 1530h Breakout Groups
- 1530h – 1600h Plenary Discussion of Breakout Group Progress

1600h – 1800h

Tuesday Poster Session

Mandalay B

- T-1 **Zuosheng Yang** | Sediment transport and deposition off the Huanghe (Yellow River) Delta and in the adjacent Bohai Sea and seasonal comparison
- T-2 **Shouye Yang** | The sediment source-to-sink patterns in large drainage basins and marginal seas: the Changjiang (Yangtze River) example
- T-3 **Naishuang Bi** | Seasonal variation of suspended sediment transport through the southern Bohai Strait
- T-4 **Houjie Wang** | Hyperpycnal flows at the Mouth of Huanghe (Yellow River): Past, Present and Future
- T-5 **Susumu Tanabe** | Strata formation in a tectonically subsiding incised valley: a latest Pleistocene to Holocene example from the Shinano River incised-valley fills, Echigo Plain, central Japan
- T-6 **Samuel J. Bentley** | Late Quaternary Sedimentary Development of the Gulf of Papua Outer Shelf and Upper Slope, S2S Focus Area
- T-7 **Erlangga Septama** | Source to Sink Siliclastic Delivery in the Deepwater Gulf of Papua from SEM-MLA-aided Provenance of Turbidite Sands
- T-8 **Evan Portier** | Sources and Distribution of Organic Matter Sequestered in Floodplain Sediments from the Fly River, Papua New Guinea
- T-9 **Rolf E. Aalto** | Imaging beneath the skin of large rivers: Clay controls on system morphodynamics revealed by novel CHIRP sub-surface sonar and deep coring along the Fly and Strickland Rivers, Papua New Guinea
- T-10 **Elizabeth Johnstone** | Three-Dimensional Clinof orm Architecture in the Gulf of Papua: Interplay Between Sediment Supply and Dispersal
- T-11 **Robert R. Weight** | THE HOLOCENE TEXAS MUD BLANKET: A RECORD OF MAJOR CHANGES IN SEDIMENT DELIVERY AND REDISTRIBUTION
- T-12 **Jeffrey A. Nittrouer** | Predicting the time and space properties of bed-material transport in the normal-flow to backwater transition of the lowermost Mississippi River
- T-13 **Alexander R. Simms** | The importance of winds in controlling deposition and reconstructing climate within the estuaries of the Gulf Coast
- T-14 **John B. Shaw** | Tracking the distal extent and character of distributary channels on the Wax Lake Delta, Louisiana, USA
- T-15 **Daniel N. Livsey** | Depositional facies of estuarine upper-bay deposits in arid climates; Baffin Bay, Texas
- T-16 **Timothy M. Dellapenna** | Salt wedge controlled sediment dynamics of the Brazos River, TX: Storage in the lower river, transport to the shelf

- T-17 **Anjali M. Fernandes** | Sediment Fractionation within Bypass-associated and Channel-filling Turbidites of Upper Slope Channels, Brushy Canyon Formation, west Texas
- T-18 **Daniel E. Lawson** | Sediment Flux Variability of Temperate Terrestrial and Tidewater Glaciers, Chugach-St Elias Mountains, Gulf of Alaska Region
- T-19 **Irina Overeem** | FJORD SEDIMENT PLUMES AS INDICATORS OF WEST GREENLAND ICE SHEET FRESHWATER FLUX
- T-20 **Katherine V. Boldt** | The impact of marine melting and sedimentation on glacial advance and retreat in Patagonia, Chile
- T-21 **Rodrigo A. Fernandez** | TEMPORAL AND SPATIAL VARIABILITY IN GLACIAL EROSION AND DEPOSITION BASED ON A STUDY OF PATAGONIAN AND ANTARCTIC PENINSULA TIDEWATER GLACIER SETTINGS
- T-22 **Sean P. Gulick** | Varying Neogene Impact of Glacial Sediment Flux from Source to Sink on Tectonics and Stratigraphy in the Gulf of Alaska
- T-23 **Robert Reece** | Tectonic and climate influence on the evolution of the Surveyor Fan and Channel system, Gulf of Alaska
- T-24 **Edward L. King** | Dependence of canyon-head evolution on mode of shelf sediment delivery on southeast Canadian glaciated shelves
- T-25 **Gordon D. Cameron** | Possible flood events in large shelf crossing troughs on the southeast Canadian Margin
- T-26 **Alison O'Connor** | Distribution and Composition of Organic Matter in Surface Sediments from the North American Arctic Margin: An Initial Assessment of the Arctic Shelf Sink
- T-27 **Kyle M. Straub** | Scale dependant compensational stacking of channelized sedimentary deposits
- T-28 **Michael P. Lamb** | The influence of fluvial-backwater and plunge-point dynamics on hypercynal plume generation
- T-29 **Vamsi K. Ganti** | Space-time Dynamics of Delta Evolution and Implications for Stratigraphy
- T-30 **Cornel Olariu** | SOURCE TO SINK TO SINK: ANALYSIS OF SEDIMENT ROUTING FROM CARPATHIANS TO DACIAN BASIN TO BLACK SEA BASIN FROM MIOCENE TO PRESENT
- T-31 **Andrew Petter** | Estimation of the paleo-flux of terrestrial-derived solids and its implications for the growth of continents and long-term biogeochemical cycles
- T-32 **Jonathan R. Rotzien** | Provenance and overall evolution of the Upper Miocene Upper Mount Messenger Formation, coastal Taranaki, North Island, New Zealand

- T-33 **Rina Schumer** | Which statistical characteristics of sediment dispersal and deposition are recorded in the stratigraphic record?
- T-34 **Timothy I. Eglinton** | Developing a Global Perspective on Dynamics of Riverine Transfer of Terrestrial Biospheric Carbon to the Ocean
- T-35 **Bernhard Peucker-Ehrenbrink** | Controls on the Flux, Age, and Composition of Terrestrial Organic Carbon Exported by Rivers to the Ocean
- T-36 **Hang Yin** | Effects of Salinity on the Size and Strength of Clay-biopolymer Floes

1900h – 2100h **Conference Banquet**

Field Trip Presentations

Presiding: Kathie Marsaglia
Embassy Ballroom

- 1900h – 1915h **Jonathan A. Warrick** | A Summary of the Source-to-Sink Sediment System of the Semiarid Santa Barbara Channel, California
- 1915h – 1930h **Glen T. Leverich** | Geomorphic Landscape Units: An effective approach to quantify relative sediment-production rates across large areas, as applied to the Santa Clara River watershed in southern California
- 1930h – 1945h **Brian Romans** | Linking Terrestrial Denudation to Marine Deposition for the Holocene Santa Clara River Sediment-Routing System

WEDNESDAY, 26 JANUARY

Wednesday Session

Mandalay A

- 0800h – 0820h **Andrew Kurtz** | Upland Weathering Processes in the Fly River System
- 0820h – 0840h **Basil Gomez** | Sediment Production
- 0840h – 0900h **Peter D. Clift** | Controls on the Flux of Sediment to the Arabian Sea from the Western Himalaya since the Last Glacial Maximum
- 0900h – 0910h Discussion
- 0910h – 0930h **John D. Milliman** | Episodic Events and Resulting Sediment Discharge from Small Mountainous Rivers
- 0930h – 0950h **Robert Wheatcroft** | Timing is Everything: The Role of River-Ocean Coincidence in Ocean Sediment Dispersal and Accumulation

- 0950h – 1010h **Piret Plink-Bjorklund** | Stratigraphic Record of Terrestrial Floods: Impact of Monsoon Pattern Changes
- 1010h – 1020h Discussion
- 1020h – 1050h Break
- 1050h – 1110h **Chris Paola** | Experimental studies of linked depositional systems
- 1110h – 1130h **Mike Blum** | Significance of Coastal-Plain and Cross-Shelf Incised-Valley Systems for Source-to-Sink Sediment Routing
- 1130h – 1150h **Alan R. Orpin** | THE CONTINENTAL SLOPE AS A PATHWAY AND SINK FOR TERRIGENOUS SEDIMENT: SOURCE-TO-SINK STUDIES OF CONTRASTING SYSTEMS SINCE THE LAST GLACIAL
- 1150h – 1200h Discussion
- 1200h – 1220h Poster Previews
- 1220h – 1230h Presentation of Afternoon Plans
- 1230h – 1400h Lunch
- 1400h – 1530h Breakout Groups
- 1530h – 1600h Plenary Discussion of Breakout Group Progress
- 1600h – 1800h **Wednesday Poster Session**
Mandalay B
- W-1 **Tilmann Schwenk** | The surface channel-levee systems on the Bengal Fan as late quaternary sink of the Himalaya-Bengal source-to-sink system
- W-2 **Luisa Palamenghi** | Anthropogenic stress and natural processes change the sediment partition in the Ganges-Brahmaputra Prodelta as Sink for the Himalaya Denudation
- W-3 **Maarten Lupker** | Glacial-interglacial weathering in the Himalayan system, a source to sink approach
- W-4 **Liviu Giosan** | Transfer of climatic signals along large monsoonal rivers
- W-5 **Valier Galy** | Organic carbon residence time in the Ganges-Brahmaputra river system: how long is the journey to the Bay of Bengal?
- W-6 **Penny M. Youngs** | Geochemical fingerprints unravel complex source-to-sink behavior under a variety of forcing conditions: Unparalleled insights from the Ganges-Brahmaputra Delta
- W-7 **Jingping Xu** | Modes of Suspended Sediment Transport in Hueneme Submarine Canyon, Southern California
- W-8 **Jim Shobe** | Terrestrial sediment flux across a fringing reef in Moloka'i, Hawai'i

- W-9 **Danielle C. Heston** | Organic Matter Burial in Estuarine Sediments affected by Subduction Zone Earthquakes
- W-10 **Roxanne H. Hastings** | Terrestrial Sediment and Particulate Organic Carbon Deposition Patterns in Ocean Margin Sediments Adjacent to the Umpqua River, Oregon
- W-11 **Miguel A. Goni** | Trends in the Magnitude and Composition of the Particulate Organic Matter Load of Small Mountainous Rivers from the West Coast of the U.S.: What are Some of the Critical Factors?
- W-12 **Curt D. Storlazzi** | Spatial and Temporal Variability in Coastal Grain Size due to River Floods and Storm Waves
- W-13 **Christopher H. Conaway** | The Importance of Episodic Events on Small, Mountainous River Sediment Discharge to the Coastal Ocean and the Efficacy of ⁷Be as a Tracer of Recent Floods
- W-14 **Kristen Lee** | Export and Retention of Fine-Grained Sediment on the Intertidal Complex of a Small Mountainous River: Skagit River Tidal Flats
- W-15 **Daniel J. Nowacki** | Multiple scales of controls on sediment transport in intertidal flats: tidal stage, storms, and seasons
- W-16 **Tara Kniskern** | River discharge along the US West Coast margin: identifying rivers that flood concurrently
- W-17 **Benjamin H. Mackey** | Punctuated Sediment Supply in the Eel River Catchment Caused by Landslide Dams
- W-18 **Leah J. Hogarth** | New Insight Into Lowstand Subaerial Accommodation: Implications for Fluvial Processes in a Sequence Stratigraphic Framework
- W-19 **Benjamin A. Sheets** | Linking terrestrial and submarine processes: a preliminary bathymetric and sub-bottom survey of the Stehekin Delta, Lake Chelan, WA
- W-20 **Rebecca J. Dorsey** | A Preliminary Mass Balance for Colorado River Sediment Since 10 Ma
- W-21 **Volkhard Spiess** | The partial decoupling of source and sink in the current-controlled sediment dispersal systems on the East African and Northern Madagascar continental margin
- W-22 **André O. Sawakuchi** | OSL sensitivity as a tracer of quartz sand grains in a coastal sandy barrier from Southern Brazil
- W-23 **Ines Voigt** | A submarine canyon as sink in the interplay of down-slope and along-slope processes – The Mar del Plata Canyon offshore Argentina
- W-24 **Benedict Preu** | Contourites as source and sink on continental margins – a case study off Argentina and Uruguay

- W-25 **Steven L. Goodbred** | Source-to-margin behavior of an arid, El Niño-influenced mountain drainage and coastal plain: The Chicama River, northern Peru
- W-26 **Jung-Hyun Kim** | Tracing soil organic matter from source to sink
- W-27 **Gert Verstraeten** | The changing anthropogenic impact on sediment source-to-sink transfers since the introduction of agriculture
- W-28 **Bastiaan Notebaert** | Late-Holocene hillslope and fluvial sediment dynamics: a field and modeling approach
- W-29 **Luke McGuire** | Quantifying sediment generation, colluvial transport, and erosion/deposition in a dated, topographically-closed (source-to-sink) landscape: Banco Bonito, New Mexico

THURSDAY, 27 JANUARY

Thursday Session

Mandalay A

- 0800h – 0820h **James P. Syvitski** | Source to Sink Numerical Modeling of Whole Dispersal Systems
- 0820h – 0840h **Courtney K. Harris** | Sediment Dispersal Offshore Of Small Mountainous Rivers: Insights from Numerical Models
- 0840h – 0900h **Alan D. Howard** | Thinking Source-to-Sink on Mars and Titan
- 0900h – 0910h Discussion
- 0910h – 0930h **Ross D. Powell** | Interaction of Eustasy, Ice Sheet Dynamics and Glacial Regime Controlling Sediment Yields, Glacial Sequences and High Latitude Continental Margin Architecture
- 0930h – 0950h **John B. Anderson** | Different Stratigraphic Architectures Offshore Texas Reflect Spatial and Temporal Variability in Sediment Supply and Dispersal
- 0950h – 1010h **Carlos Pirmez** | Sediment flux from source to sink in the Brazos-Trinity Depositional System, Western Gulf of Mexico
- 1010h – 1020h Discussion
- 1020h – 1050h Break
- 1050h – 1110h **Stephan A. Graham** | Source-to-sink in the stratigraphic record: capturing the long-term, deep-time evolution of sedimentary systems
- 1110h – 1130h **Tor O. Sømme** | Use of source-to-sink concepts to provide insight to the stratigraphic record

- 1130h – 1150h **Ole J. Martinsen** | Perspectives on source to sink: methods, tools and development for subsurface interpretation and energy exploration and exploitation
- 1150h – 1200h Discussion
- 1200h – 1230h Final Comments
- 1300h – 1800h **Santa Clara River Basin Field Trip**

ABSTRACTS

listed by name of presenter

Aalto, Rolf E.

Imaging beneath the skin of large rivers: Clay controls on system morphodynamics revealed by novel CHIRP sub-surface sonar and deep coring along the Fly and Strickland Rivers, Papua New Guinea

Aalto, Rolf E.¹; Grenfell, Michael C.¹; Lauer, John W.²

1. Geography, College of Life and Environmental Sciences, University of Exeter, Exeter, Devon, United Kingdom
2. Civil and Environmental Engineering, Seattle University, Seattle, WA, USA

Tropical rivers dominate Earth's fluvial fluxes for water, carbon, and mineral sediment. They are characterized by large channels and floodplains, ancient constructional histories (compared to temperate rivers), frequent and prolonged periods of flooding, and a clay-dominated sediment flux transported above a sandy bed. However, limited insight is available regarding these underlying strata – material that underpins system mobility & morphodynamics. Available data commonly stems from “skin-deep” approaches such as image analysis, shallow sampling of a surface veneer & topographic profiling. Given the large temporal & spatial scales of such systems, new approaches are needed to see below lag deposits on mobile beds & across expansive floodbasins. Furthermore, such data are needed to test whether we can usefully interpret large tropical river morphology using direct analogies to observations from smaller temperate systems. Systems in a dynamic state of response to sea level rise, pending avulsions, or an increase/contrast in sediment load would provide especially valuable insight. We conducted a field campaign along the Fly and Strickland Rivers in Papua New Guinea using a novel CHIRP sub-bottom profiler optimized for shallow, fluvial environments (with which we were able to image 10-20m below the river/lake bed – a new technological advance). We documented stratigraphy, distinguished sandy deposits from harder clay and silt lenses, & also collected bed grab samples to verify our sonar results. Deep borehole samples (5-15m), push cores, and cutbank profiles of material strength confirmed observations from the sonar profiling. We simultaneously collected side-scan sonar imagery plus DGPS water/bed elevations. Findings include: 1) The prevalence of hard clay beneath the bed of the Lower Fly River and many locations along the Strickland River, retarding migration; 2) Unusual bed morphology along the lower Middle Fly River, where the channel traverses a clay bed, with minimal evident bedforms and giant scour holes carved 35m deep into clay at INNER apexes of the peculiar dog-leg meander bends; 3) Hard (old) clay ridges & an intervening channel network buried ~15m below the current bed of Lake Murray, indicating a ~10m rise in the Strickland River near that location; 4) A survey up newly formed rapids of the Mamboi River (though a recently

buried forest) into the middle Strickland River, the pathway for a pending avulsion; 5) The prevalence of clay in many of our deep floodplain cores; and 6) an example of the rapid infilling of a recent oxbow cutoff by clay deposition. It appears that clay (and peat) units dominate the floodplains and large portions of the channel bed. Furthermore, this clay often controls the morphodynamics of the channel, from the head-cut clay knick points of the pending avulsion, to many frozen meander bends, to the unusual dog-leg meanders of the lower Middle Fly River. We conclude with a synthesis of how diffuse clay deposition can play a major role in orchestrating the channel morphodynamics of large rivers.

Alexander, Clark

Timing, Magnitude and Extent of Sediment Distribution and Redistribution on the Poverty Continental Margin, North New Zealand

Alexander, Clark¹; Kuehl, Steve²; Orpin, Alan³; Rose, Lila²; Ponderoux, Hugo⁴

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Active continental margins have the potential to preserve high-resolution records of fluvial sediment transport from land to sea, as well as the redistribution and accumulation of these sediments within the shelf and slope environment. Five long cores collected from the Poverty margin, North Island, NZ, a margin which receives sediment input from the high-sediment yield Waipaoa River, contain such records, allowing an examination of the partitioning of sediment across the margin during Late Pleistocene to Recent times, and reveals dramatic changes across the Poverty continental shelf and slope in response to sediment supply from changing sources, tectonics and sea-level rise. Three cores were collected from tectonically-controlled basins on the shelf, whereas two cores are from the slope: one from a mid-slope plateau at 1450 m, and the other from a lower slope basin at 2293 m. Over 130 14C dates from shells and foraminifera within these cores afford detailed chronostratigraphic control. Long-term (14C) accumulation rates from the slope cores show that rates there were highest during the late Pleistocene and early Holocene periods, and are lower today. In contrast, rates on the shelf have varied significantly, and show a peak in magnitude at approximately 6-7 ka. Comparison with Modern (100-y) rates and patterns of sediment accumulation show that within the existing depocenters, rates are generally higher today than at any time during the past 18 kyrs, reflecting the strong overprint of anthropogenic activity on land. Eustatic

effects emplace the strongest signal within the long-term margin stratigraphy. Detailed stratigraphy of coherent beds within the cores (i.e., coarser beds within the generally muddy sediments) was examined to provide insight into the dominant processes acting to redistribute sediment from the shelf to the slope and within the slope. Graded turbidite(?) units are common sedimentary components within the slope cores. The age structure of the cores indicates that prior to 12 ka, the Waipaoa River directly discharged to the slope, as evidenced by an abrupt shift in mean grain size from coarse (~5 phi) to fine (~8 phi) sediments in the mid-slope plateau core. Turbiditic units, which are frequent in the lower sections of the mid-slope plateau core, decrease in number in the upper half of the core, suggesting that large downslope sediment flows decreased as sea level rose and sediment supply to the shelf edge decreased. Turbidites make up most of the preserved record in the lower slope core, and accumulation rates abruptly decrease at about 9.5 ka as the sediment provided by direct discharge to the slope and the initial phase of the transgression were effectively cut off.

Aller, Robert C.

Source to sink serial reactors and the critical importance of energetic topsets in biogeochemical cycling

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The terminology: “source to sink”, implies a regular progression of material generation, processing, and storage within a sedimentary system. Geochemically such a progression can in some ways be viewed as a serial set of reactors, or successive facies, each having characteristic reactants, conditions, residence times and sequential products. Material transport need not be one-dimensional or unidirectional, however, and parts of these systems have a disproportionately important role as geochemical alteration - redistribution centers. Flood plains and energetic topset regions of clinoform deltas serve such functions. In the case of topset regions, terrestrially derived reactants, reflecting cumulative drainage basin weathering and well developed biological communities, are mixed with highly reactive marine organic matter and inorganic biogenic debris generated in biologically productive coastal zones. Onshore – offshore compositional gradients are imposed by terrestrial – marine boundary conditions and diagenetic reactions, and are modified by cross – shelf exchange both seaward and shoreward. Seabed reactions in energetic topset regions are strongly influenced by sediment remobilization and typically have unsteady suboxic diagenetic features characteristic of episodically mixed batch reactors rather than steadily accreting piles. Distinctive diagenetic reaction balances reflect drainage basin weathering regimes (e.g., Fe, Al-oxide supply), the extent and nature of coastal wetlands (e.g., terrestrial C_{org} production), marine production patterns (e.g., marine C_{org} , biogenic Si), seawater compositions (oxygen, salt), and sediment remobilization refluxing

(magnitude, frequency, duration). The cycling of C and Si, and minor elements coupled therewith are intense, and topset regions serve as globally significant incineration zones for sedimentary C and reverse weathering regions for Al-silicates and minor elements. Topset products reflux shoreward into coastal wetlands and tidal channels, and seaward to bioturbated storage sites on the foreset and bottomset. Preservable diagenetic signatures of energetic conditions from tropical topset systems include lack of biogenic structures, low C loading (0.1 - 0.4 mg C/ m² particle surface), high C/S (>4), heavy $\delta^{34}S$ (>0), low degree of pyritization (<0.1), and a high fraction of nonsulfidic reduced Fe minerals (siderite, Fe-rich clay). Such energetic muddy systems may have played an important biogeochemical and evolutionary role throughout much of Earth history.

Amblas, David

Canyon development on prograding continental margins: an example from the NW Mediterranean

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Three-dimensional seismic images from deep-water settings around the world show the ancestors of modern submarine canyons within constructional margin strata. These canyons are preserved beneath modern continental shelves and evidently co-evolve with prograding margin clinoforms in a net-depositional setting. We propose a model for the long-profile shape of canyons in such settings that includes the effect of sediment gravity flows and background sedimentation from the water column. The key element in our approach is the treatment of canyons on constructional margins as clinoforms which, together with intercanyon slopes, define the strike-averaged long-profile shape of the margin. We therefore expect to see a conformable stacking pattern of nested canyon strata preserved during margin progradation in the same way that margin clinoforms are preserved and stacked. In the present study we identify the stratigraphic signature of canyon and intercanyon upbuilding and outbuilding in a 600 km² 3D-seismic data set from the Ebro margin, in the NW Mediterranean. Following stratigraphic and geomorphologic

criteria we identify a preserved Base Pleistocene paleosurface representing one of the initial phases of the Ebro Turbidite System. The comparison of stacked ancient and modern canyon long-profiles allows us to discuss on the evolution of the sedimentary conditions in the margin from the Base Pleistocene, thus since the onset of the glacial cycles in the northern hemisphere that caused an increase in sedimentation rates in the world's ocean margins, and particularly in the Ebro margin. By addressing these points, we emphasize on the need to treat together the morphodynamic processes that control submarine canyons and their interfluvies in constructional margins, and on the predictability of these systems. This research is funded by projects EDINSED3D (CTM2007-64880/MAR), PROMETEO (CTM2007-66316-C02-01/MAR), GRACCIE-CONSOLIDER (CSD2007-00067) and HERMIONE (EC contract 226354). 3D-Seismic data is kindly provided by British Gas BV.

Amorosi, Alessandro

Heavy metals as indicators of source-to-sink sediment transfer from the Apennines to the Adriatic Sea: the example of the Po Plain

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A reliable quantitative estimate of changes in source-to-sink sediment transfer during the Holocene requires that high-resolution sequence-stratigraphic studies be coupled with accurate reconstruction of spatial and temporal variability of the sediment-routing system through time. Source-to-sink patterns from the contributing upland river catchments to the delta/shelf system are reconstructed from the Holocene succession of the Po Basin (Northern Italy) on the basis of selected geochemical indicators. Sediment supplied to the delta area by the major trunk river (the Po) exhibits naturally high Cr and Ni values, which invariably exceed the maximum permissible concentrations for residential and recreational sites. This 'anomaly' reflects remarkable sediment contribution from ultramafic (ophiolitic) parent rocks cropping out in the Po drainage basin (Western Alps and NW Apennines). In contrast, alluvial and coastal plain deposits supplied by the NE Apenninic rivers, which drain ophiolite-free rocks, display invariably lower Cr and Ni contents. Within each sediment provenance domain, metal distribution is observed to be controlled primarily by hydraulic sorting, finer-grained deposits (floodplain, interdistributary bays and lagoonal facies associations) invariably showing higher metal concentrations than their coarser-grained (fluvial-channel and distributary-channel facies associations) counterparts. An integrated sedimentological and geochemical investigation of both superficial and subsurface geological units enables accurate characterization of the individual facies associations in terms of their peculiar metal contents. Examples are shown of how the detection of a geochemical signature for individual sedimentary bodies may allow

precise reconstruction (and geochemical mapping) of spatial and temporal variability of sediment dispersal patterns through time. Specifically, thick monotonous successions of prograding (highstand) beach sands can be split into different (and mappable) facies associations on the basis of compositional data. Similarly, lithologically indistinguishable overbank deposits can be attributed to their feeding river channel following geochemical characterization. From a sequence-stratigraphic perspective, while the transgressive surface appears as a readily identifiable stratigraphic surface from core analysis alone, changes in sediment dispersal patterns taking place at the turnaround from retrograding (transgressive) to prograding (highstand) conditions (see the vertical transition from Cr-poor offshore clays to overlying Cr-rich prodelta clays) allow a clear identification of the maximum flooding surface within otherwise undifferentiated mud deposits. One-to-one provenance attribution for each sediment body thus provides the basis for a reliable, quantitative estimate of spatial and temporal variability of sediment flux through the Holocene.

Anderson, John B.

Different Stratigraphic Architectures Offshore Texas Reflect Spatial and Temporal Variability in Sediment Supply and Dispersal

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During the last 12,000 years, the lower (onshore) Brazos and Colorado rivers filled their lower valleys with 30 to 40 km³ of fluvial sediments. The paucity of pre-Holocene deposits in these valleys indicates that they were purged during the previous eustatic fall, a process that we call "fill and purge". This sediment contributed to the formation of large falling stage, fluvial-dominated deltas on the continental shelf. Considerable volumes of sediment was also delivered to intra-deltaic and settings and beyond the shelf break, but it is not possible to constrain this part of the falling stage and lowstand sediment flux. Sediment supply to the central Texas shelf during the falling stage was minimal. During the previous transgression, sediment supply by smaller rivers, including the Sabine, Trinity, Lavaca and Nueces rivers, was mainly trapped in their estuaries (Sabine Lake, Galveston Bay, Matagorda Bay and Corpus Christi Bay). These estuaries all display a back-stepping stratigraphic architecture that was regulated by changes in valley shape and variable rates of sea-level rise and sediment supply. The relative role of these three factors has been isolated using detailed maps of the incised valleys and by constraining the timing of flooding events. Contemporaneous loading events are attributed to sea-level rise and diachronous events are attributed to reductions in sediment supply. The estuaries also lack significant pre-Holocene fill, which indicates that they too were purged of tens of cubic kilometers of sediment during the previous falling stage and lowstand. The central Texas shelf is buried

in transgressive and highstand mud (Texas Mud Blanket) that is ~ 300 km² in area. A total of 26 radiocarbon ages from three drill cores was used to measure the flux of sediment to the mud blanket. Since ~ 9 ka, the mud blanket has accumulated ~ 250 km³ of sediment, of which 57% accumulated during the current highstand, or since ~ 3.5 ka. Approximately one third of this sediment was derived through transgressive ravinement of falling stage deposits. The mineralogical composition of the mud indicates that fluvial contributions came mainly the Brazos and Colorado rivers, with some contribution from the Mississippi River, and that the source did not vary significantly through time. This calls for a dramatic increase in the sediment yields of these rivers during the late Holocene, which is best explained by a more variable climate at this time and elimination of accommodation space within the river valleys as they were filled to capacity. During the current highstand, sediment supply from Texas rivers has varied widely, due partly to anthropogenic effects, but also to natural climate (e.g. ENSO) oscillations. Thus, modern sediment yields is a poor indicator of the long-term yields of these rivers.

Bender, Carrie

Evaluating sediment routing from source-to-sink: South Island, New Zealand

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A longstanding goal of continental margin stratigraphic studies is to establish the timing of sediment transfer between source-to-sink depocenters during eustatic sea level cycles. Sequence stratigraphic models provide a theoretical case for enhanced cross-margin transfer during base-level cycles, yet there are few sedimentological records from modern continental margins to test these models against known proxies of eustasy. The recent completion of Integrated Ocean Drilling Program Expedition 317 to the Canterbury Basin, South Island New Zealand now provides a more complete sedimentary record of the timing of sediment transfer from onshore fluvial systems to offshore deep-sea fans. The Canterbury Basin is part of the Eastern New Zealand Oceanic Sedimentary System (ENZOSS; Carter et al., 1996). The distal component of ENZOSS was targeted by ODP Leg 181, which focused on deeper water depocenters, including the Bounty Trough and Fan. Expedition 317 complements Leg 181 drilling by focusing on more proximal marine portions of ENZOSS, namely three continental shelf sites and one upper slope site. We discuss preliminary results of sediment provenance work done to map the sediment distribution pathways from onshore catchments to the slope and fan. In this system, sediment carried in by currents from the south has a distinct compositional fingerprint imparted from its largely schistose source area which contribute mainly sand-sized quartz, feldspar, and mica. In contrast, sediment from the immediately adjacent metasedimentary

Torlesse Terrane, comprises higher lithic fragment content and only minor mica and feldspar. Thus sediment composition is a significant indicator of extrabasinal vs. intrabasinal sediment supply comprising the Canterbury shelf to slope stratigraphic succession, providing critical information that constrains sediment budget estimates through time. Carter, L., Carter, R.M., McCave, I.N., and Gamble, J., 1996. Regional sediment recycling in the abyssal southwest Pacific Ocean. *Geology*, 24(8):735-738.

Bentley, Samuel J.

Late Quaternary Sedimentary Development of the Gulf of Papua Outer Shelf and Upper Slope, S2S Focus Area

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Jumbo piston cores and sonar data from the shelf edge and upper/ middle slope in the northeastern Gulf of Papua document spatially and temporally heterogeneous patterns of sediment delivery, accumulation, and slope failure during the post-Last Glacial Maximum (LGM) sea level rise, apparently influenced by evolving shelf morphology, physical oceanographic processes, and sediment sources. Five jumbo piston cores, subbottom 3.5 kHz sonar profiles, and extensive multibeam data collected from the R/V Melville in 2004 have been analyzed for this study, as part of the NSF-Margins-S2S research program. Cores were analyzed using a multi-sensor track, digital X-radiography, and for sedimentological characteristics and radiocarbon ages. Results document an outer shelf depocenter that formed during several thousand years near the time of the Younger Dryas, from proximal fluvial sediment sources that diminished in importance after Melt Water Pulse 1B. While outer shelf sedimentation slowed, sedimentation on the adjacent upper slope regions continued, apparently fed by topographically steered currents from the newly flooded shelf. Upper slope and outer shelf morphology also suggest failure and down-slope transport for portions of the shelf-edge depocenter, after the Younger Dryas. The findings from this study suggest that physical oceanographic processes such as waves, tides and bottom boundary currents were important factors in building the mud wedge on the northeastern GoP shelf during the early Holocene, were broadly similar to the physical oceanographic processes acting today building the clinothem in the western GoP shelf. In contrast to more recent shelf clinothems, however, early Holocene deposits on the shelf edge and steep upper slope were more prone to failure and mass transport into deeper water.

Bever, Aaron J.

The influence of the geometry of Poverty Bay on sediment deposition, dispersal, and sorting within the Waipaoa Sedimentary System, New Zealand: numerical model investigations comparing present-day, 2 kya, and 7 kya configurations

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Poverty Bay plays a significant role in the Waipaoa River sedimentary dispersal system. It has acted as a sediment sink over the past 7,000 years, and processes within the bay significantly modify the fluvial sedimentary signal en route to the continental shelf. We used numerical modeling experiments to explore the role that basin geometry and river mouth configuration have played in sediment retention within and export from Poverty Bay. The Simulating WAVes Nearshore (SWAN) model coupled to the Regional Ocean Modeling System (ROMS) numerically estimated wave characteristics, current velocities, and sediment-transport within Poverty Bay. Three different bay geometry and river mouth combinations were investigated; (1) the modern bay, (2) the modern bay circa 2 kya when the river mouth discharged at the bay's northern end, and (3) maximum marine transgression (~7 kya) when the shoreline was 12 km landward of its present position. Modeled representations of realistic yearly floods and a 40 year recurrence interval storm were conducted using present-day and 7 kya sediment loads. Model estimates were analyzed to characterize the wave energy, sediment-transport dynamics, sediment preservation, and coarse and fine sediment segregation for these configurations. Sediment dispersal patterns were sensitive to river mouth orientation, shoreline position, and sediment load. Model estimates indicated that changes to river mouth configuration could subtly modify sediment export from the bay. Of the processes considered, however, the wave sheltering effect dictated by basin geometry provided the most dominant control on sediment dispersal. Wave height on an along-bay transect of the 7 kya bay varied inversely with shoreline progradation rate along the same transect, indicating a link between wave energy, sediment retention, and shoreline progradation. Higher wave energy and proximity between the river mouth and continental shelf have led to increased export of sediment from the modern bay and coarsened sediment supply to the continental shelf, compared to the 7 kya bay. Relative to the modern bay, the 7 kya bay less effectively segregated sediment by size and retained more sediment, which likely fueled the rapid shoreline progradation occurring at that time.

Bi, Naishuang

Seasonal variation of suspended sediment transport through the southern Bohai Strait

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Based on field observations in winter 2006 and summer 2007 and on multiscene MODerate resolution Imaging Spectrometer (MODIS) imagery, the seasonal variation of suspended-sediment transport in the southern Bohai Strait was examined and its possible mechanisms was discussed in this study. The Huanghe water and sediment discharges into the sea have significant seasonal variability due to the effect of the East Asian monsoon. More than 60% of the water discharge and 80% of the sediment discharge occur during the summer due to the southerly or southeasterly summer monsoon from April to September. However, most of the river-delivered sediment is deposited around the river mouth and in the nearshore area in summer. Since the water column is highly stratified in summer and the vertical mixing is significantly weakened, resulting in the rapid deposition of river-delivered sediment within 30 km of the river mouth, even during flood events. Consequently, only ~8 Mt sediment is transported from the Bohai Sea to the Yellow Sea through the southern Bohai Strait from April to September. The huge suspended sediment from the Huanghe river mouth is hard to be transported off the coastal area and further to the Bohai straight. During the winter time (October–March), the northerly and northwesterly monsoon prevails and is much stronger than the summer monsoon. The strong winds generate waves up to 7 m high that propagate towards the coast of the Huanghe delta. The large waves result in intensive resuspension of the seabed sediment off the Huanghe delta due to the enhanced bottom shear stress. In addition, the intense vertical mixing keeps the sediment in suspension and produces uniform suspended sediment concentration (SSC) profiles. These conditions are favorable for long-distance transport. Although the Huanghe water and sediment discharge are quite low compared with that in summer, the area covered by the high turbid waters is much larger than in summer. Highly turbid waters are formed off the Huanghe delta and extend along the coast of Shandong Peninsula to the Yellow Sea via the southern Bohai Strait during winter period. As a result, the SSC in winter in the Bohai Strait is much higher than it is in summer and ~32 Mt sediment was estimated to be transported through the southern Bohai Strait towards the Yellow Sea. Therefore, the sediment transport in the southern Bohai Strait has a significant seasonal variation due to the seasonally varying structure of the water column and the hydrodynamics resulting from the seasonally alternating monsoons. Considering the seasonal variation of water flux (WF) and SSC, the annual sediment flux (SSF) through the southern Bohai Strait was estimated to be approximately 40.0 Mt/yr, about 4–8 times previous estimates, which did not take into

account seasonal variation. Although the Huanghe discharges a large amount of sediment in the summer, the SSF through the southern Bohai Strait in the winter (~ 32.0 Mt) was about 4 times greater than it was in the summer. Thus, winter is the major season for sediment transport from the Bohai Sea to the Yellow Sea through the southern Bohai Strait.

Bilderback, Eric

Timing and magnitude of latest Pleistocene and Holocene deep-seated landslides in the Waipaoa Sedimentary System, New Zealand

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Deep-seated landslides are pervasive in the non-glacial Waipaoa River catchment, New Zealand and are an indication of a landscape in transition. Landslides are important agents of local mass wasting but their overall role in sedimentary systems is generally poorly understood. Using new high resolution topographic data sets, tephrochronology, and field mapping, we investigate the spatial and temporal relationship between river incision and deep-seated landslides and approximate the sediment flux from post 18 ka deep-seated landslides. In the Waipaoa, and for much of the eastern North Island, the shift from the LGM to the current interglacial resulted in catchment-wide channel incision (Berryman et al., 2000; Litchfield and Berryman, 2005). Incision was accomplished by knickpoint retreat that had progressed into most of the major tributaries to the Waipaoa by the early Holocene (Crosby and Whipple, 2006; Berryman et al., 2010). Channel incision, although one of the most widespread and effective erosive processes in the catchment, only contributed $\sim 25\%$ of the total post 18 ka sediment yield (Orpin et al., 2006; Marden et al., 2008). Our analysis shows that deep-seated landslides are unlikely to make up this apparent source area sediment deficit. Geomorphic mapping and tephrochronology in the upper Waipaoa indicate that hillslopes adjusted to rapid incision through deep-seated landslides, which occupy over 20% of the surface area of portions of the catchment. Tephra cover bed ages determined by microprobe analysis suggest that hillslope adjustment in these upper reaches started between the deposition of the ca. 13,600 yr BP Waiohau tephra and the ca. 9,500 yr BP Rotoma tephra. Tephrochronology further shows that many slopes have continued to adjust to channel incision into the late Holocene. Volumetric estimates indicate that the sediment delivered to the offshore sink from these upper Waipaoa

landslides is likely to be less than 20% of the sediment volume calculated for channel incision. This analysis raises questions about erosive processes and our ability to balance large scale sediment budgets. For example, does coastal erosion contribute a significant volume to the offshore sink? Was sediment from other catchments trapped in the Poverty Bay post-glacial shelf basin? Understanding the role of deep-seated landslides in the Waipaoa Sedimentary System has advanced our knowledge about land to ocean sediment transfer and will inform future land-use, environmental and ecological planning decisions, and hazard management.

Blair, Neal E.

The Role of Watershed Storage on Exported Riverine Organic Carbon Signatures

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Lateral movement of carbon and other materials across landscapes and the seafloor is punctuated with periods of storage and reaction. Though we understand basic principles concerning transport and storage effects on the nature of some materials, an adequate understanding is lacking of the cumulative impacts of those processes as material migrates across the biogeochemical landscape. This is essential to the interpretation of geochemical soil and sedimentary records of the past as well as to predicting future responses of systems to perturbations in climate or landuse. Organic carbon in its numerous forms is especially sensitive to storage as a result of chemical and biological processes and thus the potential information content of the organic geochemical record is high. Sources of organic carbon exported from watersheds can be broadly defined as those recently derived for extant ecosystems, those derived for materials aged and altered in storage (soils), and fossil material associated with sedimentary bedrock. Separately, these materials are easy to recognize based on isotopic and molecular compositions and each could in principle be linked to specific mass transport processes such as sheet wash, shallow landsliding or gullying. The blending and alteration of original source signatures during storage appear to attenuate the variability of the exported signal within a system and complicate source identification. Do organic geochemical parameters associated with exported materials scale in a predictable fashion with extent of storage within a watershed? Radiocarbon (^{14}C) is used to probe that question. Riverine particulate organic carbon ^{14}C -compositions reveal robust relationships between radiocarbon content, suspended load concentrations and % organic C. These are easily explained by the mixing of ^{14}C -free fossil C from sedimentary rocks with ^{14}C -containing material derived from extant ecosystems and soils. In essence, the ^{14}C -content of riverine POC inversely correlates with the muddiness of the system. Less clear is a relationship

between bulk 14C-content and watershed size, which would be expected if net residence time or storage within a basin were a dominant variable. A more detailed picture may emerge if bulk 14C POC measurements can be deconvoluted into constituent signatures. Two parameters of interest are the concentration of fossil C and the apparent age of the non-fossil fraction. Fossil C derived from upland sources via the mass wasting of sedimentary rocks should decrease in abundance with time spent within surface bioactive reservoirs such as soils because of oxidative losses. The 14C-age of non-fossil C (contemporary plus aged soil C) should increase with time spent in the watershed. Though data sets are small, they are consistent with the predictions. Further study is needed using both isotopic and molecular composition parameters to determine robust relationships between storage processes and exported signals.

Blum, Mike

Significance of Coastal-Plain and Cross-Shelf Incised-Valley Systems for Source-to-Sink Sediment Routing

Blum, Mike¹

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Sediment transport to the shelf margin and beyond is presently limited due to a globally high interglacial sea-level position, and shorelines that are located in inner-shelf positions. However, the shoreline is a moving boundary that responds to sea-level change, and the shelf margin roughly corresponds to shoreline positions during global ice volume maxima and sea-level minima. River systems respond to sea-level fall by cutting valleys through coastal plains, and extending across exposed shelves. These coastal-plain and cross-shelf incised valleys are the conveyor belts that transport sediment from hinterland sources to the shelf margin, the staging area for dispersal to the slope and basin floor. This presentation uses examples from the Gulf of Mexico, the Mediterranean, and elsewhere to illustrate how incised-valley evolution modulates sediment delivery from hinterland source terrains to the shelf margin, and, ultimately, the sink. First, shelf width is a fundamental control on sediment delivery through its influence on river mouth transit distance and the corresponding time periods over which river mouths are connected to the shelf margin. Shelf gradients and widths correlate to drainage areas and onshore fluvial gradients: although there are exceptions, most large low-gradient systems therefore discharge to the inner part of broad shelves (~50-300 km wide), and are only close enough to the shelf margin for short time periods centered on full glacial sea-level minima. By contrast, short and steep river systems discharge to narrow shelves (<10-15 km), and river mouths remain close enough to the shelf margin for most of a glacial-interglacial cycle, even though flux to the slope and beyond may be significantly greater during full glacial sea-level minima. Second, coastal-plain and cross-shelf incised valleys form in a step-wise manner during sea-level fall, with periods of net incision and valley

deepening punctuated by periods of channel-belt deposition and valley widening. The total volume of sediment exported during the period of incised-valley formation is relatively small compared to the ongoing flux from the hinterlands, and periods of incision with valley deepening produce insignificant additional sediment. However, periods of channel-belt deposition and valley widening significantly increase the export of sediment from the incised valley, perhaps by 25% over background rates, such that periods of fluvial deposition during sea-level fall and lowstand correspond to increased sediment delivery to the shelf margin. Third, for low-gradient margins with broad shelves, drainage basins commonly merge as channels extend across the shelf in response to relative sea-level fall, and smaller systems become tributary to larger systems. This, in turn, increases drainage areas that contribute to single point sources at the shelf margin. Drainage merging may be insignificant for short and steep systems due to short transit distances, resulting in numerous small point sources. For large systems, then, geomorphic response to sea-level change - the merging and unmerging of drainages as they transit the shelf - may be one of the more important controls on flux to the specific parts of the shelf margin, rather than changes in supply from the hinterland per se.

Boldt, Katherine V.

The impact of marine melting and sedimentation on glacial advance and retreat in Patagonia, Chile

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Glacial retreat around the world has been used as dramatic and visible evidence of climate change, and it has considerable practical importance because it directly contributes to global sea-level rise, a major threat of climate change. On a global scale, the complex behavior of outlet glaciers is a prime factor limiting confidence in predictions of sea-level rise. The controls, however, on the fluctuations of some of the largest glaciers on the planet, are only partly related to climate variability and they remain poorly understood. Very little is known about the marine environment of tidewater glaciers except that the depth of water strongly impacts the rate of ice loss. Melting is a strong function of the circulation in the proglacial fjords, which in turn depends on a number of factors including the fjord geometry and the density structure of the water, both of which depend on sedimentation. In addition to forming shoals that can physically and thermally buttress tidewater glaciers, sediments produced by these glaciers are of interest

because they create sedimentary archives recording a wide-range of important continental-margin processes, as well as valuable information about past glacier fluctuations. Proglacial fjords, such as those in Alaska and Chilean Patagonia, offer unique opportunities to study the well-preserved sediment record of glacially eroded material and directly relate the history and architecture of the sedimentary package to variations in terminus position and internal dynamics of tidewater glaciers. Two neighboring glaciers in Patagonia display opposite terminus behavior: Jorge Montt has retreated dramatically while Pio XI has advanced, and yet they share essentially the same source area. Over the past decade, the retreat of Jorge Montt has exposed a 12 km-long fjord. Seismic surveys revealed a sedimentary sequence up to 40 m-thick in the newly exposed fjord, and in more distal locations, >100 m of sediment likely deposited since the Little Ice Age. These thick deposits likely contain a rich sedimentary history of tidewater glacier behavior. Measured water-column suspended-sediment concentrations were an order of magnitude greater near the seabed, which likely reflects sediment transport in the bottom boundary layer and could indicate sediment gravity flows. The results of this project shed light on how sediments and seawater impact the stability of glaciers by respectively controlling how much of the ice terminus is exposed to marine waters and how fast it is melting, as well as how exactly glacial-marine sediments impact and record the detailed history of glacier advance and retreat.

Cameron, Gordon D.

Possible flood events in large shelf crossing troughs on the southeast Canadian Margin

Cameron, Gordon D.¹; King, Edward L.¹

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Gordon D.M. Cameron and Edward (Ned) L. King, Natural Resources Canada, Geological Survey of Canada, Dartmouth, Nova Scotia, Canada, B2Y 4A2 Interpreted high resolution seismic profiles and core data suggest erosion and depositional elements can be attributed to flood events in large shelf crossing troughs on the southeast Canadian margin. Overdeepened basins, constructional moraine complexes, till deposits and interbedded glacigenic debris flows with glacimarine sediments are elements common to these troughs. Within this setting a giant moraine breaching, mid-axis marginal meltwater channeling in late glacial sediments, ubiquitous late glacial unconformities found in deep water below the Holocene transgression and large sandwave field are observed as possible indicators of flood events. The giant moraine breaching, located in Trinity Trough (located on the northeast Newfoundland shelf) may have been from a rapid outburst flood release of a subglacial lake found in an overdeepened basin within the trough. A disconformity and limited iceberg scoured sediment behind Trinity may be related to this event. Evidence suggests this possible catastrophic event may be related to hyperpycnal deposits in nearby Orphan basin as described by Tripsanas and Piper, 2008. Constricted

subglacial waters cut channels into the top of till and till tongue sediments seaward of the moraine complex found in Halibut Channel (located on the southwest Newfoundland shelf), after 17.5 ka cal. A late glacial unconformity in Halibut Channel may have been created by constrained sheet erosion which may also have created a large sandwave field as glacial ice withdrew for the area before 14 ka cal. These events may have contributed sediments to the slope and have similar timing to events described by Piper, et al. 2007. Two unconformities dated at 18.2 ka cal and 12.5 ka cal are interpreted as evidence of melt water erosion of glacimarine sediments in Brandal Basin (Scotian Shelf). The older unconformity is associated with till tongue deposited by glacial ice and is localized to highs in section. The younger basin wide unconformity is usually found at the seafloor and formed by sheet erosion during a basin wide flood event. Most of the eroded material was delivered to the slope since little is found within the basin. Low sea level indicators and paleo-geomorphology reconstructions imply that the troughs were controlled between exposed bank tops which may have set-up stronger bottom currents. This could explain some of the erosion in deep areas of the troughs. We suggest that erosional and depositional elements in large shelf crossing troughs can be attributed to constrained, channelized and episodic floods that may have contributed to slope and rise deposits during the late glacial.

Chen, Shih-Nan

A numerical investigation of the dynamics of hyperpycnal river plume on sloping continental shelves

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A 3D hydrodynamic model (ROMS) is used to investigate the structure and transport of sediment-laden river plume across continental shelves. The idealized model consists of a narrow river channel connecting to a constant sloping shelf sea. The configuration is similar to the bathymetric profiles of systems like the Eel River (USA) and Zhuoshui River (Taiwan). A 3-day flood event with a peak river velocity of 2m/s is simulated, and the riverine sediment concentration of 60 (g/l) is chosen so that the density of sediment-freshwater mixture is denser than the receiving seawater (30psu). Shelf slope is varied between 0.001-0.02. For the various slopes considered, it is found that the location of the plunging point is well described by a critical Froude number condition. Seaward of the plunging point, the river plume dives and moves offshore as a hyperpycnal underflow. Surprisingly, the hyperpycnal layer thins as it moves offshore, contrary to layer thickening due to entrainment observed by various laboratory work. The difference lies on the 3D nature of the flow. In our cases, lateral spreading of the hyperpycnal layer is able to compensate the entrainment of ambient fluid. As a result,

the layer-averaged velocity decreases gradually with offshore distance, which in turn limits the cross-shelf penetration of hyperpycnal flow. The penetration distance is very sensitive to settling velocity. A scaling law of this penetration distance will be presented.

Clift, Peter D.

Controls on the Flux of Sediment to the Arabian Sea from the Western Himalaya since the Last Glacial Maximum

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The Indus River is the dominant drainage system in the western Himalaya and derives variable quantities of material from the Karakoram and western Tibet in the northernmost part of its basin, as well as from the monsoon-influenced Himalaya and Siwaliks ranges to the south. Since the Last Glacial Maximum (LGM) the Indus has been affected by major variations in the intensity of the summer monsoon, which is the primary control on erosion, at least over millennial timescales. Strong summer monsoons cause strong physical erosion during periods of warmer global temperatures. Provenance data show that the clays and micas of the Indus delta changed in their composition as the monsoon intensified at 12–9 ka, reflecting relatively more erosion in the Lesser Himalaya compared to the Karakoram. In contrast, changes in zircon populations postdate 7 ka, indicating a lag in zircon transport of ~5 k.y. between source and the delta. Analysis of the topography, combined with age control from ¹⁴C and OSL dating shows that incision of the flood plains within 600 km of the range front has reached ~10–20 m since the Early Holocene. We estimate that since 5 ka as much as 80% of the sediment load reaching the ocean represents reworking of sediment previously deposited in the flood plains. Much of this incision occurs during a period of weakening monsoon rains. One possible trigger for the incision is modest relaxation of the flexure in the basin following a strong erosional pulse in the Early Holocene that reduced the orogenic load. At the same time chemical weathering in the foreland basin intensified under the influence of the warmer, wetter conditions, driving up the contribution of kaolinite and smectite to the clay assemblages reaching the delta. Landsliding in the mountains during the Early Holocene caused temporary damming of the river and ponding of sediment that was released quickly as the dams were breached. Initial estimates suggest that the total volume buffered in this fashion was not significant

compared to the total flux, but would have been responsible for major, short-lived flooding events. Earlier studies demonstrated that turbidite sedimentation in the Indus Canyon ceased around 11 ka as sealevels rose. Rapid sediment supply in the Early Holocene, largely driven by the erosive monsoonal climate, allowed the Indus delta to prograde into the ocean, despite quickly rising sealevels. New seismic and coring data from the shelf now show that the fastest recent sedimentation has been in the upper canyon, but that this has yet to be communicated to the deep sea. Our work shows that source to sink transport in a large river basin like the Indus can involve transport times of 10–15 k.y. between erosion and sedimentation on the submarine fan and that monsoon

Conaway, Christopher H.

The Importance of Episodic Events on Small, Mountainous River Sediment Discharge to the Coastal Ocean and the Efficacy of ⁷-Be as a Tracer of Recent Floods

Conaway, Christopher H.¹; Storlazzi, Curt D.¹; Swarzenski, Peter W.¹; Draut, Amy E.¹

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Event-based suspended-sediment sampling of the San Lorenzo River in Santa Cruz County, CA, USA, was conducted over two winters to evaluate sediment loading and provide samples for geochemical analyses. The San Lorenzo River drains a small (300 km²), relatively steep, tectonically-active watershed that has undergone substantial anthropogenic modifications over the past 150 years. One 4-day storm event in January 2010 provided 70% of the suspended-sediment flux in water year 2010 and 60% of the suspended-sediment flux in water years 2009–2010. An increase in the river discharge-sediment flux relationship during that event evidenced a change in sediment transport processes, potentially from landslides, river-bank failures, or debris flows that accounted for approximately 30% of the 2010 water year's suspended-sediment flux. While suspended-sediment concentration was well correlated with river discharge, ⁷-Be activity per volume of water showed no clear relationship to discharge and ⁷-Be activity per mass of suspended sediment was lowest when the discharge was highest. Based on these findings, trying to map flood sedimentation by ⁷-Be in this environment would find late-season “hot spots” from small sediment-discharge events, while the bulk of peak-discharge sediment would appear “dead”. In light of the importance of short, steep watersheds to global sediment, nutrient, and contaminant fluxes to the coastal ocean, these findings suggest that while ⁷-Be can be used to discern sediment erosion processes, caution should be exercised in the use of atmospheric short-lived radionuclides for tracking flood sediment from such watersheds to the continental shelf.

Cossu, Remo

Coriolis forces influence the secondary circulation of gravity currents flowing in large scale sinuous submarine channel systems

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A combination of centrifugal and Coriolis forces drive the secondary circulation of turbidity currents in sinuous channels, and hence determine where erosion and deposition of sediment occur. Using laboratory experiments we show that when centrifugal forces dominate, the density interface shows a super-elevation at the outside of a channel bend. However when Coriolis forces dominate, the interface is always deflected to the right (in the Northern Hemisphere) for both left and right turning bends. The relative importance of either centrifugal or Coriolis forces can be described in terms of a Rossby number defined as $Ro = U/fR$, where U is the mean downstream velocity, f the Coriolis parameter and R the radius of curvature of the channel bend. Channels with larger bends at high latitudes have $|Ro| < 1$ and are dominated by Coriolis forces, whereas smaller, tighter bends at low latitudes have $|Ro| \gg 1$ and are dominated by centrifugal forces.

Cowan, Ellen A.

Fjord Sedimentation from Tidewater Glaciers

Cowan, Ellen A.¹

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Glacial fjords with tidewater glaciers at their heads directly link land-based glacial processes with marine basins and their sediment record. Sediment production is a function of glacial dynamics including mass balance and ice velocity as well as the resistance of bedrock to glacial erosion. Fluvial processes control the release of sediment into fjords from polythermal and temperate glaciers where submarine streams discharge at the base of the water column or at the sea surface over a delta plain. Downfjord sediment distribution is controlled by the geometry of fjord basins along with marine processes and sediment dynamics. In sill-floored fjords, the distribution of coarse-grained sediment is largely confined to the ice-proximal basin, with the exception of iceberg and sea ice-rafted debris, which can bypass bathymetric boundaries. Turbid plumes that are influenced by water-column stratification, wind, and tides disperse fine-grained sediment. In Alaskan temperate fjords, sediment accumulation rates from turbid plumes are as high as 13 m/yr within 300 m of the grounding line. However, sedimentation rates exponentially decline with distance from the terminus and most deposition from turbid plumes occurs within 5 km of the grounding line. Fjords are effective sediment traps but quantification of the glacial sediment flux is complicated by redeposition from sediment gravity flows originating from sloping fjord walls and sills. Basin fill is dominated by stratified sediment gravity flows as well as fine-grained suspension deposits. Failure of ice-cored sediment from fjord walls may become a significant

source of periglacial-sourced sediment gravity flows immediately after glacier retreat from the basin. Most distal basin-fill deposits have similar characteristics indicating that depositional processes are similar in all such basins, independent of basin size and depth, or source area. Glacier history should be considered in quantification of the glacier erosion rate from the sediment flux into fjord basins. For example, in Alaska the Last Glacial Maximum (LGM) ice sheet advanced to the continental shelf and scoured to bedrock within the fjords while the smaller Little Ice Age (LIA) glaciers did not. Sediment deposited from tidewater glaciers during LIA retreat includes reworked LGM sediment stored within deep basins. Research linking processes to sedimentary products in Alaskan fjords has provided the background data necessary to interpret high-resolution climate signals from the fjord sedimentary record in basins near tidewater glaciers. Key sedimentary products for interpreting this high frequency record are gravelly-mud beds and black layers that are deposited annually. During the meltwater season, deep-water tidal rhythmites are organized in distinctive half-month packages by their thickness. Identification of these time-indicators within the record allows for establishment of a meltwater discharge proxy from tidewater glaciers. In turn, this proxy can be used to estimate the fluctuation of annual meltwater production from tidewater glaciers and test the relationship with meteorological variables.

Dellapenna, Timothy M.

Salt wedge controlled sediment dynamics of the Brazos River, TX: Storage in the lower river, transport to the shelf

Dellapenna, Timothy M.^{1,2}; Carlin, Joseph²

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The purpose of this study is to determine the role that salt wedge dynamics plays in controlling both short-term storage of sediment in a lower river mouth during low flow conditions and in the deposition of sediment on the shelf during higher flow conditions for a wide, low gradient, passive margin shelf. The Brazos River is being used as the natural laboratory to conduct this on-going study. The Brazos River is located along the northwestern Gulf of Mexico, is the 11th longest in the USA, flows primarily along the coastal plain, and empties onto a shelf that is 100-150 km wide and the prodelta has a slope of approximately 0.1o. A series of stations have been established every 0.5 km from the mouth of the river and extending 15 km upstream and also every 0.5 km from the mouth of the river and extending 7 km across the shelf, perpendicular from shore. A time series has been conducted sporadically for each of these stations where profiles of water column salinity, temperature and turbidity for each sampling event. Additionally, surface sediment grab samples and/or 30 cm long gravity cores were collected at each station along with surface and bottom

water samples. For select sampling event, ultra high resolution swath bathymetry was also conducted to detect changes in bathymetry, using a Benthos® C3D® bathymetric side scan sonar system. Results to-date reveal that during low flow conditions ($\sim 50\text{-}150\text{ m}^3\text{s}^{-1}$), a well stratified salt wedge extends 1-8 km up river from the river mouth and the suspended sediment is trapped upstream of the salt wedge as ephemeral layers decimeters thick. During a moderate river flow survey of $340\text{ m}^3\text{s}^{-1}$ (Oct. 17, 2007), the salt wedge was pushed to the seaward side of the river mouth bar and the suspended sediment was trapped near the seabed, across the mouth bar landward of the salt wedge, with no hypopycnal turbidity plume. During the one high discharge event ($2040\text{ m}^3\text{s}^{-1}$) sampled (July 12, 2007) 10 days after peak discharge ($2190\text{ m}^3\text{s}^{-1}$), the shelf waters seaward of the seabed intersection of salt wedge (null point) were well stratified, with a highly turbid fresh water hypopycnal plume and a highly turbid bottom boundary layer both extending ~ 5 km offshore. Our interpretation of the highly turbid bottom layer is that it was a wave supported boundary layer of recently deposited flood sediments, deposited when the salt wedge was displaced further offshore during peak discharge. Results to-date suggests that the salt wedge provides a highly effective trap of suspended sediment. The initial placement offshore flood deposition of the Brazos River's suspended load is controlled by the offshore displacement of the salt wedge. Future work will focus on quantifying the amount of sediment stored in the lower river between flood events, the amount and initial position of sediment deposited within the river and on the shelf for various flood discharge rates, quantify the partitioning of the hypopycnal plume and near bed and use these observations to reconstruct the history of river discharge events for the existing hydrographic record of the river.

Dietrich, William E.

Sediment Supply to Rivers: Rates, Controls and Predictability

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Direct sediment discharge measurements in rivers have been used to define sediment supply to marine sediment sinks and to explore empirically controls on the supply rate. While such data provide our best estimate of what event-based signals are through the source to sink system, they are less useful in informing us about longer term delivery rates and especially in revealing causal factors. Direct measurement of rates of hillslope erosion and discharge to channels are rare, but these data can provide key observations on how pulsative sediment delivery is on the storm, to annual or decadal basis, and help define controls on erosion. New methods of cosmogenic and thermochronometric methods of measuring erosion and exhumation rates of landscapes have led to studies in a wide range of settings and scales which explore cause and effect

relationships linking climate, tectonics, and topography. These empirical studies provide estimates of sediment supply to streams averaged over periods of order 1000's of years or greater, and the rates often differ with contemporary sediment discharge measurements. Most summaries of cosmogenic nuclide data have shown that erosion rates do not vary with precipitation or mean temperature and that there may be no clear relationship with slope or basin relief or rock type. These unexpected findings arise from the tendency for erosion rates to be set by channel incision rates, which typically vary with uplift rates. Climate and lithology then influence topography form but not erosion rates. Various studies in collisional tectonic systems, however, do suggest that areas of greater precipitation induce greater rock exhumation and, correspondingly, erosion rates and discharge to the ocean. Climate may then affect not only the erosion rate but the form and scale of the uplifted landmass shedding sediment to the sea. A detectable role of climate has also been found in a transect from hyperarid to arid landscapes where with increasing precipitation channel incision increases and hillslopes erode faster. Presently, sediment supply predictions typically rely on statistical correlations which have uncertain ability to be used to estimate rates in the geologic past or into the future. Process-based models may eventually give us a better understanding of how quickly landscape erosion responds to changes in climate, tectonics, and exposed lithologies

Dorsey, Rebecca J.

A Preliminary Mass Balance for Colorado River Sediment Since 10 Ma

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Many studies have explored the influence of climate and erosion on thrust belt mechanics, crustal exhumation, and orographic effects in convergent mountain belts. In contrast, rates and dynamics of erosional mass redistribution in divergent and transtensional settings are little studied. Recent studies of the Colorado River system raise new questions about feedbacks among extensional collapse of orogenic topography, evolution of the southern San Andreas - Gulf of California transform margin, Neogene climate change, and fluvial transfer of crust from the continent interior to deep basins along the plate boundary. Here we construct a sediment mass balance for the Colorado River to help address some of these questions. Transtensional basins embedded in the San Andreas fault system in the Salton Trough and northern Gulf of California have filled with sediment from the Colorado River since ~ 5.3 Ma. The sediment is rapidly buried, heated, and mingled with intrusions in deep basins to form a new generation of recycled crust along the plate boundary (Fuis et al., 1984). Using a range of values for total basin depth, relative volume of intrusions, and possible contributions from local sources, the volume of Colorado River-derived sediment in the basins is bracketed between 2.2 and $3.4 \times 10^5\text{ km}^3$ (Dorsey 2010). The volume of crust eroded from the Colorado Plateau is

estimated with GIS tools by reconstructing a 10-Ma paleotopographic surface and subtracting present topography. Elevations of the 10-Ma surface are constrained with: (1) modern elevations of 10-Ma basalt flows; (2) thermochronologic data from canyons and boreholes (Kelly et al., 2007, Flowers et al., 2008); (3) new data on exhumation in the southern Rocky Mts (Kelly et al., unpubl.); and (4) information about erosion of the Chuska Erg and formation of Hopi Lake prior to 10 Ma (Cather et al., 2009). We assume that the low-relief surface preserved beneath 10-Ma basalts along the plateau rim extended as a low relief surface across the central Plateau (Canyonlands). New thermochronologic data show that up to 3 km of material has been removed from the Canyonlands area since 4-6 Ma (Kelley et al., unpub.; Hoffman et al., unpub.). The total volume of crust eroded since 10 Ma is bracketed between 2.8 and 4.1×10^5 km³. Because rock eroded from the Plateau is mostly sedimentary, and much of the sediment in the basins is deeply buried and compacted, a density correction is not required to compare the volume of sediment in the basins to sediment eroded from the source. The small discrepancy between volumes calculated for the Plateau source and basinal sinks may be due to: (1) remaining uncertainties in the estimates; (2) fluvial transport of sediment to other sinks between 10 and 6 Ma; and/or (3) eolian erosion and removal of sediment from the system. The mass balance supports inferences that the large volume of sediment stored in deep basins along the plate boundary - much of which has been converted to new metamorphic rock - was derived from the Colorado River in the past 5-6 m.y. Fluvial erosion and basinal processes thus appear to drive crustal recycling in this setting, and may be important at other rifted margins where a large river system is captured following tectonic collapse of a pre-rift orogenic highland.

Droxler, Andre W.

Plio-Pleistocene Evolution of Barrier Reefs along Mixed Continental Shelf Edges

Droxler, Andre W.¹

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Continental shelves in the Gulf of Papua (GoP), the western Gulf of Mexico (GoM), and along the Belize central margin are excellent examples of low latitude mixed Plio-Pleistocene carbonate/siliciclastic systems. Along the GoP shelf edges, transgressive corallgal edifices are overlying thick prograding regressive muddy siliciclastic wedges and lowstand shelf edge deltas. In the northern part of Ashmore Trough, a 30 to 50 m-high ridge parallels the GoP shelf edge with linear segments exceeding 10 km in length. Analyses of a core, recovered in a re-entrant in front of the ridge, demonstrate that a coast-line, essentially siliciclastic, reached the present-day shelf break during Last Glacial Maximum - LGM and the Oldest Dryas - OD. The ridge is interpreted to correspond to a corallgal barrier reef established on top of a LGM/OD siliciclastic beach barrier complex during a major pulse of sea level rise, between ~ 15.0 and 13.0 cal. ky. BP, and subsequently drowned. Along the northwest part of the Papua New Guinea peninsula shelf edge, an early

transgressive, as thick as 80 m, corallgal edifice established itself on top of a LGM shelf edge delta lobe, partially eroded and located at about 120-125 m below modern sea level. On seismic lines provided by Fugro/Finder Exploration Ltd, high amplitude mounded seismic facies are overlying a series of prograding transparent/low amplitude wedges. These mounds are interpreted, as in the latest Pleistocene, to represent early transgressive shelf edge carbonate edifices, established and growing on top of siliciclastic muddy wedges deposited during intervals of forced regressions. Southern Bank is one among 20 corallgal reefs of latest Pleistocene age occurring on the edge of the southern Texas shelf between the Rio Grande and Brazos/Colorado lowstand deltas. These drowned reefs, partially buried in Holocene clay-rich deposits, are cropping out today on the sea floor in water depths ranging from 58 to 82 m. Description and interpretation of single-channel seismic lines crossing several banks and multi-channel high-resolution seismic profiles in the area of Southern Bank demonstrate that the corallgal edifices, partially buried in clays, are twice as thick as the average 20 m of relief exposed on the sea floor. The seismic images clearly illustrate that the reefs along the western GoM shelf edge were initially established on top a LGM costal siliciclastic complex. These 30- to 50-m-thick corallgal edifices were constructed at maximum rates of reef growth during the first 7,000 years of the deglacial interval. The timing of reef demise falls either within or at the end of the Younger Dryas, a ~ 1,000-year-long time interval when the rates of sea-level rise first slowed down considerably, possibly dropped by several meters, and then significantly accelerated. Subsequent to the drowning of the reefs, Holocene clay-rich deposits partially buried the corallgal edifice. Finally, as several other barrier reefs worldwide, the Belize barrier reef is interpreted to consist of late Pleistocene five stacked transgressive and highstand corallgal packages, separated by exposure horizons. The late Pleistocene ~ 100 m-thick corallgal composite package is overlying an (early?) to middle Pleistocene regressive and lowstand prograding siliciclastic complex.

Dutta, Som

Turbulence Modulation due to Stratification in Turbidity Currents: Numerical Modeling and Implications for Turbidites

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Turbidity currents are phenomena which play important roles in the delivery of sediment from source to sink. They can be found in lakes and the ocean. A wide range of

structures in the depositional record have been emplaced as turbidites by turbidity currents. These currents are a subset of gravity-driven flows which differ only in the agent that renders them heavier than the ambient water. In the case of turbidity currents this agent is sediment; and the mechanism becomes complex because sediment is non-conservative and is readily exchanged with the bed through erosion or deposition. So understanding the flow conditions under which erosion or deposition dominate becomes integral to the understanding of turbidity currents themselves. Recently it has become possible to characterize several features of turbidity currents using Direct Numerical Simulation (DNS). Such simulations reveal fascinating features of sediment laden flows such as the break in flow symmetry due to presence of sediment, and the tendency for self-stratification and damping of near-bed turbulence. These features have been simulated using the simplified formalism of Turbidity Current with a Roof (TCR), which allows for flows that (upon averaging over turbulence) are steady and uniform. DNS, however, has a major limitation in that the Reynolds numbers that can be simulated are orders of magnitude below that associated with field currents. Large Eddy Simulation (LES) offers an attractive alternative allowing much larger Reynolds numbers. Here we report on several numerical experiments simulated using LES, designed to study the effect of Reynolds number (characterizing the degree of turbulence), shear Richardson number (characterizing the degree of self-stratification by suspended sediment) and ratio of fall velocity to shear velocity on flow characteristics. We focus on the conditions under which near-bed turbulence can be severely damped, resulting in the emplacement of a massive turbidite.

Eglinton, Timothy I.

Developing a Global Perspective on Dynamics of Riverine Transfer of Terrestrial Biospheric Carbon to the Ocean

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Recent studies have greatly advanced our understanding of the flux and composition of particulate organic matter that is exported by different river systems to the oceans and is sequestered in marine sediments. However, several key aspects of the transfer of carbon from biological source to geological sink remain much more poorly constrained. Fundamental questions that remain unresolved include: (i)

from where within drainage basin does the organic matter that is ultimately discharged originate (i.e., what is its provenance)? (ii) How and where does organic matter become associated with mineral phases, and how does the “partnership” between organic matter and the mineral load evolve during transit through the drainage basin? (iii) What are the timescales involved in the transfer of carbon from the terrestrial biosphere to the marine environment (i.e., what is the “residence time” of biospheric carbon on the continents)? Answers to these questions of organic matter provenance, disposition and dynamics are crucial not only for examining the role of fluvial systems in the global carbon cycle and the sensitivity of these systems to climate and anthropogenic perturbation, but also for interpretation of sedimentary records of past terrestrial vegetation change through studies of tracer organic signatures (e.g., vascular plant biomarkers, pollen) preserved within the marine sedimentary record. In an effort to bridge this information gap, we have embarked on a research program that explores the variability in the composition and radiocarbon age of terrestrial organic matter – both at the bulk and molecular level - in a wide range of river drainage basins. A primary goal of this work is to build a global perspective on the controls on terrestrial biospheric carbon residence times. Radiocarbon measurements are being undertaken on molecular markers specific to vascular land plants isolated from sediments collected close to the terminus of the river systems that differ markedly in terms of drainage basin size, elevation, latitude, and material flux. Preliminary observations suggest that the latitude of the drainage basin, as opposed to other properties such as drainage basin area or sediment load/yield, exerts a first-order control on terrestrial biospheric carbon residence times. We will discuss the potential mechanisms influencing the residence time of vascular plant-derived carbon. We will also examine the characteristics of terrestrial carbon export dynamics in the context of organic matter cycling on regional and global scales, and explore potential implications for assessment of the legacy of terrestrial productivity preserved in the marine sedimentary record.

Fernandes, Anjali M.

Sediment Fractionation within Bypass-associated and Channel-filling Turbidites of Upper Slope Channels, Brushy Canyon Formation, west Texas

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Channels on the continental slope are important pathways for sediment to reach the deep marine basin. Careful examination of deposits preserved within these channels is essential in order to constrain the spatial and temporal variation in quantity and character of sediment transport through this system. We present results of an

ongoing study of the attributes of depositional facies within turbidite-filled upper-slope channels of the Brushy Canyon Formation of west Texas. The Brushy Canyon Formation is a predominantly fine-grained clastic system (grain sizes rarely exceed 350 μm) deposited on a carbonate margin during sub-aerial exposure of the shelfal carbonate platform. The studied channel complex outcrops as a sand-rich unit, 150m thick, with roughly 50m of incisional relief into the underlying carbonate slope, at the most proximal exposure. Depositional facies form two broad classes: A) facies associated with bypass of large volumes of sediment to deeper water through open channel topography; and B) facies which filled up local channel relief. Deposits interpreted as bypass-associated are bedload-dominated channel lags (D50=156 μm , D95=381 μm , containing cm-scale carbonate clasts), and eddy bars or channel margin drapes (D50=110 μm , D95=250 μm) deposited from suspension fallout. Channel-filling deposits are thick, lens-shaped sand bodies containing stratification associated with migrating dunes or barforms (D50=156 μm , D95=381 μm). Overbank deposits (D50=60 μm , D95=200 μm) associated with both facies classes were deposited from suspension by non-channelized flow. Thick lag deposits at the base of the channel complex contain large carbonate debris, while channel lags higher in the complex are dominated by mud-clasts, probably indicating reduction in carbonate margin erosion due to channel floor aggradation. Sediment in the 200-400 μm range, while well represented in both the volumetrically insignificant lag deposits and the channel-plugging deposits, are poorly represented in the suspension-dominated drapes and eddy bar accretion sets, indicating that these size fractions were transported chiefly as bedload and marginally suspended sediment and are likely to be present in greater volumetric abundance farther downslope in the basin. Bank-attached eddy bars show a slightly higher D95 than overbank deposits, but much lower silt and mud fractions. During channel migration, the channel cut-bank probably eroded overbank or, in the initial stages, lithified carbonates, while depositing eddy bars at the depositional bank. Thus, this process caused an overall reduction in stored silt and mud fractions, which were relayed down-system, while a narrow range of grain-sizes (the difference between D95 of eddy bars and overbank) was removed from transport. We synthesize depositional style and grain-size data to discuss implications for sediment partitioning and storage within these deposits, as well as implications for partitioning between these deposits and positions farther down-slope.

Fernandez, Rodrigo A.

TEMPORAL AND SPATIAL VARIABILITY IN GLACIAL EROSION AND DEPOSITION BASED ON A STUDY OF PATAGONIAN AND ANTARCTIC PENINSULA TIDEWATER GLACIER SETTINGS

Fernandez, Rodrigo A.¹; Anderson, John B.¹

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Glaciers play a key role in the coupling between tectonics and climate through a number of processes and temporal/spatial scales, ranging from short-term glacial advances and retreats, millennial-scale glacial cycles, and million year-scale orogenies and global climate changes. In particular, glacier erosion and transport might be a first order control on mountain range exhumation and isostatic processes through the evacuation and removal of crustal material from orogens and its subsequent transport to continental margins (e.g. Molnar et al., 1990; Montgomery et al., 2001; Blisniuk et al., 2006). Glacier sediment yields and erosion rates have been estimated for a number of glaciated basins based mainly on modern observations (last few decades) of sediment fluxes (Harbor, 1992, 1993; Harbor and Warburton, 1993; Hallet et al., 1996). However, recent studies have shown that modern sediment yields are not representative of long-term (centennial, millennial or million-year time scales) trends (Delmas et al., 2009; Koppes et al., 2009; Fernandez et al., 2010). Contemporary high sediment yields from tidewater glaciers and associated high erosion rates might be the result of high ice fluxes associated with the retreat of modern glaciers from their last Neoglacial positions (Koppes and Hallet, 2002, 2006). Using sediment fluxes calculated from sediment volumes accumulated in fjords, we estimated sediment yields (Y) and associated erosion rates (Er) for centennial to millennial time scales across a broad latitudinal transect, from central Patagonia (46°S) to the Antarctic Peninsula (65°S). We show that sediment yields (Y) and associated erosion rates (Er) exhibit a power law decrease with time. Erosion rates are 10-1-100 mm/yr for subpolar glaciers of Antarctica, similar to published results from Svalbard (Elverhøi, 1995, 1998), whereas they are between 100-102 mm/yr for temperate glaciers of Patagonia, similar to Alaskan glaciers (Hallet et al., 1996; Fernandez et al., 2010). We also show that greater variability of temperate glaciers is reflected in higher Y and Er gradients with timescale, which in turn means that different source-to-sink dynamics characterize temperate and polar glacier-fjord systems.

Galy, Valier

Organic carbon residence time in the Ganges-Brahmaputra river system: how long is the journey to the Bay of Bengal?

Galy, Valier¹; Eglinton, Timothy^{1,2}; France-Lanord, Christian³

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2. ETH, Zurich, Switzerland
3. CRPG-CNRS, Nancy, France

Over short timescales (<100ka), the atmospheric CO₂ level is sensitive to variations of the residence time of carbon in continental reservoirs. In turn, environmental changes such as global warming, can affect timescales of carbon storage, potentially generating feedbacks on the atmospheric CO₂ level. Moreover, accurate interpretation of terrestrial organic carbon signatures in marine sediments critically depends on a precise knowledge of the timescale of riverine organic carbon export. Heretofore, however, the residence time of organic carbon in continental reservoirs, as well as its response to environmental changes, are essentially unknown over large spatial scales. We combine bulk and molecular-level radiocarbon dating of organic carbon carried by rivers to characterize the residence time of organic carbon in the Ganges-Brahmaputra drainage basin. We show that the average residence time of the terrestrial biospheric organic carbon varies in the Himalayan basin from 1 to 8 ka. Near the mouth of the river system, the biospheric OC is in average older than 3 ka, revealing significant aging of OC in soils. Conversely, labile vegetation-derived organic carbon has a much shorter residence time in the basin (0.1 to 1.5 ka), implying the existence of a refractory, slowly cycling component. We estimate that this refractory component has a residence time of 17 ka and represents up to 20% of the total biospheric organic carbon exported to the Indian Ocean. Destabilization of this pool of ancient carbon may occur, as future global warming would simulate microbial decomposition of soil organic carbon. This would, in turn, potentially create a positive feedback on atmospheric CO₂ levels. In addition, this significant aging of organic carbon in the basin prior to export and burial in marine sediments has to be accounted for when interpreting sedimentary records from the Bay of Bengal.

Ganti, Vamsi K.

Space-time Dynamics of Delta Evolution and Implications for Stratigraphy

Ganti, Vamsi K.¹; Straub, Kyle M.²; Foufoula-Georgiou, Efi¹; Paola, Chris³

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3. St. Anthony Falls Laboratory, National Center for Earth-surface Dynamics, Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN, USA

In depositional systems, channels migrate from one location to another causing erosion and deposition at any given point in the domain. The duration of depositional and erosional events, as well as their magnitudes lead to the formation of the stratigraphic record. In this study, we use high-resolution temporal surface elevation data from a controlled physical fan/delta experiment to quantify the probability distributions of the processes that govern the evolution of channelized depositional systems. We document heavy-tailed statistics of erosional and depositional events indicating that a small, but significant chance exists for the occurrence of extreme events. We also show that the duration of inactivity, when neither deposition nor erosion occurs, follows a Truncated Pareto distribution whose truncation scale is set by the characteristic avulsion time scale of the mean channel depth in the system. The erosional and depositional events have an upper bound that coincides with the maximum channel depths of the system indicating that the channel depths act as a first order control on delta evolution dynamics. Further, we show that the heavy-tails in the magnitudes of the erosional and depositional events are not preserved in the stratigraphic record thicknesses, but rather result in an exponential distribution for the bed sediment thickness. The temporal evolution of surface elevation at any point in the domain is shown to exhibit self-similarity with a nonlinear spectrum of scaling exponents (multi-fractality) quantifying the complex dynamics of the system. Finally, we present some preliminary thoughts on modeling the surface dynamics of deltaic systems with fractional (non-integer) derivatives that can capture the observed heavy tail behavior.

Geyer, W R.

How hyperpycnal?

Geyer, W R.¹; Chen, Shih-Nan¹

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Hyperpycnal river outflows provide a potent mechanism for cross-shelf transport of sediment in regions of high sediment yield. However the concentrations required to produce hyperpycnal flows occur so rarely that direct observations provide little guidance for our understanding of the phenomenon, so we must rely on theory, models and

the sedimentary record. We apply simple energetics arguments and numerical models to provide some context for assessing the occurrence of hyperpycnal flows. We also consider the fate of sediment-laden flows that don't make it all the way to hyper. What are the circumstances in which dense suspensions can be generated from sediment that was delivered from a surface plume to the inner shelf? We consider the initial conditions for the generation of wave-supported gravity flows, and we examine the conditions in which dense suspensions may "ignite" even in the absence of significant surface wave forcing.

Giosan, Liviu

Transfer of climatic signals along large monsoonal rivers

Giosan, Liviu¹

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The transfer efficacy of high frequency climatic signals from source to sink remains an open question. Monsoonal rivers provide the opportunity to address this fundamental issue because large changes in precipitation intensity and seasonality have affected their watersheds at millennial time scale during the Deglacial and Holocene. This presentation will contrast two cases: the Indus – a large Himalayan system influenced by glacial processes in its upper basin and the Godavari – the largest, strictly monsoonal river draining the Indian peninsula. Using landscape analysis and sedimentary records from the floodplains and deltas coupled with multiproxy paleoclimatic reconstructions in the Arabian Sea and the Bay of Bengal, I will discuss the essential roles of glacial sediment storage and release, cannibalization of the floodplain deposits, and seasonality in modulating the climatic signal reaching the continental margin.

Gomez, Basil

Sediment Production

Gomez, Basil¹

1. KBay Environmental Services LLC, Kaneohe, HI, USA

In the Waipaoa River, as in most other rivers that discharge to the coastal ocean, suspended sediment discharge has been computed with some certainty for only a few tens of years, and estimates of coarse sediment discharge are poorly constrained. Nevertheless, these data have provided sufficient information to characterize the river's contemporary transport regime and determine the magnitude of departures from it. First, I consider the principal short-term controls and time-variations of suspended sediment discharge and the influence these have on the composition and age of the appurtenant particulate organic carbon transported by the Waipaoa River. Then I consider the long-term operation of this fluvial system and attempt to elucidate the factors that have exerted the primary influence on sediment production since the Last Glacial Maximum.

Goni, Miguel A.

Trends in the Magnitude and Composition of the Particulate Organic Matter Load of Small Mountainous Rivers from the West Coast of the U.S.: What are Some of the Critical Factors?

Goni, Miguel A.¹; Hatten, Jeff A.^{2, 1}; Wheatcroft, Robert A.¹; Borgeld, Jeffrey C.³; Pasternack, Gregory⁴; Gray, Andrew⁴; Watson, Elizabeth⁴

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4. Land, Air, and Water Resources, University of California, Davis, CA, USA

Small mountainous rivers are major drivers for the erosion and transport of continent-derived materials (including sediment and particulate organic matter) to the ocean. Worldwide, small mountainous rivers are a highly heterogeneous, with marked contrasts in tectonic, climate and vegetation characteristics of their watershed and highly variable discharges on both seasonal and event scales. This presentation summarizes the results of a multi-year study that investigated how the concentrations and biogeochemical compositions of particulate organic matter changed as a function of discharge among several small mountainous rivers from the west coast of the United States. The rivers studied (Alesca, Umpqua, Eel and Salinas) have markedly distinct hydroclimate, geomorphology and land use characteristics. Coarse and fine particulate organic matter samples collected at different discharges, including several flood events, were analyzed for carbon and nitrogen content, stable carbon and nitrogen isotopic compositions, radiocarbon compositions and yields of different organic biomarkers (e.g. lignin phenols, cutin acids, amino acid products). These data are used to compare and contrast the provenance, age, and biochemical make-up of materials transported by each of the rivers. We evaluate both the processes responsible for these contrasts and the impacts they have on the delivery and fate of terrigenous organic matter in the coastal ocean.

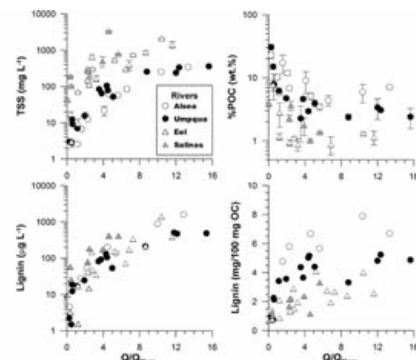


Figure 1. Trends in the concentration (L-1) and content of the particulate loads of the four rivers studied as a function of mean-normalized discharge (Q/Q_{mean}). Variables plotted include total suspended solids (TSS), lignin derived products (Lignin) and particulate organic carbon (POC).

Goodbred, Steven L.

Source-to-margin behavior of an arid, El Niño-influenced mountain drainage and coastal plain: The Chicama River, northern Peru

Goodbred, Steven L.¹

1. Earth and Environmental Sciences, Vanderbilt University, Nashville, TN, USA

The steep gradients, active hillslopes, and limited storage capacity of small mountainous dispersal systems make them good candidates for studying the linkages between source terrains and downstream depositional settings. Where such landscapes are also arid, the sparse vegetation, high runoff, and high sediment yield promote sharp responses that propagate quickly through the source-to-sink system. The sum of these characteristics are common to the desert coastal basins of Peru's collision margin, which are fed by short, seasonal rivers draining the west slope of the Andes range. Our study site, the Chicama river basin, lies along a largely aseismic reach of the margin where there are few earthquakes and little to no tectonic uplift. At 8°S latitude, though, the Chicama River is strongly impacted by El Niño phenomenon, which brings excessive precipitation and transforms the river into a sediment-laden flood. In the coastal lowlands, these floods broadcast their suspended load and have built a large silty floodplain. In the main channel, much of the gravelly bedload reaches the coast to form prograding sandy gravel shorefaces. In the early Holocene, though, this characteristic ENSO-forcing was weak to absent, and sediment flux to the coast was limited. At that time the coastal plain actually supported a freshwater lagoon with abundant algal carbonates, an environment that persisted from 8.0-6.5 ka. With the onset of El Niño flooding beginning ~6.5 ka, the increased sediment flux infilled the lagoon and initiated widespread floodplain development. Upstream in the arid mountains, the rocky hillslopes and abundant alluvial fans appear to have been largely inactive at this time based on their heavy desert varnish. However, the channels at the base of these valleys are active and braided, heavily truncating valley fans through channel migration and widening. Although we do not have ages on the bank erosion, we speculate that this reactivation of the fluvial system is associated with the onset of El Niño flooding ~6.5 ka. It is also uncertain why the hillslopes remain stable through the Holocene despite increased channel activity and fluvial sediment transport. One hypothesis is that most of the El Niño-related precipitation falls in the humid highlands (>2500 m), whereas precipitation on the talus-covered lower slopes reaches the valley floor as groundwater. Many compelling questions about source-to-sink behavior emerge from these initial observations of the Chicama River valley. Furthermore, an overarching interest in this particular system is that it hosts one of the longest-lived pre-ceramic cultural sites in the Peruvian Andes. The principal archaeological site at the coast is continuously occupied for 5000 years from 8-3 ka. During this time the society is able to adapt to changing source-to-sink behavior by shifting

from a maritime- to agriculture-based economy, which occurs concurrently with increased fluvial sediment transport and floodplain development in response to El Niño flooding ~5.5 ka.

Graham, Stephan A.

Source-to-sink in the stratigraphic record: capturing the long-term, deep-time evolution of sedimentary systems

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The elegance of source-to-sink studies of modern Earth surface and latest Quaternary sedimentary systems lies in the full plan-view display of those systems: segments are geographically arrayed, many tools can be used to investigate the elements at high spatial and temporal resolution, and ultimately, the linkage between process and product may be understood. Scrolling back into geologic time, nearly opposite conditions exist: the geologic record is incompletely accessible due to burial or erosion, fewer methodological approaches can be employed, temporal and spatial resolution is limited, and processes can only be inferred. In particular, limitations inherent to studies of ancient systems are manifested in differences between sedimentation rates measured over historical timescales, versus time-averaged long-term sedimentation derived from stratigraphic sections. This problem feeds to the physical/temporal correlation issue, because time-stratigraphic correlations are the underpinning for paleogeographic reconstructions which, analogous to geographically displayed modern systems, form the template for ancient source-to-sink studies of any particular moment in geologic antiquity. In order to address these issues, traditional methods of stratigraphic analysis increasingly are augmented by new technologies that provide enhanced temporal and spatial resolution. Sediment source areas generally long lost to erosion were once at best known only by unconformity surfaces. Now, however, thermochronologic tools yield reconstructions of uplift of rock volumes, as well as improved assessments of what rock types were being eroded in source regions. In addition, several approaches for the first time allow quantitative estimates of paleoaltimetry. On the sink end of systems and at a geologically fine scale of resolution, spectral analysis of bedding successions in some cases permits interpretations of orbital forcing controls on sedimentation, whereas at a coarser scale, 3-D seismic-reflection data have revolutionized understanding of long-term accumulation of large volumes of sediment. To that point, despite limitations and gaps, the stratigraphic record offers real advantages in understanding the long-term evolution of source-to-sink systems. Principally, if circumstances of preservation and access exist, it is possible to scroll through time and rock

volumes, thereby yielding new perceptions of long-lived sediment routing systems over timescales that modern system studies simply cannot address. Three-dimensional seismic-reflection data are especially useful in this regard in facilitating volumetric imaging of stratigraphy, analogous to medical tomography. Ultimately, cross-talk between studies of modern and ancient systems, taking advantage of the information both have to offer, optimizes studies of both modern and ancient source-to-sink systems.

Gulick, Sean P.

Varying Neogene Impact of Glacial Sediment Flux from Source to Sink on Tectonics and Stratigraphy in the Gulf of Alaska

Gulick, Sean P.¹; Jaeger, John M.²; Reece, Robert S.¹; Worthington, Lindsay L.¹; Berger, Aaron L.³; Spotila, James A.³; Ridgway, Kenneth D.⁴; Pavlis, Terry L.⁵; Christeson, Gail L.¹

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5. University of Texas El Paso, El Paso, TX, USA

The combination of highly erosive temperate glaciers in an active convergent tectonic setting in southern Alaska allows for the study of the long-term impact of climate and tectonics on source-to-sink sediment production and accumulation. For the majority of the last 6 Myr, glaciers have been the dominant force of erosion and mass redistribution in southeast Alaska. Flat-slab subduction and collision of an oceanic plateau, the Yakutat Terrane, has been ongoing in the Gulf of Alaska for at least 10 Myr, but possibly as much as 20 Myr, resulting in the highest coastal mountains (the St. Elias) in the world. Temperate glaciation has varied with climatic events and includes tidewater glaciation from 6-4 Ma, a period of limited glaciation in the Mid-Pliocene Warm Interval, re-advance of glaciers and formation of the Cordilleran Ice Sheet starting around 3 Ma, and intensification of glacial-interglacial cycles since 1 Ma. Sediment flux from the orogen onshore to the continental shelf offshore and the deep-sea Surveyor Fan has therefore varied temporally and spatially owing to changes in glaciation and Yakutat terrane collision. Seismic reflection and refraction data, structural and stratigraphic field mapping, thermochronology, and piston coring have determined the magnitude and resolution of the sedimentary record and highlighted the importance of interplay between tectonic and climatic processes. Specifically, up to ~15 km of sediment on the continental shelf reveals the increasing influence of glaciation on the sequence architecture, with glacial-marine sediments and glacial erosion first observed near the coast and then later in sea valleys. The influence of erosion and redeposition by glaciers control Late Pleistocene deformation in the Pamplona Zone fold and thrust belt are coeval with increased tectonic shortening onshore. The Surveyor deep-

sea Fan contains strata up to 4 km thick that were deposited throughout the glacial periods but appear to be dominated by sediment deposited since the mid-Pleistocene, in agreement with the shelf record of increasing glacial influence. These sedimentary depocenters therefore record mass flux from source (orogenesis) to sink (shelf and fan deposition) that is modulated by climate, in particular the Mid-Pleistocene Transition.

Hale, Richard P.

Sediment-Gravity Flows on the Poverty Bay Continental Shelf, New Zealand

Hale, Richard P.¹; Ogston, Andrea¹; Orpin, Alan²; Walsh, J. P.³; Corbett, D. R.³; Nittrouer, Charles A.¹

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2. National Institute of Water & Atmospheric Research, Wellington, New Zealand
3. East Carolina University, Greenville, NC, USA

Northeastern New Zealand is located along an active subduction margin characterized by steep mountains, frequent tectonic activity, easily erodible rock, a vigorous maritime climate, and a narrow continental shelf to the east. The combined impact of these factors led to the selection of the Waipaoa dispersal system as a region of recent focus for the NSF Source-to-Sink program. At present, we are investigating the transport mechanisms and fate of sediment exiting this small mountainous river into Poverty Bay and entering the continental shelf off the east coast of New Zealand. Bottom-boundary-layer tripods equipped with a range of acoustic and optical instruments have been deployed at three sites across the continental shelf at water depths of ~35-60 m, with the goal of monitoring the movement of water and entrained sediment throughout the water column, including the near-bed boundary layer. Locations were selected based on seabed geochemical profiles and sedimentary structures recorded from previous regional studies, and represent the most likely positions to observe sediment-gravity-flow transport and deposition. Based on the first seven months of data from this twelve-month program, a recurring dispersal pathway involves flood-sediment discharge from the Waipaoa River onto the inner shelf of Poverty Bay, with little or no sediment reaching the mid-shelf directly. Rather, sediment is progressively carried across the shelf over days to weeks by large, long-period oceanic swell not associated with the initial flood event. An example of this can be seen in the major low-pressure system that passed over the study region in January, 2010, with sufficient precipitation to generate an 8-10-year flood of the Waipaoa River. Despite the major rainfall and flooding, oceanographic conditions remained relatively calm at the shallow tripod ~15 km offshore of the Waipaoa River mouth. Here, wave heights were modest (<4 m), and near-bed wave-orbital velocities were among the lowest (<15 cm/s) observed throughout the summer deployment period, with little evidence of any flood-derived material in the instrument record. Conversely, a system that moved through the region in mid-March did not result in a flood, but generated large waves (>8 m) and wave-orbital

velocities (>50 cm/s). During this event, the downward-looking acoustic backscatter sensor on the tripod closest to the river mouth recorded significant suspended sediment in the bottom 120 cm of the water column, followed by deposition of a 4-5 cm-thick “event layer.” X-radiographs of cores collected at this tripod location two months before and after the mid-March wave event show evidence of a ~4 cm-thick layer of newly deposited lower-bulk-density material. Our observations are consistent with similar studies that have documented the generation of wave-induced fluid muds, and reinforce the importance of wave-supported sediment-transport processes in forming sediment-gravity flows capable of dispersing considerable volumes of mud across the shelf. Based on these preliminary observations we hypothesize that fluid muds nourish the mid-shelf depocenters temporally independent of all but the largest floods.

Harris, Courtney K.

Sediment Dispersal Offshore Of Small Mountainous Rivers: Insights from Numerical Models

Harris, Courtney K.¹

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The coastal ocean serves as the interface between the terrestrial and marine portions of sediment dispersal systems, and greatly modifies fluvial sediment signals as they are exported seaward. Modulation of the sediment signal within the coastal ocean includes segregation of sands from finer materials. Nearshore and estuarine systems also sequester some sediment, thereby changing the magnitude and timing of sediment export to the continental shelf and slope. Observation of these processes has proved difficult, however, because sediment fluxes are typically largest near the seabed and during extremely energetic events, and because river influenced coastal environments have inherent spatial variability. Numerical models provide an alternative means for investigating these processes, and we have used them to evaluate the ways that dilute suspended- and gravitationally-driven transport modify sedimentary signals as they travel from fluvial source toward more permanent repositories. Common themes emerged from studies of shelves offshore of three small mountainous rivers (the Eel River, California, the Waiapu River, New Zealand, and the Waipaoa River, New Zealand), all of which contain mid-shelf mud beds that store about one-fifth of the fluvial sediment. The timing of sediment delivery to the coast depended on fluvial discharge, and therefore precipitation during wet storms. Combinations of waves, currents, and winds triggered export to the middle continental shelf and beyond, and at times this transport was disconnected from the original fluvial pulse. On the Eel shelf, energetic waves triggered cross-shelf transport through wave supported gravity flows that tended to occur during times of high discharge. In contrast, wave energy was often reduced by shoreward winds during high discharge of the Waiapu and

Waipaoa Rivers, so some sediment there remained in the nearshore, being exported later when wave energy or current speed increased. Model estimates for these systems implied that dilute suspended transport exported great quantities of material from the proximal shelf, carrying it in the direction of ambient alongshelf currents. The use of numerical models to address source-to-sink issues would benefit from improved representation of gravity flows, sediment consolidation, and particle dynamics. The former seems necessary to represent the system during extreme floods most likely to leave preservable deposits. Standard three-dimensional models, however, do not have sufficient vertical resolution to represent suspended stratification present within fluid muds. Additionally, the relative timescales of consolidation of flood deposits, the duration of quiescent conditions, and the timing between flood pulses impacts the preservability of flood deposits. We are pursuing the use of a time-dependent bed consolidation module to evaluate the role of sequencing of flood and wave pulses on preservability of flood deposits. Finally, the mud that constitutes flood layers can travel within the water column either as slowly settling particles or much faster settling flocs, and model estimates remain sensitive to assumptions concerning the partitioning between various floc and particle sizes.

Harris, Peter T.

Global distribution of large submarine canyons based on GIS analysis of ETOPO1 bathymetry

Harris, Peter T.¹; Whiteway, Tanya¹

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Based on the analysis of the ETOPO1 data set, this study has compiled the first global inventory of 5,849 separate large submarine canyons in the world ocean. These are “large” submarine canyons that can be resolved by the ETOPO1 (1-nautical mile) grid size and does not include smaller canyons resolved using high-resolution multibeam sonar mapping technology. The canyons mapped in this study have been geographically grouped into 17 broad regions separating active and passive continental margins. Canyons are classified into three categories: (1) river-associated and shelf-incising; (2) shelf-incising; and (3) blind canyons confined to the slope. The length, spacing, depth range, slope and dendricity (branching) were measured for each canyon using ARC GIS. As has been observed by earlier workers, this study confirms a relationship exists between canyon slope and canyon spacing (steeper canyon slope implies closer canyon spacing). The greatest canyon spacing occurs in the Arctic and the Antarctic and canyons are more closely spaced in the Mediterranean than in other areas. Active continental margins contain over 50% more canyons (3,605) than passive margins (2,244) and the canyons are steeper, shorter, less dendritic and are more closely spaced on active than on passive margins. Based on the NOAA NGDC global sediment thickness map, canyons on passive margins are associated with deposits >2.6 kms thick, which is more than 2.5 times the mean value for active margins. Furthermore, there is a correlation between canyon spacing

and the thickness of sediments associated with canyons on passive continental margins (canyons are more closely spaced on thickly sedimented, passive margins). River-associated, shelf-incising canyons are significantly more common on active continental margins (119) than on passive margins (34). They are most common on the western margins of South and North America where they comprise 11.7% and 8.6% of canyons respectively, but are absent from the margins of Australia and Antarctica. River-associated canyons are also more dendritic than blind canyons. This study provides the source-to-sink community with a global frame of reference for understanding the occurrence and morphology of large submarine canyon systems.

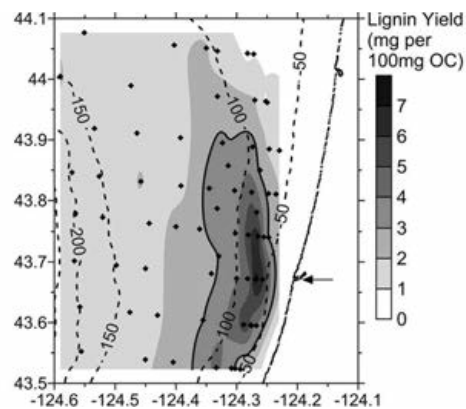
Hastings, Roxanne H.

Terrestrial Sediment and Particulate Organic Carbon Deposition Patterns in Ocean Margin Sediments Adjacent to the Umpqua River, Oregon

Hastings, Roxanne H.¹; Goni, Miguel A.¹; Wheatcroft, Rob A.¹

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The Umpqua River is a small, mountainous river in Oregon. A large number of small rivers, like the Umpqua, can be found along the US West Coast and discharge their materials into this narrow, energetic margin. Small river systems show both seasonal and episodic event coherence since these storms cause both the flood inducing precipitation and high wave energy environment in the ocean at the time of delivery. The coastal ocean characteristics of this ocean margin influence the dispersal, deposition and burial of sediment and particulate organic carbon. Sixty-five short cores were collected from the shelf and upper slope adjacent to the Umpqua River. Elemental, stable isotopic and biomarker analyses of surface sediments from these cores indicate a terrestrial depocenter characterized by high lignin yields, high elemental OC:N ratios and depleted stable carbon isotopic compositions. This terrestrial organic matter depocenter is centered at 8 km north of the river mouth at 80-90 m water depth, stretches along-margin for ~40 km, is 6-8 km wide and covers an area of approximately 200 square km. Grain size data from surface sediments indicate that the sand mud transition occurs at ~85m water depth. These depths of deposition reflect winter wave conditions on the Oregon margin and not average conditions throughout the year. This is consistent with the timing of delivery and resuspension events that occur on the margin. However, most previous studies of the region have been focused on the high primary productivity that occurs during the summer upwelling season. This has resulted in a limited understanding of winter conditions on the Oregon margin. The well studied Eel River dispersal system offers a good comparison to the Umpqua to address questions about what processes might be influencing the dispersal and burial of terrestrial sediment on this margin.



Higher lignin yields indicate more terrestrial organic matter character. This contour map shows the total lignin yield (in mg/100 mg OC) distribution on the Umpqua margin. The arrow indicates the location of river. Water depth is represented by the dashed contour lines. Diamonds indicate coring locations. The black contour line indicates a lignin yield of 3 mg/100mg OC.

Heston, Danielle C.

Organic Matter Burial in Estuarine Sediments affected by Subduction Zone Earthquakes

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Subduction zone earthquakes (SZE) are major events that shape the coastal margin of Cascadia (i.e., northern California to British Columbia). One well-documented effect of SZE is coseismic subsidence of many estuaries in this region. To investigate how coastal subsidence affects sediment and organic matter accumulation, two 2.5m-long cores were collected in Siletz Bay, a small estuary along Oregon's central coast. Core locations included a non-vegetated intertidal mud flat and a vegetated upper marsh, and display modern sedimentation rates that are comparable to local rates of sea level rise (1.9 mm y⁻¹). Radiocarbon analyses indicate the cores span the last ~2,000 years and include stratigraphic sections that resulted from several well-dated SZE. Grain size and X-ray analyses indicate major down core changes in the texture and depositional characteristics of the sediments. Organic geochemical analyses show that clay-rich and organic-rich sediments co-occur in horizons, which appear to be associated with modern and buried marsh soils. These sediments are characterized by slightly elevated carbonate contents that suggest presence of calcite secreting infauna. The organic matter in these horizons is enriched in angiosperm-derived lignin and cutin biomarkers, consistent with significant contributions from marsh vegetation. In the mudflat core, the marsh soil horizon is buried under ~1m of sediment of higher sand content (10-30%). These sediments contain no carbonate and are characterized by lower contents of organic matter. Biomarker analyses reveal carbon-normalized lignin yields are quite high and display molecular compositions that are characteristics of gymnosperm-dominated, woody plant detritus. The age of this latter deposit indicates it was entrained following one of the most recent SZE. Its

biomarker composition suggests its organic matter originated from conifer vegetation, which dominates the upland regions of the Siletz River watershed. In combination our results suggest that following coseismic subsidence of the marsh surface in the southern part of the bay, upland-derived materials contributed to the infilling of the accommodation space.

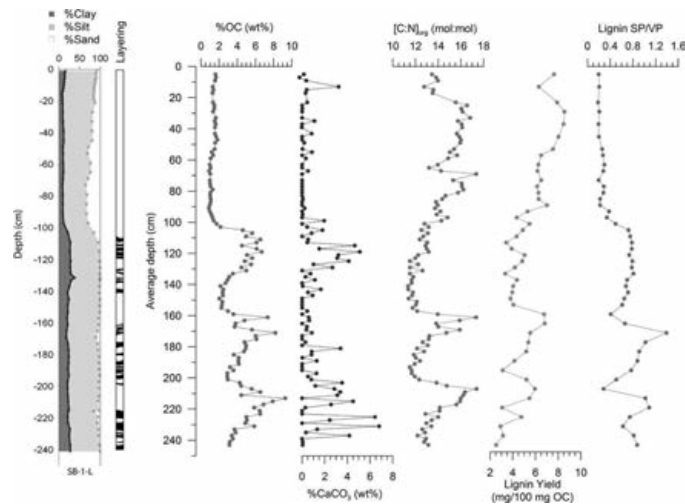


Figure 1. Downcore trends in grain size, recognizable layers based on X-ray data, weight percent organic carbon (%OC) and calcium carbonate (%CaCO₃), molar carbon:nitrogen ratios ([C:N]_{org}, carbon normalized lignin yields and syringyl:vanillyl phenol ratios (Lignin SP/VP).

Hogarth, Leah J.

New Insight Into Lowstand Subaerial Accommodation: Implications for Fluvial Processes in a Sequence Stratigraphic Framework

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High-resolution CHIRP seismic data collected along the Eel River Margin provide evidence for subaerial aggradation and preservation on the shelf during the last sea-level lowstand. Sequence stratigraphic models predict that channel incision and downcutting across the shelf occur during lowstands, with channel deposits being reworked during the subsequent transgression. In such a scenario, any channel fill would be reworked and truncated by the transgressive surface, and in the adjoining interfluvies the transgressive surface should coalesce with the lowstand erosional surface (i.e., the sequence boundary). In the Eel River Basin, however, we observe little evidence of incised channels or shelf edge and slope deposits, but rather a seaward thinning wedge of sediment between the erosional surface and the transgressive surface. Within this package are a number of channels that we interpret as distributary channels based on their morphology. Sediment, up to ~8 m thick, is preserved across the interfluvies. Divergence of the sequence boundary and transgressive surface is expected in incised valleys where lowstand sediment has been deposited, but regional divergence of these two surfaces requires the formation of subaerial accommodation during the lowstand. We interpret this unit as part of the progradational package

deposited subaerially during lowstand, which was later partially truncated by the transgressive surface. Cores show the transition between subaerial and marine deposition and are consistent with the observed sediment wedge being lowstand subaerial deposits. Possible mechanisms to explain the observed aggradation include: (1) sea-level fall exposed a continental shelf with a gentler slope than that of the highstand fluvial system, (2) the depth of the shelf edge lay below sea level during the last glacial maximum, (3) high rates of tectonic subsidence created accommodation despite sea-level fall, and/or (4) the inherent characteristics of the fluvial system promoted aggradation during initial baselevel fall. With continued sea-level fall beyond the shelf edge, which would expose a steeper gradient, fluvial incision and retrogressive erosion may have cannibalized some of the deposits sequestered on the shelf during early lowstand. Observations from this study suggest that sediment yield on tectonically active, mountainous margins varies little throughout the sea-level cycle, which has important implications for the global sediment budget and sequence stratigraphic models.

Hovius, Niels

Sediment Production, Mobilization, Storage and Remobilization in Uplands

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Uplands where tectonic processes create topographic relief are the principal source of clastic sediment in many routing systems. A small set of processes acts to produce and mobilize sediment in these environments. Tectonic processes may cause fragmentation of solid rock mass, and weathering drives further breakdown of the substrate, prior to exhumation and at the surface. Fluvial incision acts with rock uplift to create local relief and hillslope mass wasting removes oversteepened topography, even when weathering has not occurred to any great extent. In this simple landscape, mobilization of sediment occurs primarily during and after episodes of external forcing that induce hillslope mass wasting. Earthquakes and rainstorms are important drivers of mass wasting in many upland areas, and their spatial and temporal patterns are reflected in the sediment load of rivers. In a given setting, these triggers produce sediment in proportion to their magnitude, and gradients in the intensity of forcing are matched by gradients in the magnitude of geomorphic response. Large forcing events have a prolonged effect on sediment mobilization. The erosional effect of a given perturbation can, therefore, only be understood in the context of the history of the source area. Elevated rates of sediment mobilization after a strong perturbation may be due to long-lived weakening of the substrate, or deposition of erosion products out of reach of channel transport processes. Only the lower segments of hillslopes are effectively coupled with adjacent channels. Sediment mobilized above this zone is likely to remain on hillslopes until it cascades down during subsequent episodes of mass wasting. These notions will be illustrated with

examples from Taiwan where we have determined the intensity and location of chemical weathering, the distribution and rate of hillslope mass wasting, the length scale of coupling between hillslopes and channels, the efficiency of external drivers of erosion, and the response time of the mountain catchment system to very strong seismic and climatic perturbations.

Howard, Alan D.

Thinking Source-to-Sink on Mars and Titan

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Mars and Titan exhibit surface modification by weathering, sediment transport, and deposition. The provenance and depositional environment of sedimentary deposits on Mars are particularly important for landed missions, which target such deposits because of the preservation of records of early environmental conditions, particularly those consistent with microbial habitability. Interpretation of the composition and origin of sedimentary deposits is based on spacecraft remote sensing of visual and multispectral imagery as well as landed missions that offer detailed imaging, chemical and elemental analyses as well as roving capability. The forthcoming Mars Science Laboratory mission will select one of four sites for study by its rover, Curiosity. These sites have strong evidence for sedimentary rocks, and two offer the chance to study clear pathways of sediment transport from source to sink. Terminal sink deposits all contain hydrated minerals, including phyllosilicates, which could be indicative of a formerly habitable environment. The source-to-sink is an important criterion enhancing their potential for selection. Thick sections of intricately layered sedimentary deposits within craters and other basins in the highlands of Mars attest to a complex history of deposition and erosion. Three issues must be considered when resolving their origin: (1) the source of the granular material, (2) the mode of transport into the region, and (3) the final depositional mechanism. These may or may not be causally and temporally interrelated. Fine granular material can be produced by processes including physical and chemical weathering, pyroclastic eruptions, impact cratering, comminution during transport, and chemical precipitation. Long-distance transport into a region can occur by pyroclastic surges, airfall deposition from a variety of sources (wind erosion, volcanic ash, globally distributed ejecta from basin-scale impacts), fluvial and lacustrine processes. The terminal depositional process can be the same as the long-distance transport mechanism, or it may involve reworking by wind, fluvial, lacustrine, masswasting, or glacial processes. The origin, transport and deposition may be related to a single environment, such as erosion, transport and deposition of till by a glacier, or a sequence of environments may be involved, such as production of regolith by impact cratering, its erosion, transport and sedimentation onto a lake by

wind, and its final deposition by lacustrine processes. The generation of wind-blown dust, forming vast non-glacial related loess deposits – or duststones – may be particularly important on Mars. These deposits discontinuously cover millions of sq km over specific regions of Mars, such as Arabia Terra. Preliminary analysis suggests they may be climatically controlled. Regions that were once dominated by net deposition of duststones are now are in a state of net erosion, with the new terminal sink perhaps located in the northern lowlands. Radar images of Titan reveal extensive networks of liquid-methane-eroded valleys, probable fans and deltas, as well as extant alkane lakes, and extensive fields of linear dunes presumably composed of long-chain hydrocarbon particles.

Hsu, Ray T.

Variations of Bulk Floc Density and Porosity of Different Sizes in Suspended Particles Corresponding to Organic Carbon in the Gaoping River Plume in Southern Taiwan

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Suspended particles are carriers of terrestrial sediment mass and biogeochemical signals transported from the land to the sea. In general, suspended particles also play an important role in the chemical and biological processes cycling in coastal and estuarine environments (Turner and Millward, 2002). The organic matter in suspended particles influences the physical property of the particulate matter and thus change the particle dynamics and the transport process in the estuarine and coastal environments. The field experiment was conducted on May 23rd and 24th, 2008 in the head region of Gaoping Submarine Canyon (GPSC). In the investigation, hourly CTD and LISST-100 profiling and water sampling were carried out every 3-hours processing on board R/V Ocean Research III. This study used on-board filtration system of nested filtering instrument (CatNet) to filtrate water samples in situ in three mesh-sizes of 10, 63, and 153 μm , then the residual which contains particles smaller than 10 μm were collected and further filtered by 3 μm filter in the lab (Hsu and Liu, 2010). The filtered particles were further analyzed for mass, POC, PIC, PON, PIN, and chlorophyll-a concentrations. In this study, we use POC and PIC to illustrate their co-relations to the bulk floc density and porosity of different grain-size classes. The finest particles ($< 10 \mu\text{m}$) contributed over 50 % to the total mass of suspended particles but only 16 % to the volume. Floc densities (and porosities) also revealed decreasing (and increasing) trend with increasing grain-size. Organic matter in suspended particles affects the floc size structure during flocculation/aggregation process. More organic contents form looser and lighter flocs. Our data indicated that floc densities showed exponential decay with increasing POC fraction in the suspended particulate matter. This tendency was more significant in the grain size greater than 153 μm . In order to extract more information from the multi-variable

data of various grain-sizes, we use EOF (Empirical Orthogonal Function) technique to analyze time series of mass concentration, volume concentration, POC, PIC, floc densities in 4 different size-classes, salinity, and temperature. The result indicated that most carbon contents are of terrestrial origin, except PIC in the size-class of 63-153 and > 153 μm that are of marine origin.

Hsu, Tian-Jian

The trapping and delivery of fine sediment in the coastal environment

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The trapping and delivery of fine terrestrial sediment in the coastal ocean are mainly governed by the principles of buoyancy-driven flow. While the importance of small mountainous river contribution to the total sediment discharge into the global oceans has been recognized since two decades ago, our physical understanding on the dynamics of the near-field, highly stratified, and concentrated sediment-laden river outflow remains to be limited. Recent field evidences also identify fluid mud transport in the wave boundary layer as the main conduit for the offshore delivery of fine sediment. In this study, we focus on detailed numerical modeling that resolves these key processes related to initial deposition and resuspension of fine sediments. Convective sedimentation across the density interface (e.g., Parsons et al. 2000, *Sedimentology*, 48, 465-478) may play an important role in field observed rapid sedimentation at river mouths. We investigate convective sedimentation with a linear stability analysis and a 2DV non-hydrostatic Reynolds-averaged Navier-Stokes model. By analyzing the 2DV model results of more than 40 runs for different inlet sediment concentration, settling velocity, and inlet velocity/height, the criterion for the occurrence of convective sedimentation and the resulting deposit are studied. For large inlet sediment concentration, we observe divergent plumes similar to field observations at Sepik River, Papua New Guinea (Kineke et al. 1999, *Cont. Shelf Res.*, 20, 2239-2266) and Santa Clara River, USA (Warrick et al 2008, *Cont. Shelf Res.*, 28, 991-1009). For intermediate inlet sediment concentration and large settling velocity, intense convective fingers are predicted which are marginally affected by ambient stratified shear flow. Further reducing inlet sediment concentration or settling velocity gives weak convective fingers that are significantly affected by the ambient shear flow. A 3D turbulence-resolving simulation for fine sediment transport is developed to understand fluid mud transport in the wave boundary layer. The simulation results reveal different degrees of sediment-induced density stratification in the resulting bed state. From low to high sediment availability, we observe i) virtually no turbulence modulation in the case of very dilute flow, ii) turbulent fluid mud regime where slight turbulence attenuation is observed near the top of wave boundary layer causing the formation of lutocline. However, wave boundary layer remains

turbulent; iii) a regime where flow laminarization occurs during peak flow, followed by shear instabilities and sediment bursts during flow reversal; iv) complete laminarization throughout the wave cycle due to strong sediment-induced stable density stratification. As future work, our recent large-scale modeling effort for a small mountainous river system, the Gaoping River in southern Taiwan (Liu et al. 2009, *Marine Geology*, 264, 152-164), using a 3D primitive equation ocean model, FVCOM (Chen et al. 2003, *J. Atmosphere and Oceanic Tech.*, 20, 159-186) is briefly discussed. Our main goal is to incorporate these key small-scale processes into the coastal modeling system to predict sediment source to sink.

Huang, Jyh-Jaan

Mega-flooding and Human Settlement Abandonment Over the Past Millennium in the Lan-Yang River's S2S System

Huang, Jyh-Jaan¹; Wei, Kuo-Yen¹; Chuang, Chih-Kai¹; Yang, Tien-Nan²; Lee, Meng-Yang³; Chen, Yu-Be⁴; Lee, Teh-Quei²; Huh, Chih-An²

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2. Earth Sciences, Academia Sinica, Taipei, Taiwan
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4. Anthropology, National Taiwan University, Taipei, Taiwan

Active tectonic activities plus frequent landing of typhoons make Taiwan unique in having very high rates of uplift, precipitation, denudation and sedimentation. Particularly, intense rainfall associated with typhoons often causes flooding, large-scale landslides and debris flows in river systems, affecting human activities today and during historical time. This study assembles radiocarbon dates of upland river terraces, organic proxies in flood plain lake sediments and content of wood shreds in nearby marine sediments. These data are synthesized to infer the frequency and magnitude of ancient floods over the past 1250 years in the Lan-Yang River's drainage basin in northeastern Taiwan. Alluvial fan terraces distributed along the banks of upper Lan-Yang River are considered to be remains of ancient debris flow events, and their radiocarbon dates fall in two time ranges: 1100-850 and 550-350 cal. yr BP. Organic proxies such as TOC and C/N ratio representing terrestrial plant input, were measured from bulk sediments of Lake Dahu and Lake Meihwa on the Lan-Yang Plain. Peak values of TOC and C/N ratio are conspicuous during 1000, and 550-400 cal. yr BP, implying frequent debris flow events. Abundance peaks of wood shreds in marine box core ORI-801-7A occurred during 1000-900 and 550-400 cal. yr BP, coinciding with those terrestrial input events recorded in terraces and lake sediments. Furthermore, a cultural hiatus during 600-450 cal. yr BP at the archaeological Site Kiwulan on the Lan-Yang Plain suggests that the settlement was once abandoned, possibly due to the inferred mega-floods. In summary, multiple lines of evidence collected from the Lan-Yang River drainage system suggest that flood events were

more frequent during two particular periods: ~ 1000 cal. yr BP and 550-400 cal. yr BP; the latter event might have destructive impacts on the living of Taiwan's aboriginal tribes on the Lan-Yang Plain.

Huh, Chih-An

Magnetic Properties as Source-to-Sink Tracers of Sediments: A Case Study in the Taiwan Strait

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The Taiwan Strait (TS) is a relatively narrow and shallow sea between Taiwan, the Asian continent, the South China Sea (SCS) and the East China Sea (ECS). Regulating water flow between two large marginal seas (i.e., SCS and ECS) and the open Pacific, and receiving sediments from the largest land mass (i.e., Asia) and a mountainous island with the highest sediment yield in the world (i.e., Taiwan), the TS is an important gateway for sediment transport in the western Pacific. We have found that magnetic properties are ideally suited for tracing sediments in the TS. It is because magnetic minerals in sediments from two sides of the strait are very different. The dominant magnetic minerals in sediments from Taiwan and mainland China are pyrrhotite and magnetite, respectively. While magnetite also exists in sediments from Taiwan, pyrrhotite is not found in sediments from China. Such a distinction results in vast differences in magnetic susceptibility, HIRM, SIRM and the S-ratio between sediments from the two shores. Therefore, the magnetic composition of Taiwan Strait sediments can be well explained using a two-component mixing model based on these parameters. From the distribution of these parameters in surface sediments, provenances and transport pathways of sediments in the TS can be delineated. Based on profiles of these parameters in well-dated sediment cores from the middle of the northern TS, it is calculated that sediment supply from Taiwan has increased in the past five decades, which may be related to land development and increased frequency of intense rainfalls during this period.

Jaeger, John M.

Cross-Margin Signal Transfer in a Glacial Source-To-Sink Sedimentary System, Southern Alaska

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Deciphering autogenic and allogenic controls on sedimentary signal generation and preservation is complex, yet key to the utilization of margin stratigraphy. Glacially dominated basins are an environment where it is possible to isolate and identify the stratigraphic response to allogenic sediment production. The Gulf of Alaska margin offers the opportunity to study the complex interactions between

glacial, tectonic, and oceanographic processes responsible for creation of one of the thickest Neogene high-latitude continental margin sequences. We focus on documenting the sedimentary response to three global climate events: the Little Ice Age (LIA); the Last Glacial Maximum (LGM); and the Mid-Pleistocene Transition (MPT). The Bering Glacier-Bagley Icefield is the largest glacier in North America and situated in a climatically sensitive area. The marine record of the LIA-period advance (160-360 yr BP) of the Bering is evident in a transect of jumbo piston cores from the inner continental shelf to the distal Surveyor Fan. The LIA signal is recorded in sediments as an increase in magnetic susceptibility and bulk density, resulting from increased silt content. The thickness of the signal decreases exponentially from >30 m onshore to ~ 10 cm on the Surveyor Fan. Within the temporal resolution of the radioisotopic and paleomagnetic geochronometers, the LIA signal appears in all cores within decades to a few centuries after the well-dated onshore advance. The sedimentary signal created by the Bering Glacier on the slope during the late glacial-Holocene transition is evident in the sediment lithology, including ice-rafted debris (IRD >250 μm) flux rate and C-14-based mass accumulation rate between 10-18 cal kyr BP from a jumbo piston core also used in the LIA core transect. Ancillary geophysical data indicate that the Bering was likely at tidewater at the shelf edge during the late glacial, which is also supported by high IRD and sediment fluxes prior to 17.0 cal kyr BP. Exponentially decreasing mass fluxes between 16.6-17.4 cal kyr BP indicate that the terminus of the Bering Glacier was retreating landward, and much of the high IRD flux prior to 16.6 cal kyr BP may have resulted from intensified calving associated with catastrophic terminus retreat, possibly driven by global climate changes. Lastly, the study region contains seismic stratigraphic evidence of a substantial shift in sedimentation that approximately coincides with significantly increased global glaciation following the MPT. The MPT possibly resulted in the formation of the presently observable cross-shelf sea valleys that isolated sediment transport pathways to the Surveyor Channel. The signal of this event is examined from fine-grain compositional and textural changes in Surveyor Fan sediments from DSDP Site 178, which show no gross compositional or textural transitions between pre- and post-MPT constituents. Yet, elemental composition and textural variability is significantly decreased post-MPT, indicating that transport pathways from source-to-sink changed following the MPT.

Johnstone, Elizabeth

Three-Dimensional Clinof orm Architecture in the Gulf of Papua: Interplay Between Sediment Supply and Dispersal

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CHIRP seismic data acquired in the Gulf of Papua (GoP) reveal that the modern mid-shelf clinof orm consists of three depositional lobes, a central lobe downlapped by younger northern and southern lobes. Defining the three-dimensional architecture of this clinof orm provides the ideal opportunity to examine the evolution of a sediment dispersal system, and thus gain insight into the role of sea level, sediment supply, and climate on annual to millennial timescales. The depocenter shift and infilling of available accommodation within the central lobe appear to be predominantly controlled by depositional processes and stacking patterns (autocyclic forces). Conversely, the marked shift in deposition away from the central lobe to the northern and southern lobes (~60-80 km), which bypassed adjacent accommodation, is difficult to explain by depositional processes alone and likely is controlled by fluctuations in the intensity and frequency of regional climate cycles. Radiocarbon dates show that the marked shift in deposition away from the central lobe occurred after 2 ka, approximately 5 ka after the last rapid eustatic sea-level rise. The timing of this abrupt shift is roughly coincident with millennial scale changes observed in climate proxy data from the region. As it is unlikely that sediment flux from the various contributing rivers (e.g., Fly, Purari, Kikori, etc.) changed appreciably, we speculate that lobe shifting reflects a change in coastal circulation, perhaps the result of fluctuations in the intensity of El Niño-Southern Oscillation (ENSO).

Kim, Jung-Hyun

Tracing soil organic matter from source to sink

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The transport of terrestrial organic matter (OM) to coastal sediments represents a significant flux in the global carbon cycle. Although a large range of bulk and molecular proxies for terrestrial OM is available, quantification of the relative inputs of terrestrial OM to marine sediments is still difficult. The incomplete understanding of the transfer of

terrestrial OM from land to the ocean is probably due to the lack of diagnostic (geochemical) proxies especially for soil OM which accounts for two third of the total terrestrial carbon budget. Recently, several developments have however led to new insights into the recognition of soil OM in marine environments. The Branched and Isoprenoid Tetraether (BIT) index (Hopmans et al., 2004) has been introduced as a proxy to trace soil OM input from land to the marine environments (e.g. Kim et al., 2010). This index is based on the relative abundance of non-isoprenoidal glycerol dialkyl glycerol tetraethers (GDGTs) versus a structurally related isoprenoid GDGT "crenarchaeol". Branched GDGTs are produced by anaerobic bacteria thriving in soils (Weijers et al., 2006), whereas crenarchaeol is produced predominantly by marine Crenarchaeota (Sinninghe Damsté et al., 2002). We will discuss the use of the BIT index to trace soil OM input in contrasting depositional settings: the Rhone prodelta (NW Mediterranean), the fjords of Svalbard (Arctic Ocean), and the Amazon fan (tropical Atlantic). Hopmans, E.C., J.W.H. Weijers, E. Schefuss, L. Herfort, J.S. Sinninghe Damsté, and S. Schouten, A novel proxy for terrestrial organic matter in sediments based on branched and isoprenoidtetraether lipids. *Earth Planet. Sci. Lett.* 224, 107-116, 2004. Kim, J.-H., B. Zarzycka, R. Buscail, F. Peters, J. Bonnin, W. Ludwig, S. Schouten, and J.S. Sinninghe Damsté, Factors controlling the Branched Isoprenoid Tetraether (BIT) Contribution of river-borne soil organic carbon to the Gulf of Lions (NW Mediterranean). *Limnol. Oceanogr.*, 55, 507-518, 2010. Sinninghe Damsté, J.S., E.C. Hopmans, S. Schouten, A.C.T. van Duin, and J.A.J. Geenevasen, Crenarchaeol: the characteristic core glycerol dibiphytanyl glycerol tetraether membrane lipid of cosmopolitan pelagic crenarchaeota. *J. Lipid Res.*, 43, 1641-1651, 2002. Weijers, J.W.H., S. Schouten, E.C. Hopmans, J.A.J. Geenevasen, O.R.P. David, J.M. Coleman, R.D. Pancost, and J.S. Sinninghe Damsté, Membrane lipids of mesophilic anaerobic bacteria thriving in peats have typical archaeal traits. *Environ. Microbiol.*, 8, 648-657, 2006.

Kineke, Gail C.

The Role of High Concentration Suspensions in Dispersal of River Sediment

Kineke, Gail C.¹

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High-concentration suspensions of fine sediments, or fluid muds, have been investigated for several decades, early on in conjunction with dredging activities and sediment dispersal from rivers with extremely high suspended-sediment concentrations. Studies have been specific to particular sites such as estuaries, muddy rivers and muddy coastlines. More recently, studies demonstrated the critical role these suspensions play in sediment dispersal from rivers, often accounting for differences in the pathways of a surface plume and the location of a depocenter, even if the source river concentrations are moderate. The formation of high concentration suspensions occurs in dispersal systems influenced by a wide range of discharge, sediment

concentration, and tidal conditions. When present, these suspensions generally dominate the cross-shore transport, which in some environments can even be onshore. Recent field studies in the Petitcodiac River and on the shallow shelf off western Louisiana provide insight on the necessary conditions for formation of these suspensions and the influence on sediment dispersal in coastal systems.

King, Edward L.

Dependence of canyon-head evolution on mode of shelf sediment delivery on southeast Canadian glaciated shelves

King, Edward L.¹

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Canyons along the SE Canadian shelf break are second only to large submarine slides as conduits for sediment transport from shelf to ocean sink under pre-glacial, full and partial glacial, and interglacial conditions. A range of examples through time and space demonstrates that their development is sensitive to mode of sediment supply, especially meltwater versus till dominated glacial regimes, and to ice margin proximity. Some settings enhance, interrupt or even disrupt this conduit, diminishing or enhancing overall canyon morphology of the slope both regionally and locally. A large, buried canyon system of Miocene age is now recognized at the mouth of the largest shelf-crossing trough, Laurentian Channel. It represents the response to large volumes of fluvial and shallow shelf sourced late Oligocene and Miocene supply from large prograding sheets. Near syn-depositional incision reached 80 km into the shelf with a tributary system 50 km across and mouth 1 km deep at the present shelf break. It is filled with successive ice stream fed tills with flat-lying bounding erosional contacts, aggrading stepwise over upper slope prograding chaotic deposits, remnants of glacially-derived mass failures. A water-rich deformable bed is inferred, devoid of meltwater in conduits (no channels). Distal tilting of the older surfaces indicates subsidence and this glacial record probably spans much of the Pleistocene. This nearly 1000 km³ deposit, preserved due to ample accommodation space, effectively ceased tributary canyon morphology development, evolving rather to a line-source feeding the abyssal plain. A similar fate is observed in a banktop canyon head where infilling tills from successive glaciations, migrated the canyon at least 12 km seaward. Rather than focus sediment transport to the slope, glaciation healed and partially incapacitated the conduit for following low-stands. Furthermore, competent shelf-edge tills can curtail retrogressive mass failure at canyon heads. "The Gully" is large but fully open canyon system. It has been erosion-dominated over the long term with products bypassing the slope to the ocean basin. Here, the glacier reached 1000 m water depth but deposits consist only of a sandy till with subtle retreat moraines and deglacial plumites. Active cutting during deglaciation removed flanking tills. In contrast to glacially filled canyon, free meltwater was in large supply, even with retreat to the mid-shelf. This is a notable

but lone exception because tunnel valley systems ring entire bank areas marking LGM and deglaciation still-stands but they abate before reaching the shelf break. Sub-glacial meltwater flux could not generally communicate directly with canyon heads except for occasional glacial outburst events. Some canyons reacted more typically, evolving and switching while fed outwash and morainal sands in successive stages during post-glacial low-stands. Canyon heads outside the glacier margin on Grand Bank are erosion-dominated, well maintained by sand from adjacent low-stand sand ridges. Instrumented landers in shallow canyon heads record present (high-stand) sediment transport activity but diminished orders of magnitude compared to lowstand condition, though locally enhanced by contour currents.

Kniskern, Tara

River discharge along the US West Coast margin: identifying rivers that flood concurrently

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The river basins along the US West Coast are generally small, less than 15,000 km², and tend to flood immediately after rain events. The storm systems that deliver rain to the West Coast margin are considerably larger than the river basins such that multiple river basins receive rain within hours of each other. Subsequently, these proximal rivers likely disperse fresh water and sediment to the coastal ocean at relatively the same time. Therefore many conceptual and numerical models may underestimate sediment delivery, dispersal, and burial, as well as buoyant circulation on shelves adjacent to small rivers with mountainous catchments. The hourly discharge records from 96 USGS river gauges were analyzed to ascertain which river systems flooded concurrently from the period beginning October 1, 1987 through September 30, 2007. Since the discharge record of many of these rivers is episodic, with long periods of little to no discharge, analyses were confined to the top 5% and 25% of the discharge records. These thresholds were chosen by comparing probability of exceedance curves from each station. Pairwise correlations were calculated for each partial duration series with lag/lead offsets ranging from -50 to +50 hours. Results with fewer than one year's worth of overlapping records for any two discharge records were discarded. Additionally, the data were corrected to account for the variable distances of the USGS gauging stations from the coastal ocean. Several river gauge discharge records above the 25% exceedance percentile correlated significantly with each other, $r > 0.8$ and 0.9 . Where multiple river gauge stations strongly correlated, groupings were identified. Fewer groupings were identified above the 5% exceedance threshold, largely due to the decrease in data considered. Overall, more groupings were identified along the

Washington and Oregon coasts than along the California coast. This is likely due to the relatively greater rainfall and higher frequency of floods to the north, whereas mid- to southern California River basins are more arid and floods are relatively more episodic. Analysis of temporal offsets indicated that these rivers disperse to the coastal ocean within a few hours of each other. These data suggest that more freshwater, sediment, and other nutrients and contaminants are concurrently dispersed along a relatively small length of coastline during an individual storm than has been generally considered.

Koppes, Michele N.

On The Rate Of Production And Transfer Of Sediment From Glaciated Terrains

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The history of ice dynamics and ice extent is recorded in the sediments produced and delivered by glaciers, which reflect variations in both climate and in the erosional efficacy of the ice. The high-latitude continental margins in particular contain a rich record of past climatic changes reflected not only in proxy environmental data (del-18O, foraminifera, etc.) but also in changes in sediment production and delivery from the adjacent glaciers and ice sheets. To evaluate properly how such glacial sediment yields may reflect climate variability, we need to understand how changing ice dynamics, as a function of climate, control erosion rates over a range of timescales. Contemporary glacial erosion rates based on annual sediment yields from glaciated basins in temperate orogens such as Alaska and Patagonia are up to a factor of 5 higher than erosion rates averaged over a full glacial cycle, and up to an order of magnitude higher than long-term exhumation rates derived from detrital apatite thermochronometry. Current erosion rates from tectonically-active orogens are also up to an order of magnitude greater than rates from quiescent margins, and can vastly outpace rock uplift rates. One issue likely to contribute to such high contemporary sediment yields is the fact that most of the glaciers studied have been in rapid retreat over the past century. The marked retreat and thinning of these glaciers suggests that much more ice is being conveyed through the system than can be sustained by the input of snow, resulting in accelerated sliding at the bed and more rapid erosion of both stored sediment and new bedrock. The order of magnitude difference in rates across timescales suggests that current rates of erosion are highly anomalous and reflect only periods of warming climate and enhanced glacial retreat. To investigate this influence of transient climate and changing ice dynamics on glacial erosion rates, we compared sediment yields to reconstructed fluxes of ice through glaciers across a range of climatic regimes. Centennially-averaged basin-wide erosion rates decrease by almost two orders of magnitude between temperate and polar glaciers with similar ice fluxes, from

over 16 mm/yr in temperate Northern Patagonia to 0.02 mm/yr in the Antarctic Peninsula, suggesting that climate, and not ice volume, is the primary driver of glacial sediment yields. The substantial increase in glacier erosion rates as many glaciers shift from polar to temperate regimes implies significant changes in geomorphic response and sediment delivery to the continental shelves as climatic boundary conditions change.

Kurtz, Andrew

Upland Weathering Processes in the Fly River System

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The rivers of Papua New Guinea have long been appreciated for their tremendous sediment yield. Our work addresses the complementary issue of solute yield, produced by chemical weathering processes. Chemical weathering is important because it is the main process responsible for sequestration of CO₂ on geologic time scales, and at shorter time scales controls the production of biologically-relevant materials (Si, P, Fe, clay minerals) delivered to the continental margin. A compilation of solute flux data for the world's 60 largest rivers (Gaillardet et al., 1999) indicates that the rivers of PNG, particularly the Fly, Purari, and Kikori, deliver the world's highest alkalinity yields, that is, area-normalized alkalinity fluxes. This is significant because the portion of alkalinity produced by silicate weathering is a direct reflection of CO₂ consumption by silicate weathering. We conducted the first systematic study of chemical weathering in the Fly River basin. Our work was based on land and ship-based sampling, and river gauging conducted in cooperation with Ok Tedi Mining, LTD in 2007. We sampled upland streams, the two major tributaries to the Middle Fly (Ok Tedi and Upper Fly), a transect through the Middle Fly, and the confluence of the Middle Fly and Strickland Rivers where they join to form the Lower Fly. We used a combination of a major-ion based inverse method, Sr isotope mass balance, and major element and isotopic data on upland soils, suspended sediments, and floodplain sediments to better understand chemical weathering processes and the lithologic sources of solutes delivered to the Gulf of Papua. Our most significant conclusions are that 1) The overall chemistry and solute flux of the Fly river system is controlled by weathering in the highlands mostly of carbonates. Chemical weathering in the lowlands contributes additional solutes, largely derived from silicate weathering, and is likely the dominant locus for the production of clay minerals and Fe-oxides. The dissolved load of the Strickland carries a higher proportion of silicate-derived solutes than the Middle Fly. 2) The Ok Tedi mine, which has increased the sediment flux of the Fly 3-5 fold, has not significantly impacted the major ion chemistry of the river, although it may have increased the solute flux. 3) The chemical erosion rate from the Fly River is estimated to be ≈14Mt /y, about one sixth the natural physical erosion rate. 4) The CO₂ sink from silicate weathering in the Fly

River basin is $3.4\text{--}4.3 \times 10^{10}$ mol C/y, roughly equivalent to the estimated CO₂ sink from burial of organic carbon in the Fly system.

Lamb, Michael P.

The influence of fluvial-backwater and plunge-point dynamics on hyperpycnal plume generation

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Turbid river plumes can plunge to form turbidity currents (i.e., hyperpycnal plumes) where they enter a water body of lesser density providing a direct link between rivers and their associated marine sediment deposits. Owing to this source-to-sink connection and the preservation of marine event beds, hyperpycnal-plume deposits might contain an important and abundant record of the response of rivers to climate change. Indeed, a leading hypothesis suggests that hyperpycnal-plume velocity scales directly with river discharge, such that individual event beds record the rising and falling discharge of a flooding river. Using a quasi-2D numerical model, we test this hypothesis and find that turbid river flow must move through a backwater zone, depth-limited plume, and plunging zone before becoming a turbidity current. These zones can extend tens of kilometers offshore and significantly affect the transfer of momentum from river to turbidity current. The backwater zone is shown to force deposition, reduce the likelihood of hyperpycnal flow generation, and retard source-to-sink sediment transport during low to moderate discharges. In contrast, at high discharges, backwater zones can transition to a region of drawdown and erosion, charging the turbid plume with sediment, and enhancing the likelihood of hyperpycnal flow generation. Model results within the backwater zone compare favorably with measurements of river water-surface elevation and velocity over a range of discharges for the lower Mississippi River. Farther seaward, plumes that are denser than the ambient fluid are shown to plunge where the densimetric Froude number drops below 0.5, creating an offshore zone of deposition between the shoreline and the plunge point. The size of this depositional zone scales inversely with the bed slope such that, for equivalent flood events, steeper sloping margins have a higher likelihood of generating plunging hyperpycnal plumes that export sediment to canyons and deep marine depocenters. Model predictions for plunging plumes compare favorable to results from scaled flume experiments.

Lawson, Daniel E.

Sediment Flux Variability of Temperate Terrestrial and Tidewater Glaciers, Chugach-St Elias Mountains, Gulf of Alaska Region

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The tectonically active St Elias orogen has been continuously glaciated for ~6 M years, with extremely high short- and long-term denudation rates and extreme production and dispersal of sediment to develop the thick (~5 km) marine - glaciomarine sequence (Yakataga Formation) within the Gulf of Alaska (e.g. Plafker and Addicott 1976; Plafker 1987, Zellers and Lago 1992, Meigs and Sauber 2000, Sheaf et al 2003). Glaciers in the St Elias orogen have extensively eroded and transported large quantities of sediment through at least the LGM (Powell and Cooper 2002), and likely have played an important role in the long-term evolution of this glaciated mountain belt and in the infilling of Gulf sedimentary basins (Berger et al 2008). Shuster et al. (2005) showed in coastal British Columbia that onset of extensive glaciation caused notably accelerated erosion, but that continuation of glaciation was accompanied by drop-off in erosion rates. Similarly, comparison of short-term and long-term sediment yields from extensively glaciated basins shows order-of-magnitude variation (Hallet et al., 1996). Process understanding suggests that at least part of this time-variability is linked to the effects of glacial overdeepening, an insight that, if confirmed, will inform efforts to model source-to-sink sediment fluxes. Most glacially transported sediment is glaciofluvial. Rapid glacial erosion tends to form overdeepenings, with the glacier bed deeper than the proglacial environment. If the slope out of an overdeepening is too steep relative to the ice-surface slope, then the pressure-dependence of the melting point causes subglacial channels to freeze closed, greatly decreasing sediment flux and armoring the glacier bed with till that blocks bedrock erosion. Overdeepenings created by subglacial erosion thus are a critical component to understanding the role of glaciers in sediment production over time relative to tectonic uplift, periglacial erosion and glaciofluvial and glaciomarine transport and the offshore deposition of sediments. Down-glacier bed slopes modulate glacial sediment production by developing equilibrium, long bed profiles about 50% steeper than and opposed to the overlying ice-surface slope. Achievement of this slope strongly limits additional erosion. Perturbations in the ice slope may shift the subglacial regime from one of erosion to sedimentation, while potentially creating stratigraphic time-shifts and gaps important to interpreting the sedimentary record. Because of this tendency to equilibrium long-bed profiles in subglacial basins, the release of these sediments to proglacial and distal sedimentary environments over the long term will require continued down-cutting of proglacial regions and tectonically-driven tilting and uplift. Glacial sediment flux

to marine basins over the long term is thus complexly intertwined with mountain belt growth and other denudation processes. The terrestrial Matanuska Glacier, tidewater Hubbard Glacier and the LIA Glacier Bay Glacier exemplify these concepts

Lee, Kristen

Export and Retention of Fine-Grained Sediment on the Intertidal Complex of a Small Mountainous River: Skagit River Tidal Flats

Lee, Kristen¹; Ogston, Andrea¹; Nittrouer, Charles¹

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The Skagit River drainage basin delivers 1-4 million tons of sand and mud into Puget Sound each year. At the river mouth an expansive tidal flat has developed composed mostly of sand-sized particles, with limited mud. This study evaluates the transport processes and sediment deposition and accumulation across the intertidal flat and shows that within this braided tidal-channel system, strong river discharge and tidal currents act to deliver, rework and rapidly export sand and mud to the seaward edge of the flat. To investigate the sediment-transport mechanisms, we deployed instrumented tripods near the major north and south tidal-flat channels at high (both spring snow melt and autumn /winter storm seasons) and low (late summer) river discharge. Spatial water-column profiling surveys were simultaneously completed in a major southern channel. These hydrodynamic measurements were paired with seabed sampling (>60 grab samples and cores), and they provide the link between episodic to seasonal transport dynamics and seabed deposits. At high discharge, the braided-channel system delivers some limited fine-grained sediment to the flat. Recent river sediment (determined by the presence of ⁷Be) was found at the seaward edge of the flat and in isolated splay deposits adjacent to channels. Evidence of some retention of flood deposits is observed as thin muddy laminae within the seabed. During a winter flood event, suspended-sediment concentrations (SSC) were large in channels, where 5 cm of deposition formed as river discharge began to wane. Tidal currents reach 70 cm/s within channels and 50 cm/s on the flat, indicating that shear stresses are capable of resuspending sand-sized particles. The stresses act to rework the channel seabed, whereby particles are resuspended and fine-grained particles can then to be exported to the flat edge. Evidence of this reworking is seen by 1-2 cm of deposition and erosion within single tidal cycles. The fate of the estuarine particles in suspension is dictated by tidal currents. Spring flood tides trap fluvial particles in the water column of the upper flat and, on the ebb tide, particles are released and carried to the flat edge. The water-column and seabed data show that tides and river discharge within the braided-channel system deliver particles to the flat and then act to export sediment off the flat. Some fine-grained flood deposits are retained on the flat as preserved layers, but most of this material delivered by the Skagit River is exported beyond the flat.

Leithold, Elana L.

The use of continental margin organic geochemical stratigraphy to reconstruct watershed history—Lessons from the Waipaoa Sedimentary System, New Zealand

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Stratigraphic trends in the composition of sedimentary organic matter on continental margins have long been used as tools for reconstructing environmental change. Temporal trends in stable carbon isotopic ratios, for example, have been widely interpreted in terms of variable contributions of terrestrial and marine organic matter driven by changes in relative sea-level. In recent years, however, increased appreciation of the multiple sources from which riverine organic carbon (OC) is derived has suggested the potential for gleaned considerably more information about terrestrial environmental change from offshore deposits. By establishing the organic geochemical fingerprints of sediment sources and delivery mechanisms in watersheds, progress can be made toward resolving the offshore stratigraphic signals of climate change, tectonics, and human perturbation. Various geomorphic processes operative in watersheds may mobilize distinct pools of organic matter. Sheet wash, for example, will primarily access surficial material, including plant litter. Shallow landslides, in contrast, tend to deliver entire soil profiles containing OC of a range of ages and reactivities, although the material tends to be skewed toward younger, more labile fractions. Bank erosion mobilizes alluvium that contains OC fractions of diverse composition and age derived from a range of upstream sources. Deep gully erosion and earthflows typically operate in watersheds underlain by weak, commonly crushed rock, and along with plant and soil OC they can deliver large amounts of rock carbon (kerogen) to rivers. Characterization of the composition and age of OC in offshore sediments permits delineation of changes in the relative roles of these processes over time. Prior and ongoing investigations of geomorphic processes and carbon cycling in the Waipaoa watershed, New Zealand, provide a strong foundation for interpreting paleoenvironmental records. Herein we report on characterization of the Holocene organic geochemical signals preserved in depocenters on the continental shelf and contained in bulk sediments as well as separate density and size fractions. Our reconstruction includes a mid Holocene interval of high kerogen input that is matched with evidence on land for a period of rapid river incision and hillslope adjustment primarily via earthflows. The record points to a later Holocene period of higher input from surficial sources. Finally, human influence is indicated

by evidence for biomass burning, vegetation change, and deep soil erosion. The signal of bedrock input from deep gullies following deforestation of the headwaters by European settlers is also evident, but weaker than the signal of the mid-Holocene episode. Results of our study of the Waipaoa system indicate promise for utilizing offshore sedimentary organic geochemical records to reconstruct the history of terrestrial environmental change on less well characterized margins and further back in time.

Leverich, Glen T.

Geomorphic Landscape Units: An effective approach to quantify relative sediment-production rates across large areas, as applied to the Santa Clara River watershed in southern California

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Accurate yet efficiently generated estimates of sediment production rates from extensive landscape areas can help management agencies to formulate scientifically based watershed management actions at geomorphologically relevant timeframes, particularly in areas with varying land cover and urban infrastructure. Generally, hillslope sediment-production rates on decadal time scales or greater are difficult to quantify in watersheds lacking regular measurements because they are driven by the episodic effects of rainstorms, windstorms, fires, earthquakes, and human and other disturbances. The inherently stochastic nature of erosion rates results in substantial year-to-year variability and makes any assessment of sediment production and subsequent transport rates sensitive to the timescales over which they are averaged. Although long-term annual averages cannot predict the sediment load for any given year, they are useful in assessing the long-term consequences of alternative management actions because different parts of the landscape can be readily isolated according to their relative sediment-production potential. Scientific literature and field experience in southern California and elsewhere indicate that a combination of geology, hillslope gradient, and land cover exerts the greatest influence on the variability on long-term sediment-production rates. Specific combinations of these physical factors constitute “geomorphic landscape units” (GLUs) that, together, largely determine sediment production from a particular unit. The GLUs are initially designated in a GIS using categorized data derived from DEMs and digitized geologic and land-cover maps. Relative sediment-production rates for individual units are subsequently calibrated using field observations of apparent erosion rates from a sample set of different GLUs. Sediment-production rates can either be left as relative values, in the absence of any corroborating data, or quantified where possible. In the Santa Clara River

watershed, quantification was achieved using debris basin cleanout records and reservoir sedimentation measurements, which capture sediment yields over decadal time scales. By integrating these rates across our relative sediment-production categories throughout the watershed, we have been able to predict average annual sediment yields at the watershed and subwatershed scale (>10 km²) with good agreement with other published sediment yields, including sediment discharge records at stream gauging stations, estimates of regional tectonic-uplift and landscape-denudation rates, and sediment dating. Once complete, the approach can cautiously be extended to predict changes in sediment production due to land cover changes, such as by wildfire and urban development—two dominant landscape altering forces present throughout southern California. This approach therefore provides a useful, rapid framework for identifying time-averaged sediment production rates for use in watershed management.

Litchfield, Nicola J.

Tectonic controls on Source to Sink Systems and the interplay with sea level change: examples from northeastern New Zealand

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Tectonic processes have a fundamental influence on the behaviour of source to sink systems on tectonically active margins. Tectonics acts as both: (i) a driver, by creating topography which results in erosion, gradients to drive sediment transport, and accommodation space for sediment deposition, and (ii) a perturbation, by causing coseismic uplift, subsidence, and/or fault rupture, and by causing widespread ground shaking which can result in landsliding and ultimately, delivery of sediment to river channels. The role of tectonics as a driver of source to sink systems such as the Waipaoa, northeastern New Zealand, is relatively well understood (Berryman et al., 2000; Gerber et al., 2010), but work on quantifying the role of earthquakes, for example, in producing earthquake-triggered landslides has only recently begun (Litchfield et al., 2009). We present the results of this preliminary study and examine the interplay between tectonics and post-glacial sea level rise by contrasting the impact on the generally subsiding lower Waipaoa River (Wolinsky et al., 2010), with the uplifting lower Pakarae River (Litchfield et al., 2010). The first step towards quantifying the role of earthquakes is to examine the landscape impacts of moderate to large historical (post 1840AD) earthquakes in the northeastern North Island. Hancox et al. (1992) have shown that the ground shaking threshold for triggering landslides is Modified Mercalli Intensity (MMI) 7. The frequency of different levels of ground shaking (MMI) in the Waipaoa River catchment is calculated using standard seismic hazard techniques, whereby earthquake magnitude and recurrence intervals from historical seismicity and active fault data are converted to MMI in different parts of the catchment using attenuation relations. Our analysis shows

that MM7 can be expected over large areas of the catchment approximately every 130 years, MM8 every 620 years, and MM9 every 10,000 years. These results can next be compared with the ages of large landslides, which are currently being analysed, as well as sediment records, to see if there is a relationship between the calculated return times and sediment delivery. One of the most important active faults to impact the Waipaoa River catchment is the Gable End Fault, a newly mapped fault (Mountjoy et al., submitted) offshore of and uplifting the Pakarae River mouth, 33 km northeast of the Waipaoa River mouth. The rapid (3.2 ± 0.8 mm/yr) uplift has resulted in the exposure of an early Holocene transgressive estuarine sequence which is correlative to that beneath the Poverty Bay Flats, and upstream of which is a fill terrace. These record a marine transgression of only 1 km, compared with 13 km in the subsiding lower Waipaoa, and a total upstream impact of 3 km (unknown in the Waipaoa). These show that, depending on the relative rates, the impact of sea level rise can overwhelm the tectonic impact, and the extent of impact is a function of the tectonic style and rate. These results will provide useful insights into the potential impact of future sea level rise at coastal sites in different tectonic settings.

Liu, James T.

From the Highest to the Deepest: A River-Sea Dispersal System on the NE Edge of the South China Sea

Liu, James T.¹

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This abstract gives a brief overview of the entire river-sea dispersal system from the Source-to-Sink perspective. Gaoping River (GPR) is a small mountainous river whose source area is located in the southern part of the Central Mountain Range of Taiwan having the elevation higher than 3997 m. It has an average gradient of 1:150. Both the chemical and physical weathering rates for GPR basin are higher than the world average. GPR annually discharges 35 Mt of sediment into the sea. Approximately 1 km seaward from the mouth of GPR is the head of the Gaoping Submarine Canyon (GPSC). The GPSC owes its existence to tectonic processes related to the collision of arc and continent where the Philippine Plate collides with the Eurasia Plate. The canyon extends from the mouth of GPR, cutting through the Gaoping shelf and slope, and merges into the northeastern Manila Trench over a distance of about 260 km in water depth over 3000 m (Yu et al, 2009). It is a major conduit for the transport of terrestrial sediment to the South China Sea (SCS) and the landward transport of particles of marine origin in the SCS. In the tidally-dominated benthic nepheloid layer (BNL), whose thickness can exceed 200 m in GPSC, the water temperature, flow, and suspended sediment concentration show distinctive tidally oscillations primarily at the M2 frequency. Both semidiurnal barotropic and baroclinic tides are important in the canyon. Within the canyon, the depth averaged turbulence kinetic energy dissipation rate and the depth averaged eddy are

more than two orders of magnitude greater than typical values in the open ocean, and are much larger than those found in the Monterey Canyon. In the GRSC the normal transport of suspended sediment associated with tidal propagation from offshore are up-canyon yet episodic sediment transports associated with episodic gravity-driven events are down-canyon. In this presentation emphasis is given to the importance of the family of gravity flows in GPSC, including typhoon-induced hyperpycnal turbidity currents and earthquake-induced debris flows in the transport of terrestrial sediment and carbon to the deeper part of the SCS basin. We found that hyperpycnal turbidity currents are the preferred process for the transport of terrestrial carbon/organic carbon exported by the GPR during a typhoon to the deep-sea. Based on sedimentological studies of 3 piston cores taken from 3 sites (distal, middle, and upper canyon) and along the thalweg of the GPSC, the upper reaches of the canyon acts as a sink for coarser turbidites. Finer turbidites are dominant in the middle and lower reaches. These findings suggest rapid transport of fluvial sediment from the GPR, controlled by fluvial load of the river and hyperpycnal turbidity currents. Earthquake-triggered episodic gravity flows are also important transport agents in the GPSC. Gravity transport events often result in post-depositional disturbance in the canyon strata. We hypothesize that the frequency of occurrence and magnitude of episodic gravity transport events determine whether the upper portion of the GPSC is filling up, down-cutting, or is just a conduit for sediment bypass in the course of eustatic sea-level rise.

Liu, Paul

Fates of River-Derived Sediments to the Sea: Longshore v.s. cross-shelf transport at passive and active margins with high or low energy shelf environments

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Collectively, the global rivers annually discharge about 35,000 km³ of fresh waters and $22-22 \times 10^9$ tons of solid and dissolved sediment to the ocean. Among them, approximately 70% has been delivered from Asian large rivers (e.g. Yellow, Yangtze, Pearl, Red, Mekong, and Ganges-Brahmaputra, etc) and numerous small mountainous rivers (e.g. rivers in Taiwan, Indonesia, and Papua New Guinea, etc) into the Western Pacific marginal seas, e.g. Yellow Sea, East China Sea, and South China Sea. Recent-year field studies off the Yellow, Yangtze, Pearl, and Mekong show nearly 50% of these river-derived sediments has been deposited in the lower reach of the river mouth, forming many extensively distributed subaerial delta plain, and rest of them discharges

into the adjacent seas. Among those being discharging into the ocean, nearly half of them (20-30% of the total) has been found to be longshore-transported several hundreds kilometers from the river mouth. This is also true in other large river systems in the passive margins, like Amazon. There is very little or few percent of the total sediment discharge has been found to be across-shelf transported into the deep ocean. Some are transported down through the adjacent canyon systems, such as Indus and Ganges. Some field observations and modeling results indicate that the driving and controlling forces for the strong longshore transport include the strong seasonal coastal current, tide and wave actions, downwelling and upwelling circulations, etc. In contrast, sediment from small rivers has a very different fate. Some major small mountainous rivers in active margins (e.g. Eel, Kaoping, Choshui, Lanyang, Waipaoe, etc), usually do not form large-scale deltas and are mainly controlled by episodic events, contribute more than 50% of global terrigenous sediments to the sea. However, more than 80% of their sediment discharges are transported directly to the shelves or deep canyons mainly via gravity/turbidity or hyperpycnal flows, which are distinctly different from the above large rivers that discharge to passive margins or shallow marginal seas.

<http://www.meas.ncsu.edu/sealevel/publications.html>

Livsey, Daniel N.

Depositional facies of estuarine upper-bay deposits in arid climates; Baffin Bay, Texas

Livsey, Daniel N.¹; Simms PhD, Alex¹

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Estuaries represent significant sediment depo-centers throughout the Earth's history. Owing to high sedimentation rates and preservation potential, estuaries are excellent localities to study coastal response to changes in climate and sea level. 6 jackhammer and 22 vibra-cores were taken from the upper-bay of Baffin Bay along the central Texas coast to study the unique suite of depositional environments found within estuaries in arid climates. Within Baffin Bay the typical bay-head delta is replaced by expansive, low-lying, mud flats covered with abundant algal-mats. Previous studies indicate that the mud flat did not form until after on-set of xeric conditions in southern Texas at 5.5 ka. Cores from the mud flat suggest it prograded 2.0 km, and subsequently retreated 4.5 km to its present location over the last 5,000 years. Despite the large area covered by the mud flat the processes operating on the mud flat are largely unknown. The mud flats contain only one main distributary channel and are seasonally sub-merged owing to wind-tides from increased prevailing southeast winds from March through October. Six facies were identified within the mud flat deposits. Algal mat facies are characterized by laminated 1-2 mm green to black organics interlaminated with blue and white clays. Bioturbated white and blue mottled clay with fine sand burrowing, few erosive lenticular sands, and sparse bivalve fragments are interpreted as pro-mud-flat deposits. Bioturbated shelly sand forms at

the flanks of shell hash spits and internal "barrier" islands composed of > 90% shell fragments. Within distributary channels cores sampled sandy gravels and overlying green mud with abundant plant fragments. These deposits are interpreted as channel and floodplain deposits respectively. Examination of aerial photographs from 1989, 1995, and 2002 show that the mud flat has remained fairly static while shelly spits and internal barrier islands have retrograded landward. These mud flats are a poorly understood sedimentary sink along the pathway between the hinterland and the deep ocean.

Lupker, Maarten

Glacial-interglacial weathering in the Himalayan system, a source to sink approach

Lupker, Maarten¹; France-Lanord, Christian¹; Galy, Valier²

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The role of Himalayan orogeny and more broadly of tectonically active mountain belts as important actor of the global, long term, carbon cycle through silicate weathering, has been proposed for a long time [Ebelmen, 1845; Chamberlin, 1899; Raymo et al., 1988]. Even if more recent studies suggest that for the Himalayan system at least, burial of organic carbon is the main sink of atmospheric CO₂ [France-Lanord and Derry, 1997; Galy et al., 2007], the precise magnitude, location and variability of weathering through time is poorly known. In this work we focus on the Ganga-Brahmaputra river (GB) system. We trace the weathering undergone by sediments during their transfer from the Himalayan catchments to the Bay of Bengal (BoB). Additionally, we compare modern GB sediments to sediment cores from the BoB to explore the variability in weathering intensity since the last glacial maximum (LGM). Building upon an extensive chemical data set of Himalayan source rocks; river suspended sediments as well as BoB sediments we trace silicate weathering using a major element approach. Na and K combined with hydration of bulk sediments [H₂O⁺] are reliable silicate weathering tracers in the Himalaya system. Mineral sorting effects, which are the primary sources of the variability in the sediment chemical composition, occurring during river transport and marine deposition have been taken into account to derive a reliable weathering signal. This work shows that even if some weathering is taking place in the Himalayan domain, with some Na depletion, the floodplain mainly controls weathering with significant Na and K losses combined to increasing hydration of the sediments during transport. The Himalayan domain, with, high erosion rates is responsible for fast transport of the sediments to the flood plain. On the contrary, long residence times and high temperatures in the flood plain, favor elevated weathering intensities. Furthermore, the BoB record reveals that the weathering intensity of the sediments exported by the GB adjusts to abrupt climate changes at the glacial-interglacial cycles timescale. During the LGM, weathering of the GB sediments, as recorded by K and [H₂O⁺] was significantly

lower. The floodplain processes, the only ones capable of driving such a change in sediment chemistry, must therefore have been different during glacial times. Reduced monsoon intensity [Duplessy, 1982], and thus weaker hydrological cycle with lower runoff limited the overall weathering. Additionally, a lower discharge and base level during LGM would limit river avulsion preventing the reworking of mature flood plain sediments. This study highlights the key role played by the floodplain in modern silicate weathering intensity as well as in modulating weathering intensity as a response to climatic changes. The further implication of this work is that modern weathering rates likely don't reflect long-term rates and cannot be extrapolated into the past. Chamberlin 1899, *Journal of Geology* 7, 545-584. Duplessy 1982, *Nature* 295: 494-498. Ebelmen 1845, *Annales des Mines* 7, 3-66. France-Lanord and Derry 1997, 390, 65-67. Galy et al, 2007, *Nature*, 450, 407-411. Raymo et al, 1988, *Geology* 16, 649-653.

Mackey, Benjamin H.

Punctuated Sediment Supply in the Eel River Catchment Caused by Landslide Dams

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The Eel River catchment in northern California has one of the highest rates of sediment yield (~ 2200 t/km²/a) of any large non-glacial river in North America. It is a classic example of a large, transport-limited fluvial system. Processes of terrestrial sediment production and marine deposition have been extensively studied, with the underlying assumption of consistently high rates of sediment production, transport, and deposition. As long recognized (e.g., Kelsey 1980), topographic form and erosion processes in the Eel River catchment are strongly influenced by differences in rock type within the Franciscan Complex. Penetratively sheared, fine-grained argillaceous matrix *mélange* is characterized by long, low-gradient (30-35%) hillslopes, and abundant earthflow activity. More competent sandstone and greenstone blocks within the *mélange* are steeper, resistant to erosion, display systematic ridge-and-valley morphology, and erode by debris flows, debris slides and rockfall processes. We present evidence for a large, long-lived landslide dam along the main stem Eel River which was generated by catastrophic failure of a large greenstone block (est. landslide volume 40×10^6 m³). This landslide dam blocked up the Eel River to a height of ~ 120 m, created a 50 km long lake, and impounded 1.3 km² of water. Evidence for the landslide dammed lake includes a prominent landslide scar, subtle terrace features at a constant elevation, and finely laminated silts preserved in the wall of a tributary valley. Radiocarbon dates on detrital charcoal within the laminated sediments indicate a calendar age of 22.5 ka. The existence of a large, landslide dammed paleolake challenges many assumptions about the Eel River sedimentary system. The lake would have impounded sediment, disrupting the

prodigious flux of sediment down the Eel River. This is potentially recorded by VanLaningham et al. (2008), who suggest the unlikely shutdown of Eel River sedimentation could explain provenance ratios of offshore sediment from 25-22 ka. Eventual failure of the landslide dam would have released a significant amount of sediment and fresh water down the Eel River. Lopes and Mix (2009) note unaccounted for pre-Missoula Flood spikes in fresh water diatoms in cores north of the Eel River mouth. Similarly, Zuffa et al. (2000) document an anomalous organic-rich layer in the Escanaba Trough at approximately the time of the paleolake, suggesting the dam may have failed catastrophically, and generated long-traveled turbidity currents. Over the long term, resistant sandstone blocks emerge from the rapidly eroding *mélange* as localized topographic highs, frequently forming peaks and ridgelines, and potentially force long term-lateral migrations of large rivers into more readily erodible rock. We propose landslide dams may be a recurring process within this terrain. Based on long term erosion rates (~ 0.5 mm/a), and the power law distribution of block size within the *mélange* of a given area (Medley and Lindquist, 1995), we can predict how frequently blocks large enough to fail catastrophically and potentially dam the Eel River will be exposed.

Marsaglia, Kathleen M.

Using Sand Composition as a Tracer to Establish Linkages and Disconnects Between Onshore and Offshore Segments of the Waipaoa Sedimentary System

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2. Landcare Research, Gisborne, New Zealand

The prediction of sandy reservoir facies in subsurface marine successions is a major goal in petroleum exploration. Our aim was to detail the origin and fate of sand in the Waipaoa Sedimentary System (WSS) of North Island, New Zealand, creating a model that could be applied to other systems, including potential Cenozoic hydrocarbon exploration targets in the WSS region. As a MARGINS source-to-sink focus site and the locus of many multidisciplinary studies, the WSS afforded us the geological framework and the collaborative means to sample across the margin, from outcrop to the coast, shelf, slope, and beyond. Through detailed petrographic analyses, we first defined the nature of sandy outcrops in the region, a potential source of recycled sand grains, as well as first-cycle lithic fragments, and then sand produced and stored within the onshore fluvial segment of the WSS. Sand detrital modes provided quantitative compositional fingerprints that would allow us to test linkages among fluvial, coastal, shelf and slope sandy deposits. Today the dominant signal (high mudstone lithic content) in the Waipaoa River appears to be a product of gullying in its headwaters region. Higher quartz, feldspar and sandstone lithic fragments in older stream terrace

deposits indicate less gullying in the Late Pleistocene paleo-river system. On the shelf, we were surprised to find little sand corresponding to the composition of the onshore river and older terrace deposits. However, this finding is consistent with sediment modeling of the fluvial/shoreline transition by others in Poverty Bay, which apparently serves as a trap for sandy sediment. Sand on the shelf appears to have been generated either by erosion of coastal outcrops and the outer shelf high, or transported into the system from the south. Anomalous greywacke gravel also points to extrabasinal input to the shelf. Analyses of slope and base of slope core samples are still underway but these show the potential for fluvial and shelf provenance, as well as significant input of pyroclastic debris.

Martinsen, Ole J.

Perspectives on source to sink: methods, tools and development for subsurface interpretation and energy exploration and exploitation

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Source to sink is a new field in earth sciences that relies on integration between various fields in geology and geophysics into composite models that hinge on input from various data types. A common denominator in the outcome from the various fields and techniques is topography, a critical factor in understanding Earth Systems and for prediction of resulting deposition. Ancient onshore catchments is a derivative of topography, and a major challenge in interpreting and predicting the fill of sedimentary basins is to understand the role of landscapes through time in a source to sink context, and their size and ability to deliver sediments to offshore sedimentary basins. Recently, numerous authors have developed semi-quantitative and quantitative relationships that address this issue, both based on flume studies, numerical and experimental modelling and natural examples on various margins. The segment-style approach is preferred, whereby the source to sink system is divided into four segments (catchment, shelf, slope and basin floor) and the empirical relationships are built using a uniformitarian approach. For confident prediction of basin fill and segments, a key issue in natural systems is the degree to which ancient topography has been preserved because obviously, the higher the preservation, the more confident the assessment of offshore sedimentation. In the perfect case, major parts or all of an antecedent catchment is preserved, but in general, the older the source to sink system, fewer parts of the system are preserved and this is particularly a challenge with the onshore catchments that are either eroded or only partly preserved. In the case where only the offshore stratigraphic record is preserved, modelling of antecedent topography can be performed by an in-house process called Predictive Earth Systems Modelling. This process involves a rigorous and complicated procedure of creating a plate tectonic model,

involves paleo-climate analysis and provides sediment yield calculations that eventually lead to a prediction of both the location of sediment entry points and volumes. An alternative procedure is to perform inversion analysis of the volume and size of deepwater submarine fans using recently established 1st order, semi-quantitative relationship from a series of complete source to sink systems. Using this method, various characteristic features of the catchment can be modelled, such as its area, and thus provide a proxy understanding of the topography of the catchment. Building such empirical relationships is extremely important because many ancient landscapes are poorly preserved and yield highly uncertain interpretations of sediment yield to offshore basins.

McGuire, Luke

Quantifying sediment generation, colluvial transport, and erosion/deposition in a dated, topographically-closed (source-to-sink) landscape: Banco Bonito, New Mexico

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The weathering of rock and the transport of soil from hillslopes to channels is the rate-limiting process in the erosion of landscapes. In this study, we quantify the rates of bedrock weathering/soil production, colluvial transport, and eolian accumulation over geologic time scales using a combination of numerical modeling, analysis of airborne LiDAR data, and field/laboratory measurements. Our field site, Banco Bonito, is a late Pleistocene (35-45 ka) rhyolite flow in the semi-arid Valles Caldera region of northern New Mexico. Within this flow, many topographically-closed basins formed as the rhyolite buckled during emplacement. The landscape has evolved from an initial state of no soil cover to its modern state, characterized by soils ranging from 0 to 6+ m depending on topographic position, via a combination of bedrock weathering/soil production, colluvial transport, and eolian accumulation. The combination of topographic closure and a dated landscape provides an unusually well-constrained system for the study of landscape evolution. Specifically, we show that it is possible to reconstruct, via numerical modeling, rates of bedrock weathering/soil production and rates of colluvial transport across the landscape and through time using only the age of the landscape, the modern topography, and measurements of modern soil thickness and mineralogy at multiple landscape positions. Our analysis yields estimates for three key geomorphic parameters in this landscape: P₀, the rate of bare-bedrock recession by weathering, D, the rate of topographic diffusivity where soil exists, and A, the rate of eolian accumulation. Eolian accumulation rates are quantified via elemental analysis of the bedrock and soil. We show how these parameters can be optimally constrained using LiDAR data (which provide information of modern topography and presence/absence of soil cover), field

measurements (soil thickness and mineralogical composition), and numerical modeling. Our study adds to the database of estimates for P, D, and A in the western U.S. and shows how dated, topographically-closed landscapes can provide a wealth of information on the coevolution of soils and landscapes.

McKee, Brent

Variable Geochemical Supply to the Ocean

McKee, Brent¹

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Sediments undergo many geochemical changes within river systems before they reach the ocean. These changes can strongly influence the partitioning (dissolved, colloidal, particulate), the reactivity and the bioavailability of materials such as carbon, macronutrients and micronutrients that enter the ocean. Particulate material transformations can occur in transit within the channel but most take place during storage in depositional centers such as banks, floodplains, point bars, and bed sediments. The environmental conditions that sediments experience, and the residence time of particulates, within these depositional reservoirs are the controlling factors for particle transformations prior to discharge to the ocean. Examples of transformations that occur between watershed source and oceanic sink will be discussed for a spectrum of rivers ranging from large to small. Possible future changes in these transformations (and the changing nature of materials that enter the ocean) will also be discussed for selected global change scenarios.

marine.unc.edu/people/Faculty/mckee

Middelkoop, Hans

The Rhine Delta: A Record Of Sediment Trapping Over Various Time Scales

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The Holocene Rhine delta in the Netherlands has functioned for about 8000 years as a sink for fine sediment delivered from the Rhine basin. Over the past decennia, numerous studies have been conducted on the palaeogeographic development of the Rhine delta, quantification of sediment storage, floodplain development and overbank deposition on the Rhine floodplains. Integration of these results provides us insight in the amounts and changes of overbank fines trapped in the Rhine delta and their controls at different time scales. Furthermore, using sedimentation models we have explored the potential changes in future sediment trapping in response to climate change and floodplain restoration interventions planned for the future. Sediment trapping throughout the Holocene was quantified using our extremely detailed database of the Holocene delta architecture. Additional historic data allowed reconstructing

the development of the river's floodplain during the period of direct human modification of the river. With OSL dating and using heavy metals as tracers, overbank deposition rates over the past century were determined. Measurements of overbank deposition and channel bed sediment transport in recent years, together with modelling studies of sediment transport and deposition have provided detailed insight in the present-day sediment deposition on the floodplains, as well as their controls. The results demonstrate that human impact on the amounts of trapped sediments has been large. Land use changes since the early Bronze age increased sediment delivery and deposition between 3000 and 1000 BP. Embankment of the river channels between 1000 and 1350 AD, however, dramatically decreased the accommodation space for sedimentation, while since the fixation of the river channels around 1850 AD the modern floodplain has become a very inefficient sediment trap. Yet, future climate change and floodplain restoration interventions might re-activate the trapping function of the lower Rhine floodplains.

Milliman, John D.

Episodic Events and Resulting Sediment Discharge from Small Mountainous Rivers

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One reason for high sediment yields in small mountainous rivers is their susceptibility to periodic flooding. In arid watersheds, a particularly intense flood is all that is required for exceptional discharge because sediment is readily available throughout the landscape. Two intense rain storms in January and February 1969 on the Santa Clara River resulted in the discharge of ~ 40 Mt of sediment, much of it at concentrations >150 g/l; together these two 3-day storms accounted for more than 25% of the river's total sediment delivered over the last half of the 20th century. Typhoon-generated floods in Taiwan are even more effective transporting agents. Typhoon Herb (1996), for instance resulted in a 12-hour discharge from the Choshui River that approached 90 Mt, more than twice the river's average annual sediment load. If a watershed is preconditioned for increased sediment supply by earthquake-generated debris slides or dry ravel and vegetation-clearing from wildfires, flood-generated discharge events can be greatly exacerbated. Following the Chichi earthquake in 1999, the Choshui River yield increased ~ 5-fold, resulting in sediment discharges as great as 200 Mt/event, primarily delivered at sediment concentrations >200 g/l. Time-series measurements from five stations along the middle reaches of the river during Typhoon Mindule (July 2004) indicate that much of the suspended and dissolved-solid discharge, including particulate carbon (mostly soil-derived) and nutrients, was generated from a

relatively small section of the watershed in which Chichi-generated landslides were most prominent. Similarly, the 1977 Marble Cone wildfire in the chaparral-dominated semi-arid watershed of the Arroyo Seco in coastal California resulted in sediment concentrations and fluxes ~35-fold greater than average (~11,000 t/km²/yr). Although this type of fire-flood event has a recurrence interval of ~100 years, over the long-term such events can result in a doubling of watershed sediment yield.

Mohrig, David

Connecting the Flow and Sediment-Transport in Coastal Rivers to Short- and Long-Term Patterns of Delta Sedimentation

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2. Earth and Environmental Sciences, Tulane University, New Orleans, LA, USA

This presentation will focus on spatial change in the transport properties of coastal rivers and how these changes influence the short-term and long-term evolution of delta morphology and deposits. Examples will be primarily drawn from rivers connected to the Gulf of Mexico, with particular emphasis on the Mississippi River and its delta. Downstream change in properties of both the flow and sediment-transport fields will be considered and these changes will be connected to the hydraulic transition from approximately normal flow associated with rivers in continental interiors to backwater flow that characterizes the coastal zone and deltas. This hand-off from normal to backwater flow strongly affects the character of flooding between the two positions. For example, a 30,000 cubic meters per second flood on the Mississippi River between river kilometers 580 and 890 is associated with a flow depth that is roughly twice as deep as that at low water discharge. The same flood discharge between river kilometers 0 and 140 is associated with a flow depth that is no more than ten percent greater than the depth at low discharge. Changes in the properties and style of overbank sedimentation connected to this substantial difference in floodplain inundation will be presented. Progressive downstream fining of bed sediment in rivers can impact the evolution of bed, bar and bank topography in coastal rivers by increasing the fraction of bed material moving as suspended sediment during floods. The median diameter of bed material at river kilometer 40 of the Mississippi River is upper fine sand and the largest grains are upper medium sand in size. All of these particle sizes were captured in both bed and suspended-sediment samples during the spring flood of 2008, indicating that all sands were moving as part of suspended and bed-material load. Measurements show values for suspended-sediment discharge of bed-size sand that are equal to the bed-material discharge. This significant suspended-sand transport, together with the minimal increases in water depth associated with flooding will be used to evaluate observed

changes in properties of deltaic river channels including bar size and shape, smaller width-to-depth ratios, and lower rates of lateral migration. Mapping the long-term sedimentation patterns on Mississippi River delta using a large, industry-grade 3-D volume of seismic data reveals delta construction via an arrangement of depositional lobes that is statistically indistinguishable from sedimentation patterns observed in other depositional environments. This lack of a unique depositional pattern at the million-year time interval suggests that construction of continental margins over long time scales is not particularly sensitive to the details of sediment transport in specific environments.

Moriarty, Julia M.

Wave- and Current- Induced Bed Stress on the Waipaoa Shelf, New Zealand: Variations in Time and Space

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Energetic waves and currents increase bed stress and therefore influence suspended sediment concentrations. Variations in the magnitude, direction, and sources of bed stress therefore influence sediment erosion and deposition patterns on continental shelves, such as the Waipaoa River shelf, New Zealand. This small mountainous river transports 15 million tons of sediment and associated nutrients per year to marine environments. Two modes of delivery carry this material from the nearshore (Poverty Bay) to the adjacent continental shelf. While some fluvial material remains suspended and is rapidly exported from Poverty Bay, other river sediment is deposited in Poverty Bay during high discharge events. Evidence indicates, however, that Poverty Bay does not act as a sediment sink within the modern day Waipaoa Sedimentary System (WSS). Material deposited during times of high discharge will be subsequently resuspended by waves, and ocean currents will then transport it to the continental shelf where it may become incorporated into long-term depocenters. Recent field observations show long-term sediment accumulation in two large shelf depocenters that parallel the coast. These are located landward of the Lachlan (southern) and Ariel (northern) anticlines, and are separated by Poverty Gap. The importance of the timing between wave energy and river discharge and the complex bathymetry and coastline indicate that both temporal and spatial variations in bed stress play a large role in sediment dynamics. Thus, this study analyzed variations in the magnitude and source of bed stress on the Waipaoa shelf. A three-dimensional hydrodynamic model (ROMS) was coupled to a wave model (SWAN) to capture temporal and spatial variations caused by both currents and waves. The study period included a large flood, periods of high waves, and low-energy interludes. Future efforts include continued development of the numerical model and comparison between model calculations and forthcoming water column and seabed observations from the continental shelf. Preliminary results

indicate that bed stresses increased in magnitude during times of high discharge and swell compared to low-energy periods. Wave-induced bed stresses during average, flood and swell conditions and current-induced bed stresses during floods were sufficiently high to resuspend sediment across the inner and mid shelf. However, sheltering from Mahia Peninsula lowered bed stresses over the coastal side of the southern depocenter. Wave-induced bed stresses decreased with depth, and were thus lower over the depocenters than Poverty Gap. High bed stresses over Poverty Gap may prevent significant long-term deposition.

Nittrouer, Jeffrey A.

Predicting the time and space properties of bed-material transport in the normal-flow to backwater transition of the lowermost Mississippi River

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This study examines the importance of gradually varied flow conditions on sediment transport and channel morphology in a major lowland river approaching its outlet. Field measurements from 40 km upstream of the Mississippi River outlet are coupled with semi-empirical, physically based models to estimate bed-material sediment transport and associated transport stress. The results show that from low- to high-water discharge, bed material flux increases 100× and skin-friction shear stress increases 10×. We show that this significant temporal adjustment arises due to a backwater hydrodynamic condition that occurs in the lower 600 km of the Mississippi River. In order to predict how the transition from normal flow to backwater flow affects the time and space properties of sediment flux, we developed a simple model that estimates water-flow velocity and bed-material transport over the lower 800 km of the Mississippi River. Channel transect measurements (n=2650) are used to determine the cross-sectional area of water flow for eight water-discharge increments from low- to high-water discharge. The local flow velocity is determined at each transect by dividing water discharge by the cross-sectional flow area under conditions where water discharge is conserved. Local flow velocity is converted to total boundary shear stress using an appropriate dimensionless drag coefficient that is determined using a one-dimensional backwater model. Estimates for skin-friction shear stress are produced from these values for total boundary shear stress based on field data that constrain the proportion of stress associated with form drag. Skin-friction shear stress values are then used to calculate bed-material transport. Our results demonstrate that during low- and moderate-water discharge, cross-sectional flow area increases downstream through the backwater segment of the Mississippi River, resulting in a downstream decrease in water-flow velocity and bed-material transport. During high-water discharge the

trend is reversed and cross-sectional flow area decreases downstream, resulting in an increase in water velocity and bed-material transport. To our knowledge, this is the first documented example of a downstream reversal in cross-sectional flow area associated with changing water discharge in a large lowland river. By conserving sediment mass over an average annual hydrograph we show that the spatial trends in bed-material flux promote a tendency for channel-bed aggradation in the upper reaches of the backwater segment (150-600 kilometers above the outlet) and a region of channel-bed erosion in the final 150 kilometers of the Mississippi River. The implications of these results for channel morphology, such as channel-bed sediment composition, and kinematics, such as reduced lateral mobility in the backwater reach, will be explored in detail.

Notebaert, Bastiaan

Late-Holocene hillslope and fluvial sediment dynamics: a field and modeling approach

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The human impact on sediment fluxes is evidenced by numerous integrated field studies, while the impact of the limited Holocene climate variations in temperate zones remains often unclear. Most of these studies, however, remain qualitative. Detailed field-based approaches have recently been made for several areas that now provide quantitative data. These include time-differentiated catchment sediment budgets, catchment-wide analysis of historic sedimentation rates and cumulative density functions of colluvial and alluvial activity. However, the poor temporal resolution of the sedimentary record makes it in most cases impossible to decipher e.g. the impact of short-lasting climatic events. Spatial modelling techniques could provide a means for estimating the impact of past (and future) environmental change on hillslope and fluvial sediment dynamics. Here, we present results from a combined field based and modeling study on the Belgian Dijle catchment (760 km²). The field study combines a quantification of sources and sinks on a Holocene timescale with a detailed dating of sediment sinks on a site specific and catchment scale, including statistical analysis of obtained ages. This sediment budget is differentiated for three time periods: 9000 BCE-2000 BCE, 2000BCE-1000 CE, and 1000 CE-present. In addition, the geomorphic WATEM/SEDEM model was applied on the catchment. This model was combined with a climate reconstruction model and a spatially distributed land use model driven by historical and archaeological data. The model was applied for several scenarios representing a certain time period, and a sensitivity analysis was conducted in order to determine the individual contribution of involved parameters – notably land use, soil properties and climate. The results of the field study clearly indicate the overwhelming influence of land use changes on sediment dynamics and the different reaction of the different sinks. Model results match the

history of sediment dynamics as evidenced by the sediment budget very well. Moreover, the model approach made it possible to estimate the relative importance of human and climatic impact on the Holocene sediment dynamics. Compared to the mid-Holocene time period, human induced land use change increased sediment fluxes by 6000%, whilst climate change modified sediment flux by only 9%. Furthermore, with the model it is possible to simulate the importance of settlement density and patterns on slope-channel coupling as illustrated by changing sediment delivery ratios. The combination of the modelling and field approach allows to recognize the important influence of land use on both soil erosion and sediment redistribution, including the changing connectivity of the different parts of the sediment pathway.

Nowacki, Daniel J.

Multiple scales of controls on sediment transport in intertidal flats: tidal stage, storms, and seasons

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Intertidal areas represent an important gateway in the delivery of sediment from land sources to their ultimate marine sites of deposition. Tidal flats, which generally occur in meso- and macrotidal environments, can experience large amounts of sediment flux over a tidal cycle but are thought to have a balanced sediment budget. However, little has been done to understand the mechanisms of sediment transport between channels and flats that span multiple morphological and temporal scales. The muddy flats of southeastern Willapa Bay, Washington, are tidally dominated and receive relatively little direct freshwater influence. We use data from instrumented tripods in representative channel and flat pairs of different orders to a) better understand sediment dynamics in each morphological setting, b) investigate whether sediment fluxes are balanced between channels and flats, and c) determine the importance of channel order on these sediment dynamics. Data from intensive field efforts as well as longer-term deployments help to inform how the hydrodynamic regimes of each environment serve to export or retain sediment and to further characterize the total sediment budget of intertidal flats. Results from several week-to-month-long deployments during 2009 and 2010 show channels of all orders in southeastern Willapa Bay are flood dominated in terms of unit-width discharge. This phenomenon is driven by longer durations of and sustained higher velocities during flooding tides, and suggests that larger circulation patterns are active within the tidal flat complex. The deployment periods were characterized by a range of meteorological conditions, including rain and several wind events. The wind events were correlated with increased flood dominance of water and sediment transport. Near-bed observations of velocity and suspended-sediment concentration (SSC) give insight to processes active over the flat when during the brief period when water levels are shallow (< 30 cm) over the flat. These processes are important in determining the net flux of water

and sediment of the system. High-resolution water-column velocity and backscatter profiles reveal complex sediment-flux dynamics between channel and flat environments. Pulses of velocity and SSC were observed in the channel during flooding and ebbing tides when water levels were near the flat elevation, a phenomenon often observed in tidal flats and salt marshes. Instrumentation deployed near the bed on the flat measured elevated flow velocities and SSC when flat water depth dropped below 20-30 cm. This “skimming” of sediment on the flat contributed to the SSC pulse in the channel during ebbing tides. Water convergence into the channel from the flat led to increased channel bottom stresses and resuspension of freshly deposited sediment temporarily stored within the channel. These fine-scale observations allow us to address the mechanisms that govern the total sediment balance of channels and flats within tidal flat systems.

O’Connor, Alison

Distribution and Composition of Organic Matter in Surface Sediments from the North American Arctic Margin: An Initial Assessment of the Arctic Shelf Sink

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Despite their importance and sensitivity to climate change, source-to-sink processes in Arctic margins (i.e., discharges by glacial and fluvial sources, coastal erosion, ice-rafted and aeolian transport, and autochthonous production) are poorly understood. To better understand the sediment sink in the North American Arctic, we analyzed sediment cores collected from all of its major regions. ²¹⁰Pb inventories were used to constrain accumulation rates and sediments were analyzed for a variety of geochemical parameters, which reveal major compositional differences. For example, while organic carbon contents are relatively uniform in all regions, inorganic carbon contents are extremely elevated in the Canadian Archipelago sites. The elevated carbonate contents in these latter sediments likely reflect inputs from glacial erosion of limestone rocks in the adjacent terrain. The distribution of terrigenous biomarkers, such as lignin-derived phenols, illustrates additional differences in the inputs of land-derived materials. For example, the highest lignin yields are found in the west Alaskan shelf portion of the Beaufort Sea along Barrow Canyon, not in the Mackenzie Shelf, whereas Baffin Bay and Archipelago sediments are starved of these terrigenous markers. Additional biomarker compositions indicate organic materials in the Mackenzie Shelf have different provenance than those of the western Beaufort, Chukchi and Bering seas, whereas terrigenous sources are far less

important within the archipelago or Baffin Bay. Our hypothesis is that coastal erosion in these latter regions versus export from the Mackenzie River in the eastern Beaufort provide a strong, characteristic terrigenous imprints at the shelf margin. As climate change diminishes the extent of pack ice, it seems likely that coastal erosion will play a larger role everywhere.

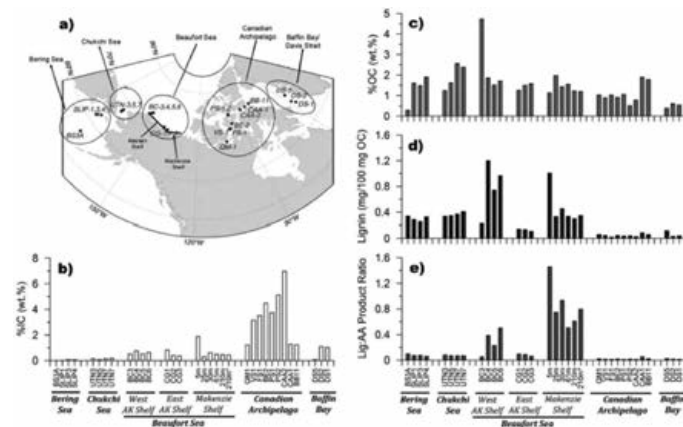


Figure 1. a) Map of the North American Arctic margin showing the locations of the analyzed cores. Several compositional parameters from surface sediments are also shown: b) inorganic carbon content (%IC), c) organic carbon content (%OC), d) carbon-normalized yields of lignin derived phenol products (Lignin), and e) the ratio of lignin- to amino acid-derived CuO products (Lig:AA).

Ogston, Andrea S.

Contrasts in sediment delivery and dispersal from river mouth to modern accumulation zones in high sediment load systems: Fly River, Papua New Guinea and Waipaoa River, New Zealand

Ogston, Andrea S.¹

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As part of the NSF Source-to-Sink program, the relationships between sediment-transport processes, short-term sedimentary deposition, subsequent burial and long-term accumulation are being investigated. The present study focuses on processes involved in formation and evolution of the clinoform in the Gulf of Papua, Papua New Guinea in which much of the riverine sediment accumulates and comparison to those processes active off the Waipaoa River, New Zealand that form mid-shelf deposits and exports sediment to the slope. In tidally dominated deltas, sediment discharged from the river sources must transit through an estuarine region located within the distributary channels, where particle pathways can undergo significant transformations. Water-column profiles and time-series data were collected in the distributaries and shallow nearshore region offshore of the Fly River, Papua New Guinea, during monsoon conditions of 2003 and 2004. Within the distributaries of this tidally dominated delta, near-bed fluid-mud concentrations were observed at the estuarine turbidity maximum and sediment delivery to the nearshore was controlled by the morphology of the distributary. El Niño creates a large negative perturbation (i.e., low flow) to the relatively constant sediment discharge. This reduction of

discharge limits transport of sediment from the distributaries to the nearshore zone of temporary storage. As the sediment stored nearshore feeds the prograding clinoform found seaward, the perturbation propagates throughout the dispersal system. In wave-dominated regions, transport mechanisms actively move sediment away from the river source and separate the site of deposition and accumulation from the river mouth. Fluvial and storm-wave events each create discrete deposits on the Waipaoa River shelf, New Zealand and data is presently being collected to determine their form, distribution, and relationship to factors such as flood magnitude or wave energy. In this case, the combined fluvial and marine processes can initiate and maintain gravity-driven density flows, and transport pathways appear to be influenced by structurally controlled shelf bathymetry. These studies provide a basis for understanding the interactions between physical processes responsible for the transport of sediment from river mouths to the sites of ultimate deposition. The results are synthesized with those from multiple environments to link sediment delivery and dispersal mechanisms with the formation and preservation of sediment deposits.

Olariu, Cornel

SOURCE TO SINK TO SINK: ANALYSIS OF SEDIMENT ROUTING FROM CARPATHIANS TO DACIAN BASIN TO BLACK SEA BASIN FROM MIOCENE TO PRESENT

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This study discusses the timing and magnitude of sediment volumes delivered from the Carpathian Mountains to the Black Sea Basin via Dacian Basin. At present the Danube drains a large area from the Alps to the Carpathians Mountains, and is the main source of sediments to the western Black Sea with an approximate load of 25 Mt/ year. During the late Miocene, however, the Pannonian and Dacian basins served as active marine or lacustrine sinks along the present course of the Danube River. The Dacian Basin thus trapped most of the sediments derived from the Carpathians, at least, prior to 5 Ma. The Pannonian and Dacian basins were simultaneously active during this period but their transitions from marine/lacustrine to fluvial fill was accelerated by successive occupation by the pre-Danube river system (first the Pannonian followed by the Dacian). The Dacian Basin received sediments from a river located in the west of the basin that probably was connected with the Pannonian Basin as well as from local rivers draining the Carpathians which would have been similar in size to

modern tributaries of the Danube in Romania. The western river system has been interpreted by some studies to be the proto-Danube River. The well-documented Messinian salinity crisis of the Mediterranean Basin was also recorded as a significant base level fall in both the Black Sea and the Dacian basins as evidenced by extensive unconformities. Sediment flux to the Black Sea immediately following the Messinian crisis increased by an order of magnitude which led to significant (> 100 km) progradation of the shelf margin in less than 1 My. Several possible explanations for the high post-Messinian sediment input include: 1) high erosion rates caused by large-scale landscape readjustment to Messinian base-level fall, 2) increase in proto-Danube (rivers draining Carpathians and discharging to the Black Sea) drainage area, and/or 3) joining of the proto-Danube with the southward flowing Dniepr and Dniestr rivers.

Orpin, Alan R.

THE CONTINENTAL SLOPE AS A PATHWAY AND SINK FOR TERRIGENOUS SEDIMENT: SOURCE-TO-SINK STUDIES OF CONTRASTING SYSTEMS SINCE THE LAST GLACIAL

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Continental margins adjacent to high-discharge rivers show a spectrum of off-shelf sedimentation processes, ranging from where essentially all material (incl. surface plume) nourishes the slope and deep ocean directly (e.g. Sepik River), to where, despite massive loads (Amazon, Huanghe), the slope receives little sediment. At steep, active margins rivers typically discharge directly to the ocean, driving variations in the sediment flux over short timescales. Here, terrigenous sediment sources and ocean sinks are closely linked, and rapid inter-basin transport of erosion products is amplified by flood severity, short-river courses, and shelf morphology. Adjacent shelf basins preferentially sequester the riverine input, their trapping efficiency limited by the combined balance of sediment supply, shelf hydraulics and accommodation space (Waipaoa, Gulf of Papua), oceanographic forcing (Eel, Santa Clara), and canyon-shelf geomorphology (Gulf of Lyons). The slope seaward of high-yield catchments with medium-narrow width shelves receive sediment flux indirectly from oceanographic cross-shelf nepheloid transport, intraslope sources including deposits remobilised by earthquakes and other triggers, and biogenic sediment. The transfer of sediment occurs at monthly to seasonal timescales, preferentially accumulating in the heads or mid-slope reaches of shelf-indenting canyons and in upper slope gullies at rates of cm/y, demonstrating the fidelity between

terrestrial sources and marine sinks. Over millennial timescales sediment reaching lower-slope basins by mass wasting and hemipelagic settling can be retained in a developing frontal wedge. However, the absence of a fan may not reflect the efficiency of tectonic erosion, but rather sediment baffling by the imbricate thrust ridge and basin topography and accumulation in canyon heads (Poverty margin). In contrast, where canyons incise across extremely narrow shelves, the shelf is bypassed, riverine supply feeds the mid-slope and slope fan directly by gravity-driven flows (Sepik, Markham). Such systems traditionally offer insights into lowstand system behaviour, where canyon-focussed transport is geomorphically favoured. However, an evaluation of the global potential for modern off-shelf transport suggests a disproportionately high component of very muddy rivers at convergent margins have shelves <50 km wide, inferring that direct, gravity-driven supply to the deep ocean is large even during high stands of sea level. The role of tectono-morphologic character and climate forcing in controlling sedimentation at deep sea sediment sinks has been argued, the fan area being a correlative to the depositional rate and the slope length. Moreover, slope and fan sedimentation can continue throughout the complete glacial-eustatic cycle. Evidence from the Waipaoa margin shows that human-induced landscape change is the largest perturbation in the last 2.4 ky, fundamentally shifting the dynamics of the sedimentary system at sub-century timescales, hyper-sensitising the source, to impact even the mid-slope sink.

Overeem, Irina

FJORD SEDIMENT PLUMES AS INDICATORS OF WEST GREENLAND ICE SHEET FRESHWATER FLUX

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Meltwater runoff from the Greenland Ice Sheet (GrIS) exceeds 300 km³/yr and is the primary driver of river dynamics for the ~293 potential outlets around the periphery of the ice sheet (1). Runoff is concentrated between May and August and constitutes a large sediment-rich, freshwater pulse to the fjords and the global ocean with significant implications for ocean circulation and sediment budgets. Discharge observations in Greenland are rare, only 4 river systems of the ~293 mapped drainage systems are actively monitored. We hypothesize that river sediment plume characteristics can be used to assess the timing and volume of freshwater drained to the ocean. Plumes are visible in satellite imagery from the MODerate-resolution Imaging Spectroradiometer (MODIS, Band 1, 620-670 nm, 250-m resolution) and thus plume development can be mapped on a daily to weekly basis along the entire Greenlandic margin. We tested our hypothesis for Kangerlussuaq Fjord, W Greenland (67°N, 50°W) (2), where

measurements of meteorology and ablation on the ice sheet (AWS station S5), and discharge of Watson River (3) were correlated with plume characteristics derived from MODIS imagery for 2001 - 2008. Plume onset and cessation are a sufficient proxy for the onset and duration of freshwater runoff from a localized drainage basin of the GrIS. Ablation season at the Kangerlussuaq Transect automatic weather station S5 (490 m asl, 6 km from the ice margin) is positively correlated with the sediment plume formation and cessation ($r^2=0.88$, $r^2=0.93$, 2003–2008). We found that the onset and cessation are comparable for the nearby Nassuttooq and Sisimiut fjords, together providing the timing of the meltwater drainage season for a considerable portion of the GrIS. Plume extent, defined by a 3-5% reflectance value, is correlated ($r^2=0.52$, $n=35$, $p<0.05$) with the 4-day mean Watson River discharge for the 2007 and 2008 melt seasons. This relationship is applied to plume length variability derived from the MODIS imagery to reconstruct annual Watson River discharge from 2001–2008. Reconstructed values using plume length overestimate measured cumulative discharge values for 2007 and 2008 by 15% and 29%, respectively. We validate the MODIS plume reflectance data against snapshots of collected Suspended Sediment Concentration samples and >80 15 m deep casts of Conductivity-Temperature and Depth plume data (June 2008, August 2008 and June 2010) to test the appropriateness of a simple 2D plume model to predict river discharge. Ultimately, we aim at coupling a glaciological model to an inverted plume model within the CSDMS framework to predict river-driven freshwater and sediment fluxes along the West-Greenland margin to the global ocean.

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Palamenghi, Luisa

Anthropogenic stress and natural processes change the sediment partition in the Ganges-Brahmaputra Prodelta as Sink for the Himalaya Denudation

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3. MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany

The Himalaya and Tibetan Massive are the source for all East and South-East Asian megadeltas and their alluvial and deltaic plains support the live hood of millions of people. As not subjected to major trapping in large water reservoir, the Ganges and Brahmaputra Rivers could be utilized to

decipher the anthropogenic impact on natural processes in apparent equilibrium. Of the huge amount of suspended sediment load (1×10^9 t/yr), 2/3 sink into the Bengal Bay equally distributed in the prodelta and in the greatest submarine fan on Earth. The Bengal Basin and Fan are connected by a deeply incised shelf canyon from where turbidity currents are initiated. The prodelta started to sink sediment at ca. 7 ky in coincidence with the deceleration of the sea level rise of Termination 1 and with a general weakening of monsoon precipitations. The prodelta base level was a primary factor controlling the initial growth resulting in the uneven distribution of the first, mostly aggrading deposits. Since the convergence and confluence of Ganges with Brahmaputra within the last 300 yrs the combined river flux has deposited a homogeneously distributed sigmoid clinoform pointing to the sediment input as the main factor controlling the prograding system. However this time frame coincides also with the progressive intensification of the anthropogenic impact on the deltaic area. In order to verify the state-of-art and the proportion of sediment stored on the shelf compartment or exported to the deep sea, direct comparison and quantification of high-resolution seismo-acoustic data collected during several campaigns on board the RV Sonne in 1993, 1998 and 2006 have been reviewed. It resulted that only the 13.8% of the delivered sediments instead of the expected 20% has been deposited in the actively prograding foreset beds during the last 12 years. The dispersal system is driven by tides and shelf currents induced by the SW monsoon wind during flood peaks and by cyclones activity. Intensification of cyclone strength reported for the last 35 yrs will favor the fraction of sediment delivered offshore and, as the canyon head intercept the 10 m bathymetric line, the canyon will accommodate more sediment than the deeper prodelta slope. The massive deforestation, extensive river embankments, accelerated subsidence due to offshore gas exploitation, together with natural subsidence and expected sea level rise, will all favor the seaward export. However as the deposition in the prodelta decreases, it could be argued that the canyon is replacing the prodelta as major sink on the Bengal Shelf. This study is addressing in general the significant impact of anthropogenic stress on sediment dispersal in source-to-sink systems.

Palanques, Albert

CANYON AND OPEN SLOPE AS SOURCES OF SUSPENDED SEDIMENT TRANSPORT IN THE MARGIN AND BASIN OF THE WESTERN GULF OF LIONS

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Dense shelf water cascading in the north-western Mediterranean has been identified as a major transport mechanism able to generate high sediment fluxes in submarine canyons and in the basin during the colder and drier years. However, observations of the spreading of dense shelf water cascading across and along the entire continental slope are scarce and its effects on sediment transport towards the continental rise and basin are largely unknown. A network of mooring lines deployed between 300 m and 1900 m depth along Lacaze-Duthiers and Cap de Creus canyons and the southern open slope allowed to study the water and sediment transport in the deep margin of the Western Gulf of Lions during the 2006 intense cascading period. Recorded data indicate that the dense water and sediment transport was not only through submarine canyons, but also along the southern open slope. During the deeper cascading pulses, the main sediment source to the deep margin was not the shelf but the slope itself. During these deep pulses suspended sediment transport began first at mid slope depths, whereas suspended sediment concentration at the canyon head increased later in some cases and did not increase in others. This indicates a redistribution of sediments previously deposited at mid-canyon depths or even the erosion of ancient sediments. Deeper than 1000 m, net fluxes show that most of the suspended sediment left the canyon and flowed along the southern open slope towards the Catalan margin, whereas a small part flowed downcanyon and was exported basinward through the canyon mouth. Additionally, on the mid and deep slope there was an increase of the deep near-bottom currents induced by open-sea convection processes. This combined with the arrival of deep cascading pulses, also generated moderate but continuous suspended sediment transport at the deeper slope regions. Open sea convection water was spread by deep eddies. The combination of sediment transported by cascading and these eddies could be related with the formation of sediment waves around the deep open slope southward from the Cap de Creus canyon mouth.

Paola, Chris

Experimental studies of linked depositional systems

Paola, Chris¹

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Laboratory experiments using “basins in a box” complement field studies by allowing access to a subset of linked morphodynamic processes running at, in effect, greatly increased speed due to the small size of the systems and the fact that the main forcings are never turned off. Here we review results from about ten years of research, mostly using the Experimental EarthScape (XES or “Jurassic Tank”) subsiding-floor basin at the University of Minnesota. Findings of particular relevance to source-to-sink include: (1) experimental demonstration of how tectonic and channel time scales combine to influence sediment routing across tectonically active depositional systems; (2) evidence for self-organized sediment storage and release within the fluvial system that mediates shoreline response to base-level cycles and can destroy high-frequency input signals; and (3) strong coupling between offshore and fluvial systems via natural “chokepoints” that limit sediment flux and control the dynamics of the upstream fluvial system. Many of these ideas can be unified under the general theme of sediment mass balance as a control on grain size, channel properties, and other major sedimentary attributes. Mass balance and sediment budgets have served as a unifying concept for source-to-sink field studies as well. Initial results suggest that sediment mass extraction can serve as a powerful tool for comparison of systems of differing scale and geometry, and for making first-order predictions of down-transport facies changes in depositional systems.

Parker, Gary

Turbidity Currents and Submarine Debris Flows: Mechanisms for the Dispersal of Sediment from the Nearshore Zone to Deep Water

Parker, Gary^{1,2}

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Terrigenous sediment delivered to the nearshore zone by e.g. rivers or coastal cliff erosion does not necessarily stay there. Several mechanisms are available to move this sediment from the nearshore environment to deeper water. Three of these are hemipelagic sedimentation, turbidity currents and submarine debris flows. Here the focus is on the last two. Both turbidity currents and submarine debris flows are examples of sediment gravity flows. That is, they are driven by gravity acting solely on the sediment phase of a water-sediment mixture. The two are distinguished most simply in terms of concentration of suspended sediment: turbidity currents are relatively dilute, whereas debris flows tend to have volume sediment concentrations that are of the same order as that of water. The distinction between the two

is not always sharp. Repeated submarine debris flows in the same vicinity tend to create deposits that show compensational stacking, but are otherwise relatively disorganized. Turbidity currents, on the other hand, can excavate canyons, fill basins, construct levee-bounded meandering channels, and sculpt large-scale submarine fans with intricate structure associated with thousands of events. The underlying cause of these flows is sediment accumulation in either the nearshore zone (e.g. delta) or along the shelf-slope break. Turbidity currents can be triggered by such mechanisms as seismic events, nearshore sediment suspension due to storms, the slow sediment failure known as breaching and hyperpycnal flows. In addition, turbidity currents can devolve from submarine debris flows, which in turn can be generated by submarine landslides associated with sediment accumulation along continental margins. Here the role played by submarine gravity flows in delivering sediment to deeper waters is explored at a wide range of scales, from that of individual events to that associated with margin architecture. Several unanswered questions are posed for discussion by the larger group of conference attendees.

<http://vtchl.uiuc.edu/people/parkerg/>

Petter, Andrew

Estimation of the paleo-flux of terrestrial-derived solids and its implications for the growth of continents and long-term biogeochemical cycles

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Growth of continents is achieved by accretion of sediment on shelf margins. The rates and patterns of continental growth are therefore partially dependent on the magnitude and distribution of mass transfer from eroding hinterlands to continental margins, fluxes which also play a critical role in global biogeochemical cycles. A simple inversion scheme for estimating sediment flux from ancient shelf-margin successions is presented here by treating shelf-margin clinothems as the product of deposition associated with migration of a shelf-edge clinoform with constant shape at a rate equal to the shelf-margin progradation rate. Assuming sediment conservation, deposition can be broken into components of 1) response to subsidence and sea-level changes, and 2) basinward migration of the clinoform profile. Paleo-sediment flux can therefore be estimated with knowledge of progradation rate, subsidence/sea-level change rate, and clinoform dimensions. An advantage of this methodology is that it requires only two-dimensional data (i.e. dip-oriented cross-sections) rather than three-dimensional volumes, making it ideal for use with sparse datasets as well as with outcrops. This methodology is also useful for analyzing aerially limited datasets because it can

predict the flux of sediment transported beyond the area of data coverage. The approach is able to accurately reproduce the sediment-flux estimates of previous workers from several margins (the Fox Hills-Lewis, Zambezi, New Jersey, and North Slope margins) using both volumetric and forward-modeling methods. Not only are our predicted distributions for sediment flux across ancient shelf-margins similar to distributions predicted by more data intensive theoretical models, the estimated magnitudes for paleo-fluxes on margin topsets favorably compare with measured loads from modern rivers, even out to the shelf edge. This observation indicates that repetitive delivery of sediment to margins by shelf-edge deltas is fundamental to the long-term process of continental accretion. Flux estimates cast into a mass-balance framework show that approximately two-thirds of continental sediment is exported past the shelf edge into deeper water at long-term geologic timescales while one-third is stored in fluvial, deltaic, and shelfal deposits. We propose that this is the natural long-term sediment partitioning of progradational continental margins, at least within the Neogene, and that deviations from this norm reflect either autostratigraphic transitions to different growth styles or major readjustment of the margin to allogenic forcing or basin reconfiguration. This finding implies that two-thirds of the terrestrial-derived, particulate organic carbon (POC) delivered from rivers to the ocean can be stored in deepwater over geologic timescales. Extrapolation from present-day fluxes of terrestrial POC in rivers shows this to be a significant transfer of carbon into storage which is not well characterized in current representations of biogeochemical cycles.

Peucker-Ehrenbrink, Bernhard

Controls on the Flux, Age, and Composition of Terrestrial Organic Carbon Exported by Rivers to the Ocean

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Export of organic carbon, alkalinity and silicate-derived dissolved Ca and Mg to the ocean exerts important controls on the sequestration of atmospheric carbon dioxide. As this export is mediated to a significant extent by river systems, understanding processes that control transport of land-derived matter to the coastal ocean is of fundamental importance to successful models of past and future environmental conditions. Scientists from the Woods Hole Oceanographic Institution, the Woods Hole Research Center and the University of New Hampshire have formed a river research consortium that investigates large river systems with a holistic approach. The National Science Foundation

is funding this initiative through its Emerging Topics in Biogeochemical Cycles (ETBC) program. The project focuses on the biogeochemistries of the Lena and Kolyma rivers in the Russian Arctic, the Yangtze river in China, the Ganges and Brahmaputra rivers in India and Bangladesh, the Congo river in central Africa as well as the Fraser river basin in western Canada. Campaign-style sampling, including depth-specific sampling of suspended particulate matter, is conducted on the main stems and important tributaries. This campaign-style sampling is complemented by time-series sampling of dissolved and particulate matter near the river mouths that is accomplished through collaborations with scientists at local institutions such as the East China Normal University in Shanghai (Yangtze), the University of the Fraser Valley in Abbotsford (Fraser), schools and research institutions in the Russian Arctic (Lena and Kolyma), the University of Nancy, France, as well as Dakha University, Bangladesh (Ganges, Brahmaputra), and collaborators in the Republic of the Congo (Congo). We combine a standardized sampling approach for organic and inorganic constituents with spatial analyzes of digital, mostly satellite-derived data products with the aim of obtaining an integrated understanding of the response of river ecosystems to past, ongoing and future environmental changes. We will present examples from the river basins we are studying that address the spatial and temporal variability of river systems located in tropical, temperate, and high-latitude environments. Particular emphasis will be placed on the integration of organic and inorganic geochemical parameters that help elucidate the transport and modification of particulate organic carbon from source to sink.

Pirmez, Carlos

Sediment flux from source to sink in the Brazos-Trinity Depositional System, Western Gulf of Mexico

Pirmez, Carlos¹; Prather, Bradford E.²; Droxler, Andre³

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A series of four intra-slope basins linked by submarine channels in the northwestern Gulf of Mexico form part of a source to sink depositional system that starts in the headwaters of the Brazos, Trinity and other smaller rivers, and terminates in a ponded intra-slope basin offshore Texas – the Brazos-Trinity depositional system. The system is well imaged with 3D seismic data and two of the basins have been drilled, with three Integrated Ocean Drilling Program wells and two geotechnical wells providing an exceptional dataset with which to quantify the amount and distribution of sediment types, the sediment volumes and the rates of accumulation through time and space. We have combined seismic-litho-bio-tephro-stable/radio-isotope stratigraphic methods to generate a millennial-scale resolution chronostratigraphy for this system. Basins I through IV are infilled with about 62 km³ of sand-rich sediments (~ 1.6 x 10¹¹ metric tons) transported by sediment gravity flows since

the last inter-glacial (Oxygen Isotope Stage 5e). The bulk of the sediments, about 49 km³, were deposited within a short time period within Oxygen Isotope Stage 2, starting at 24.3 ka at the latest and ending at ~ 15.3 ka. Sediment accumulated in the slope basins at rates which varied over time between 1.4 – 55 million tons per year. Except for a short time interval when the Brazos River was diverted to the shelf edge at the head of Basin I, sediment flux to deepwater was on average less than the present day sediment discharge of the Trinity-Brazos-Sabine Rivers combined. In the period 24-15 ka the sediment accumulated in the slope and shelf margin delta sinks can be balanced against the fluvial sources if the river discharges were somewhat lower than present day, and if the contribution from incised valley erosion was relatively small. This indicates that during glacial times sediment yield from the central Texas drainage basins must have been reduced compared to present day. Sediment eroded from the shelf during sea level fall also does not appear to represent a significant contribution to sediments accumulated in the slope basins. The history of sedimentation on the slope basins is modulated by sea level changes, but it is also strongly influenced by basin topography and by the dynamics of delta development on the shelf. During peak high stands of sea level the slope area receives only pelagic sediments; during low sea level stands, the sedimentation in each basin results from a complex combination between fluvial input at the head of the first basin, and the rate of subsidence/sedimentation causing basin topography. The ages of sediments in separate basins show that sedimentation occurs at the same time in multiple basins with trapping of sand in updip basins while mud is preferentially deposited in downdip basins.

Plink-Bjorklund, Piret

Stratigraphic Record of Terrestrial Floods: Impact of Monsoon Pattern Changes

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The fluvial to lacustrine succession of the Early Eocene Colton/Wasatch and Green River Fm of the Uinta Basin in Utah reveals a stratigraphic record of terrestrial floods of variable intensity and frequency. Comparison to carbon isotope records, sampled from the same succession shows that high-magnitude floods occur during the peaks of the Early Eocene hyperthermals. The most impressive package of the terrestrial flood deposits is related to the peak of the Paleocene-Eocene Thermal Maximum. These deposits characteristically contain deeply incised river channels with up to 30 m of local erosion. The channels are filled with simple, dominantly downstream-accreting barforms that consist of thick (10-10s of m) depositional packages, separated by bioturbated or pedogenically modified surfaces. The barforms consist dominantly of plane-parallel-laminated sandstones with minor cross-strata and climbing ripples. The barform thickness, accretion characteristics as well as the sedimentary structures indicate high deposition

rates and rapid accumulation. The bioturbated or pedogenically modified bounding surfaces between individual barforms indicate times of non-deposition. Together, this suggests highly seasonal water supply with very intense, short rainy seasons and long dry seasons. The paleosols in this succession indicate arid conditions, whereas ichnofacies from the same succession indicate wet soils, confirming the high seasonality with long dry and short wet seasons. Similar, but slightly less-extreme packages are related to the younger Early Eocene hyperthermals. In contrast, the river deposits that correspond to non-hyperthermal times resemble “normal” rivers with much more continuous water supply, much less erosion, much lower deposition rates, and lower avulsion frequency. Thus our dataset suggests that (1) Early Eocene hyperthermals significantly modified climate in the interior of North America; (2) PETM was the most intensive of the hyperthermals; (3) climate warming during Early Eocene hyperthermals intensified the monsoon pattern in the interior of North America; (4) the intensified monsoon caused extreme terrestrial floods with deepening of river channels, rapid local infilling of channels, and high-frequency and high-magnitude avulsion events; (5) intensified monsoon during future climate warming may cause larger-magnitude flooding and intensify avulsion frequency in rivers that drain active mountain belts.

Portier, Evan

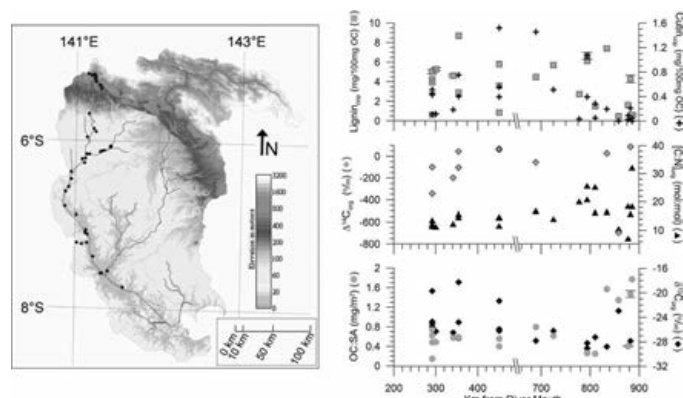
Sources and Distribution of Organic Matter Sequestered in Floodplain Sediments from the Fly River, Papua New Guinea

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The Fly River fluvial system in Papua New Guinea contributes a significant portion of the global organic matter (OM) flux into the marine environment. This OM flux is potentially altered by an extensive system of floodplains where fluvial-derived organic materials can a) accumulate and be stabilized, b) undergo degradation and modification and c) be amended by inputs from floodplain vegetation. We used a combined elemental, isotopic and biomarker approach to characterize the sources and composition of OM deposited along the Fly River floodplain. Alkaline cupric oxide oxidation was performed and characteristic products were quantified using gas chromatography-mass spectrometry. Quantification of lignin- and cutin-derived products is particularly interesting as these compounds represent terrestrial biomarkers exclusively synthesized by vascular plants. Together with elemental and isotopic data (i.e. C/N ratios, $\delta^{13}\text{C}$, and %OC), the biomarker data provides the first comprehensive

examination of OM sequestered in this system. The results suggest that floodplain OM is a heterogeneous combination of allochthonous soil materials originating from the uplands and autochthonous angiosperm plant detritus. In particular, the input of organic matter from woody and non-woody angiosperm sources demonstrates the incorporation of surrounding grassland and forest vegetation. Except for high-elevation areas within the floodplain boundary above the level of maximum inundation, preliminary analysis of downcore sediments indicates the active sequestration of OM in the floodplain



Map of the study area indicating the locations of sampling. Compositional trends of surface sediments/soil as a function of distance from the river mouth including, organic carbon:surface area ratios (OC:SA), stable carbon and radiocarbon age compositions of organic matter ($\delta^{13}\text{C}_{\text{org}}$, ^{14}C -Age), carbon-normalized lignin and cutin CuO product yields (Lignin:cop, Cutin:cop).

Powell, Ross D.

Interaction of Eustasy, Ice Sheet Dynamics and Glacial Regime Controlling Sediment Yields, Glacial Sequences and High Latitude Continental Margin Architecture

Powell, Ross D.¹

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At several times through earth history glacial and glacialine systems have dominated sedimentation along high-latitude continental margins; the Cenozoic provides excellent examples. Ice sheet dynamics is not only important to understand for constraining global proxy records of eustasy, but also for interpreting high-latitude continental shelf records and sediment mass transfer from continental interiors to margins. Ice dynamics at continental margins is a complex mix of factors: climate, ocean currents and glacial regime (temperate, polythermal/subpolar, polar), and the interactions and feedbacks among ice sheet mass balance, glacial and glacialine sedimentation, and relative sea level. Quantified glacial and glacialine processes help us interpret key lithofacies and glacialine landforms and enable the interpretation of high-latitude continental shelf sequences (glacial sequences) and continental margin architecture. Such records constrain ice dynamics and provide independent, direct evidence of ice volume contributions to eustasy. Quantified modern processes also provide excellent data for constraining glacial erosion rates

and sediment mass transfer at high-latitudes over annual, decadal and century time-scales. By defining glacial sequences through continental margin sedimentary architecture and glacial facies models, mass transfer rates can also be assessed over millennial time-scales. These data provide important proxy constraints on vertical motion of continental interiors and margins and their possible relief history.

Preu, Benedict

Contourites as source and sink on continental margins – a case study off Argentina and Uruguay

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Contourites and their related processes are important for the evolution of continental margins. The sediments are well-sorted, were transported along-slope by contour currents and can form sedimentary units of several hundred of kilometers length and hundreds of meters thickness. Furthermore, contourite depositional systems are often associated with strong erosional surfaces, where bottom currents not only inhibit deposition, but also erode and remobilize material. Therefore, from the source-to-sink perspective, they play a significant role in the dispersal of sediments from the shelf to the abyssal plain, and act thereby both as (temporary) sinks and as (temporary) sources. As a prominent example, a contourite depositional system was studied along the Argentine and Uruguayan continental slope between 600 m and 2000 m water depth by means of seismo-acoustic measurements. Here, sediments transported to the Atlantic ocean by rivers, especially the Rio de la Plata, interact with a complex current regime. While surficial currents form the Malvinas-Brazil confluence zone, the current regime at the upper slope is dominated by northward flowing Antarctic Intermediate Water (AAIW) and Upper Circumpolar Deep Water (UCDW). The middle slope is dominated by southward flowing North Atlantic Deep Water (NADW), which separates UCDW from Lower Circumpolar Deep Water (LCDW). The Argentine-Uruguayan contourite depositional system is characterized by erosive as well as depositional elements in depth levels. Between 600-900 m, the slope reveals an area of erosion or non-deposition with truncated and high amplitude reflections directly at the seafloor. Further down-slope, a plastered drift is located between the middle slope and the lower slope. Between 1200 to 2000 m water depth, the drift with its convex-upward shape forms an elongated sediment deposit, ~90 km long, ~50 km wide with a thickness of ~0.8

s TWT. The depositional sequences that comprise this drift show an overall aggradational stacking pattern and a lens shape, being distally (eastward) affected by gravitational processes like sediment deformation and failure. Erosional surface and depocenter shifts through time indicate changes in the thermohaline circulation (e.g. increase of Antarctic glaciation ~15Ma) and therefore, changes in the sediment dispersal system. In summary, the contourite depositional system offshore Argentina and Uruguay offers the opportunity to study in detail how the sediment distribution from source to sink changes in time and space under the influence of a varying ocean circulation.

Proust, Jean-Noël

Controls on Relief and Sediment Fluxes of Active Margins at 10 ka to 1 Ma Timescales: The Hawke Bay Forearc Domain Example From New Zealand

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Tectonics and climate are the two key parameters that control the evolution of relief in tectonically active areas, but their respective influences are difficult to distinguish as they act simultaneously and can generate similar signals in the sedimentary record. Moreover, these influences and their record vary depending on the timescale (ka to Ma). Fully integrated qualitative and quantitative approaches of well-documented sedimentary systems, from catchment source to the deep ocean basin are required to proper estimates of their relative contributions. This work presents the results of a quantitative and three-dimensional source-to-sink study of the Pleistocene Hawke Bay forearc domain based on the interpretation and integration of an extensive geophysical and geological data set. The last 150 ka sedimentary record of New Zealand provides results on the 10-100 ka timescale. Offshore, climato-eustasy is responsible for the development of a eustasy-driven 100 ka-type depositional sequence. Inland, climate and eustasy control erosion rates, and incision or aggradation of rivers. The interplay of these divers results in unusual sediment partitioning. Interpretations are supported by the results of preserved volume estimates that confirm a significant increase in the sediment flux around climatic maxima. The distribution of active structures defines the areas subject to erosion or deposition, and influences river and offshore sediment pathways. The last 1.1 Ma basin fill is made up of 11 sequences preserved in structurally controlled basins. Sequences show a stacking pattern characterized by a general retrogradational trend and an arcward migration of depocentres. Incremental, preserved sediment volumes show an important increase since c.430 ka due to broad scale tectonic reactivation, which is believed to be the major

parameter that also controlled the long-term (0.1-1.0 Ma) evolution of the forearc domain. This study represents one of the first attempts to quantify sediment fluxes across a range of timescales significant for margin-building processes at an active tectonic setting. It provides insights into the balance of interconnected parameters that simultaneously control the evolution of the landscape and seascape.

Puig, Pere

Contemporary Off-shelf Sediment Transport on the Ebro Margin (COSTEM)

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3. Instituto Español de Oceanografía, Madrid, Spain

The COSTEM project deals about the study of contemporary sedimentary processes that control the shelf-to-slope sediment transport and the sedimentary dynamics at the outer shelf, submarine canyon heads and continental slope of the Ebro margin. This margin has been intensively investigated from the sedimentary point of view. Nevertheless, no previous research has addressed the study of the mechanisms controlling the off-shelf sediment transport and the characteristics and fate of the exported particles towards the slope. Preliminary results suggest that most of the transport occurs across the southwestern end of the Ebro margin, in the Gulf of Valencia, where the width of the shelf dramatically decreases favoring the advection of suspended particles towards the continental slope. Swath bathymetry conducted in this margin reveals the presence of two large sediment wave fields on the Valencia continental slope (300-750 m depth), which indicate preferential accumulation in that region. This morphology contrasts with the one from the continental slope in the central part of the Ebro margin, where numerous submarine canyons, apparently controlled by slope instability processes, develop. Hydrographic sections across the sediment wave fields reveal the presence of multiple intermediate nepheloid layer detachments that suggest active resuspension processes. Data from three moorings recently deployed on the slope and from one tripod placed on the Valencia shelf will provide direct observations to assess the role played in the sedimentary dynamics of the area by high energetic events, such as major storms, internal waves and the formation of dense shelf waters and its subsequent down-slope cascading.

Reece, Robert

Tectonic and climate influence on the evolution of the Surveyor Fan and Channel system, Gulf of Alaska

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We show that tectonic and climatic events in southern Alaska incited large-scale channel development and changes in sediment distribution in the deepwater Surveyor Fan, the terrigenous outwash body that comprises the majority of the Alaska Abyssal Plain in the Gulf of Alaska. Present-day seafloor morphology and sediment distribution in the Surveyor Fan is dominated by the >700km long Surveyor Channel system, an anomaly in a system with no major fluvial input or shelf canyons. The sediment supply has instead been provided by glacial erosion in the still-active Chugach-St. Elias orogeny, and glacial transport across the shelf. Varying degrees of glacial erosion and rock exhumation in the St. Elias Range since the Miocene distributed sediment into the Gulf of Alaska, and led to periodic significant increases in growth of the Surveyor Fan. Through the formation of the Surveyor Channel, two climate events created three major differentiable sequences across the Surveyor Fan visible in multiple seismic datasets acquired since the 1970's. The first sequence overlies pelagic chalk and clay deposits and consists of basement topography-controlled depocenters. The second sequence was spurred by the first tidewater glaciation in the Gulf of Alaska ~5.5 Ma, which doubled the terrigenous sediment flux and created a shelf-proximal proto-Surveyor Channel. The third sequence overlies the second and includes the modern seafloor. This sequence was induced by glacial intensification ~1 Ma, which may have been a regional response to the mid-Pleistocene transition (MPT), a change in glacial-interglacial cycles from 40 to 100 Kyr. The MPT glacial intensification again doubled the terrigenous sediment flux, carved sea valleys to the shelf edge, added several major tributaries to the Surveyor Channel and provided the impetus to grow the channel system across the Surveyor Fan. The close proximity of St. Elias Range relief and glacial systems to the Gulf of Alaska marine system made possible the creation of cross-shelf sea valleys by advancing ice during glacial maxima. The sea valleys acted as surrogates for fluvial canyons and narrowed the focus of subsequent sediment flux to shelf-edge depocenters in the fan. The sea valleys combined with major increases in sediment flux, associated with climate events since the Miocene, to develop the Surveyor Channel. The Surveyor Channel system has since dominated sediment dispersal and seafloor morphology in the Surveyor Fan.

Roering, Joshua J.

Hillslope form, function, and sediment contribution

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Hillslope processes control the pace and character of sediment delivered to channel networks and thus initiate much of the dynamics of 'source-to-sink' sediment dispersal systems. Traditionally, hillslopes have been defined as divergent or planar landforms that juxtapose valleys and lack persistent channelization. Valley incision imposed primarily through tectonic forcing serves as the baselevel signal to which hillslopes respond and adjust their form. The extent to which hillslope processes may in turn regulate the rate of valley incision through their influence on grain size and supply, for example, remains an area of active research, as is the role of orogen-scale erosion patterns in driving tectonic deformation and variations in rock uplift. Thus, the simple notion that hillslopes are purely 'reactionary' components of the landscape likely requires revision. In a given setting, the suite of active hillslope processes depends on diverse variables that include: rock type (e.g., rock mass strength), climate (e.g., storm frequency and intensity), biology (e.g., ecosystem composition), human activity (e.g., timber harvest), and tectonic forcing (e.g., earthquake magnitude and frequency). The formulation of quantitative relationships for sediment production and transport processes that account for these variables in a particular landscape implies that characteristic (although perhaps non-unique) hillslope forms will emerge given sufficient time. This construct indicates, for example, that hillslope erosion rates do not directly depend on climate variables, such as annual precipitation; instead, hillslopes adjust their form according to climate-related processes and erode at rates that match channel incision. Quaternary climate fluctuations, predominantly glacial-interglacial fluctuations, may have profound influences on hillslope processes across many parts of the world, complicating our ability to associate current landform characteristics with observations of process rates and mechanisms. Nonetheless, recent advances in erosion rate estimation via cosmogenic radionuclides and morphologic quantification using airborne lidar have enabled the calibration and testing of hillslope process models applied to real landscapes. Empirical relationships for soil production, for example, have been documented on nearly every continent and demonstrate that rates of bedrock-to-soil conversion tend to decrease with soil depth although we lack theoretical models that can account for how biology and rock type dictate the observed relationships. The transport of soil on hillslopes has been proposed to vary with slope angle and soil depth and increase rapidly as angles approach a threshold value. Few quantitative models have been developed to represent bedrock landscapes and landsliding. Existing landslide models include diverse mechanisms (e.g., from discrete

bedrock slope failures to nonlinear viscous deformation) although the spatial and temporal patterns of sediment delivery predicted by these models have not been systematically addressed. As a result, we have limited capability to predict sediment load for a catchment if the rock type, climate, and channel incision rate are specified.

Romans, Brian

Linking Terrestrial Denudation to Marine Deposition for the Holocene Santa Clara River Sediment-Routing System

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The Santa Clara River is one of the highest sediment-flux rivers on the western margin of North America as a result of high uplift rates in the nearby Western Transverse Ranges, easily erodible Cenozoic sedimentary strata as bedrock, and a semi-arid climatic regime with highly variable precipitation. The record of sediment flux from the mouth of the Santa Clara River drainage basin during the 20th Century corresponds well with decadal fluctuations in El Niño-Southern Oscillation precipitation (ENSO) patterns. The timing of terrigenous sediment accumulation in distal parts of the Santa Monica and Santa Barbara basins for the past 7,000 years is also well correlated with millennial-scale ENSO records. However, rates and amounts of mass transfer from source-to-sink at these timescales are not well constrained. We construct a millennial-scale mass balance for this southern California land-to-deep sea sediment-routing system by comparing (1) cosmogenic nuclide-derived bulk denudation rates for the Santa Clara, Ventura, and Calleguas drainage basins with (2) sediment accumulation rates in Santa Monica and Santa Barbara basins and adjacent continental shelves from seismic-reflection mapping constrained by radiocarbon-dated cores. The denudation rates obtained for each watershed correspond to timescales similar to radiocarbon-based deposition rates (10^4 - 10^5 yr) and, thus, capture sediment transfer periods longer than measured historical fluxes. We found that the terrestrial denudation rates are about twice as large as those derived from 20th century measurements, and are approximately half the mass deposition rates in the offshore sinks during a similar time interval. Our mass balance suggests that erosion of the continental shelf and coast could have been significant, which would close the deficit between the deposition of mass in deep-sea sediment sinks and its supply from terrestrial catchments. Additional sediment from erosion of the continental shelf and coast is generally contrary to stratigraphic models of continental margin evolution, which dismiss the occurrence of shelf and coastal erosion during sea-level rise as a source of significant volume of sediment to the deep sea; instead, the shelf is typically characterized as a permanent sink or an area of

bypass to the deep sea. These results also suggest that temporary storage of sediment along the source-to-sink pathway followed by erosion and redistribution should be considered in the reconstruction and/or modeling of sediment-routing systems.

Rose, Lila E.

Sediment Records Holocene Transgression in a Tectonically Controlled Shelf Environment, Waipaoa Sedimentary System, New Zealand

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Over geological timescales, sedimentary sequences on continental margins develop through competing sedimentological, climate, glacio-eustatic and tectonic influences. Textural and geochemical proxies of these influences can be used to understand their relative importance, although complete sequences are rare on passive margin shelves since the LGM as a result of rapid sea level rise and limited accommodation. However, the creation of accommodation space through subsidence related to active tectonism allows for expanded sedimentary sequences that provide a high-resolution Late Quaternary record of naturally and anthropogenically influenced environmental change from the high-yield Waipaoa Sedimentary System, Poverty Margin, New Zealand. Using a suite of 4 giant piston cores retrieved from Poverty Margin, Holocene stratigraphy is reconstructed with unprecedented detail and sensitivity to the complex interplay between sea level rise, tectonics, sediment supply and climate during this critical period of recent earth history. Cores were chosen to target areas where sequences have the greatest likelihood of preserving an expanded record based on seismic profiles and represent a cross-section of environments from inner shelf depocenter to shelf break to upper slope. Detailed $\delta^{13}\text{C}$, C/N and grain size sampling, and Multi-Sensor Core Logs are used to track Holocene transgression across the shelf and between environments. Robust age models based on ^{136}C analyses of in situ shells provide insight into sedimentation rate changes on shelf and slope in relation to geochemical proxies. At lowstand, the base of the upper slope and shelf break cores (~16ka) record enhanced capture of terrestrial material relative to present isotopic signatures (more than a 2‰ difference) as well as textural coarseness (mean ~5 phi) as the paleo Waipaoa likely bypassed the modern inner shelf (150m water depth). Abrupt gross shifts from terrestrial to marine $\delta^{13}\text{C}$ in slope (15ka) and shelf (11ka) cores signify a decrease in sediment supply resulting from initiation of shelf trapping as transgression proceeded. As sea level rapidly rose, accumulation rates on the shelf increased and display a fining upwards signature marking a reduction in riverine bedload and an increase in suspended load components as the Waipaoa mouth moved landward culminating ca. 7ka,

when the rate of sea level rise subdued and paleo Poverty Bay reached its farthest inland configuration. As efficiency of sediment trapping waned and Poverty Flats infilled (~7ka-present), coarser material reached the shelf depocenters and a dramatic increase in terrestrial $\delta^{13}\text{C}$ is preserved. A period of enhanced coarsening on the shelf is similar to a trend seen by other authors, attributed to the intensification of ENSO ca. 4ka. The isotopic trend reverses ($\delta^{13}\text{C}$ becomes enriched) ~1ka when mass deforestation by Polynesian settlers commenced, potentially recording an increase in material sourced from marine sedimentary rocks due to increased erosion or perhaps signifying enhanced productivity in coastal waters due to related eutrophication.

Ross, Kristen

Active Seismic and Tectonic Events Recorded in the Rapid Accumulated Sediments between the Taiwan Lanyang River and South Okinawa Trough

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The Southern Okinawa Trough is characterized by rapid sedimentation rates (>0.1 cm/yr) and contains an excellent record of past episodic events, such as seismic activities and large storms. Previous studies have identified a positive correlation between the sediment accumulated in sediment traps in the Southern Okinawa Trough and runoff from the Lanyang River. Several studies have documented the sediment properties of the Southern Okinawa Trough, but there is little seismic data documenting the morphology of the seafloor between the Lanyang River and the Okinawa Trough. This study analyzed the morphology of the seafloor and the sediment properties offshore from the Lanyang River and the Southern Okinawa Trough using seismic analysis. CHIRP sonar was used to obtain seismic tracts in the area. Primary results show that immediately off the Lanyang River mouth there have accumulated 150-200-m riverine sediments since the last glacial maximum. This thick sediment body is featured by distinctive faulting, landsliding, slumping, etc. This small-river-derived sediment can be traced all way into the southern tip of South Okinawa Trough, in result of a rapid accumulated muddy depocenter.

Rotzien, Jonathan R.

Provenance and overall evolution of the Upper Miocene Upper Mount Messenger Formation, coastal Taranaki, North Island, New Zealand

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We determine the provenance and overall evolution of the Upper Mount Messenger Formation using over 200 m of high-resolution measured stratigraphic, geochemical, petrographic and detrital zircon geochronologic data collected along the length of Pukearuru Beach on the Taranaki coast of the North Island of New Zealand. These

data are interpreted to show a Late Miocene (Tongaporutuan Stage) relative base of slope environment that records a progressive change from an unconfined setting to a confined channel-levee setting, with evidence for progradation westward across the Taranaki shelf. The remarkably thick, sand-rich deposits of the Upper Mount Messenger Formation, characterized by Bouma Tbcde turbidite sequences deposited predominantly by discrete, long-lived, low-density flows, record a continuous look at the evolution of a relative base of slope environment. The spectrum of grain sizes, mineralogy and detrital zircon geochronology, stacking patterns, nature of bounding surfaces and large-scale architecture of the formation record a) transport and funneling from continental and offshore volcanic arc sources, b) sediment merging and sorting along the proto-shelf prior to deposition in middle to upper bathyal depths and c) the stratigraphic evolution of a relative base of slope environment and its systematic transition from a thin-bedded and shaly distal environment to a thick-bedded, sand-rich channel-levee environment rife with potential lateral accretion packages (LAP). This study highlights the evolution of a specific depositional environment in the deep marine ultimate sediment sink and the importance of understanding ancient sediment transport and deposition over the scales of millions of years in order to constrain modern systems.

Saito, Yoshiki

Monsoon control of sediment discharge and dispersal in Asia: Examples from a steep river/narrow shelf and a large river/wide shelf

Saito, Yoshiki¹

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Sediment discharge from rivers to the ocean and sediment dispersal in coastal zones in Asia are mainly controlled by the monsoon. The monsoon climate is characterized by a rainy summer with prevailing south winds and a dry winter with strong north winds in Asia. More than 70–80% of annual sediment discharge occurs in summer, and re-suspension of sediment in the coastal zone by waves is dominant in winter. Here I show two examples of seasonal changes of sediment delivery and dispersal in a river-coastal system: the Kurobe fan delta in Japan and the Mekong River Delta in Vietnam. The Kurobe River is one of the largest suppliers of coarse sediment into the Japan Sea: 86 km in length, 680 km² in drainage area, 2924 m in max elevation in central Japan. Peaks of water/sediment discharge occur during the spring snowmelt and the summer monsoon. The river forms a sand-gravel fan delta that is 10 km in diameter and has a gradient of 0.1. The continental shelf around the delta is very narrow (<0.5–1 km) and steep, with gullies and canyons that supply sediments to the 700-km-long Toyama Deep Sea Channel in the Japan Sea. The coastal area is wave-dominated with a mean tidal range of <0.3 m and a mean wave height of about 1 m. Most large waves occur in winter, except for a few typhoons that occur each year in the

summer and autumn. Detailed repeated bathymetry surveys, side-scan surveys, and near-monthly aerial photos of the river mouth show the following: (1) bowl-shaped slump scours 50–100 m in width on the upper part of the delta front (mostly <20 m water depth); (2) these scours became filled in the time between the surveys (~ 1 yr later) as new slump scours developed between former scours; (3) the depositional delta front having an elongated tongue-like feature with gravel dunes on the middle shelf, indicating an offshore flow direction with wavelengths of 20–40 m; and (4) seasonal changes of the shoreline at the river mouth, indicating seaward advances along several channels caused by high water discharge and calm waves in summer and landward retreats with a more linear shoreline caused by strong waves in winter. The major sedimentary processes are flood events and related sediment transport directly from the river mouth to the deep ocean, including mass wasting and hyperpycnal flow in summer and coastal erosion and longshore transport mainly in winter. The Mekong River Delta in Vietnam and Cambodia is one of largest deltas in the world with a delta plain that is about 300 km wide plain in a wave-tide dominated setting (mesotidal). Repeated surveys between November 2005 and February 2008 along shore-normal beach transects have shown that muddy sediment delivery occurs in summer, resulting in thick mud distribution on upper parts of the delta-front platform at the river mouth and a slightly muddier beach. During summer, the wave direction is relatively weak southwesterly. However, mud and very fine sand in the surface sediments tend to be removed during winter, suggesting that the sediment supplied from the river during summer is temporarily deposited near the river mouth and later transported southwestward during the winter monsoon. This feature coincides with the long-term sediment distribution.

Sawakuchi, André O.

OSL sensitivity as a tracer of quartz sand grains in a coastal sandy barrier from Southern Brazil

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Cycles of irradiation and light exposure increase the OSL sensitivity of quartz. In sedimentary systems, these cycles correspond to cycles of deposition and erosion. Thus, the OSL sensitivity would indicate the sedimentary history of quartz. But, the OSL sensitivity also depends on factors linked with quartz crystallization (primary sensitivity). We evaluate the OSL sensitivity of quartz single-grains extracted from igneous (granite, hydrothermal vein and rhyolite) and metamorphic rocks (schists and gneisses); and from Holocene fluvial and coastal (the Ilha Comprida Barrier)

sediments with different sedimentary histories and known source rocks. The spatial variation of the OSL sensitivity within the studied barrier was evaluated through measurements in quartz aliquots. This sample suite allows assessing the variability of the OSL sensitivity of quartz with respect to their primary origin and sedimentary history. The OSL measurements were made on a Risø TL/OSL DA-15 reader using a green laser (532nm) for optical stimulation of quartz single-grains and a blue LEDs (470nm 20nm) for stimulation of quartz aliquots of same volume. All samples were irradiated with a constant radiation beta dose, after bleaching under the sunlight. The OSL sensitivity was obtained by integrating the total (single-grains) or the first two seconds (aliquots) of the shine down curve. The OSL sensitivity of fluvial sediments (short transport) is relatively low and similar to the sensitivity of their main source rock (chlorite-sericite schist). The quartz from coastal sands shows high sensitivity, which is consistent with their long sedimentary history. Thus, the increase in OSL sensitivity due to cycles of erosion and deposition surpasses the sensitivity inherited from the source rock. The high variability of the OSL sensitivity of quartz from coastal sands is attributed to the mixture of grains with distinct sedimentary histories. In the Ilha Comprida Barrier, the OSL sensitivity of quartz aliquots increases alongshore from north to south, indicating high proportion of sand with short depositional history in the northern portion of the barrier. This agrees with the present pattern of sediment transport in the barrier system. High reworked sediments derived from distal southern coastal sectors reach the barrier through northward alongshore currents active during storm periods. Low reworked sediments are supplied by the Ribeira de Iguape River, which reaches the coast at the northern end of the barrier. These sediments are distributed along the barrier by southward alongshore currents active during fair weather periods. We conclude that the OSL sensitivity of quartz can be used to describe patterns of sediment transport in coastal systems, discriminating sediments with different sedimentary histories.

Schumer, Rina

Which statistical characteristics of sediment dispersal and deposition are recorded in the stratigraphic record?

Schumer, Rina¹

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Since the 1950s, statistical characteristics of deposition and erosional processes have been represented using stochastic models based on random walks. Distributions of bed thickness and hiatuses found in the stratigraphic record are similarly described using probabilistic models. The link between process and record is the stratigraphic filter, which for every time t , records the lowest surface elevation that occurs in the future. Here we advance interpretation of sediment dispersal and deposition from the geologic record by linking the stratigraphic filter with a mathematical model

known as a stochastic ladder process. Results on stochastic ladder processes found in the mathematics literature relate the presence or absence of long-range correlation or extremes in depositional events and resulting bed thickness and hiatus characteristics. For example: 1. If an average subsidence rate does not dominate deposition rates, a wide (power-law) distribution of hiatuses will arise in the stratigraphic record. This suggests that scale-dependence of rate measurements estimated from the geologic record will be the rule rather than the exception. 2. Positive correlation in deposition rate decreases the probability of extremely large hiatuses, while negative correlation in deposition rate increases the probability of encountering extreme hiatuses. The level of correlation is directly related to the hiatus length density. However, long-range correlation in deposition rates does not influence bed thickness distribution. 3. Bed thickness distribution in the geologic record can only be more heavy-tailed than the deposition/erosion regime from which it arises. Observations of hiatus length distributions in a variety of geologic settings (shoreline, shelf, delta, seafloor) fit within this framework. Similarly, characteristics of bed-thickness distributions (in turbidite sequences, sandstones, etc.) can also be related to depositional setting using this model. This work has potential to generalize disparate analytical and numerical frameworks for relating deposition, erosion, and the geologic record.

Schwenk, Tilmann

The surface channel-levee systems on the Bengal Fan as late quaternary sink of the Himalaya-Bengal source-to-sink system

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Channel-levee systems as main architectural elements of submarine fans play a significant role in source-to-sink systems. Build-up by turbidity currents transporting terrigenous material, they represent high-resolution archives of the erosional history of the hinterland. However, to use these archives a detailed understanding of internal architecture and stacking pattern of channel-levee systems is necessary. The Bengal Fan located in the Bay of Bengal is fed by the Ganges-Brahmaputra river system which drains approximately $\frac{3}{4}$ of the Himalayan mountain range and delivers more than 1 Gt/yr of terrigenous sediment. One third of these sediments is transported to the deep sea fan via a deeply incised shelf canyon. During four cruises with the German Research Vessel "Sonne" (1994, 1997 (2), and 2006) in the Bay of Bengal bathymetric swath-sounder and sediment echosounder PARASOUND were operated continuously. All together data are available from profiles of 23,000 km length crossing the fan in international waters. For the first time these multibeam data were compiled to one map imaging the surface channel-levee systems. Some of

the profiles are long profiles running from west to east, i.e., perpendicular to the channels, but some profiles track distinct channels from north to south. Using the morphological character of the channels and their relative succession revealed from overlapping levee deposits visible in the sediment echosounder data, channels can be traced from profile to profile. Comparison with the map published by Curray et al. (2003) shows partly good agreement as shown for a few profiles by Schwenk & Spiess (2009), but especially multibeam profiles along channels reveal more avulsion points and more terminating channels on the middle fan. These results demonstrate that dispersal of the sediments on the fan in time and space is significantly more complex than expected. Only two channel-levee systems have been dated so far, the active channel as active during the Holocene, and one eastern channel as has been active before 300,000 yrs bp (Weber et al., 2003). However, most channels can be arranged in this framework and (relative) ages can be estimated for them. Therefore this new compilation gives the opportunity to link distinct channel-levee systems to time slices of quaternary Himalayan erosion. Additionally, these data generally offer to study transport and depositional processes on significant different channel-levee systems in detail. References: Curray, J.R. et al., 2003, The Bengal Fan: morphology, geometry, stratigraphy, history and processes: *Mar. and Petr. Geol.*, 19, 1191-1223 Schwenk, T. & Spiess, V., 2009, Architecture and stratigraphy of the Bengal Fan as response to tectonic and climate revealed from high resolution seismic data. In Kneller, B., Martinsen, O.J., and McCaffrey, B., *SEPM Spec. Pub.* 92, 107-131 Weber, M.E. et al., 2003, Bengal Fan sediment transport activity and response to climate forcing inferred from sediment physical properties: *Sed. Geol.*, 155, 361-381

Septama, Erlangga

Source to Sink Siliclastic Delivery in the Deepwater Gulf of Papua from SEM-MLA-aided Provenance of Turbidite Sands

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An integrated provenance, textural and chronostratigraphic analysis of Pleistocene-Holocene turbidite sand in the Gulf of Papua (NSF Source to Sink Focus Area) has been undertaken to elucidate glacio-eustatic influences on sedimentary behavior in a modern deepwater depositional system. Sands were sampled in seven jumbo piston cores from the slope and basin floor, yielding 53 samples. A quantitative modal mineralogy analysis was conducted using scanning electron microscopy (SEM) and mineral liberation analysis (MLA) of ~15,000 individual grains per sample. Tests using the Gazzi-Dickinson ternary diagram show a lack of differentiation among samples. Although free from grain-size effects, use of this diagram is strongly affected by the detailed mineralogical classification that results from automated MLA. MLA does allow sample differentiation using mafic/felsic ratio (m/f), light/heavy-

heavy minerals ratio (l/h-hm), total heavy-minerals and pumice content. Furthermore our analysis of core thin sections and x-radiographs allows discrimination of two turbidite lithofacies with implications for separate routing: lithofacies A includes a unique succession of sand, woody debris and foraminifera, whereas lithofacies B is composed of thinly bedded very fine to medium sand turbidites, inter-layered with hemipelagic mud. Time-sliced provenance based on our C-14 age model shows three major pathways: (1) long-distance NW-SE sediment transport of quartzofeldspathic sand sourced from the Papuan Mainland, delivered from the Fly-Strickland fluvial system through Pandora shelf and slope (core MV-54), Pandora basin floor (cores MV-23, 33) and Moresby Channel (MV-25, 29), characterized by low m/f and pumice content and decreasing of l/h-hm and unstable/tourmaline (uti) ratio basinward, incorporating turbidite lithofacies A and B; (2) short-distance NNE-SSW transport of felsic-mafic volcanic sand apparently from the collision margin of the Papuan Peninsula, delivered via small rivers narrow shelf, and deep-sea canyons (MV-22) characterized by high m/f ratio without distinct pattern of heavy minerals ratio, characterized by lithofacies B; and (3) intermediate-distance delivery from the Fly-Strickland and Papuan Peninsula along coastal pathways to the Moresby Trough (MV-22) characterized by high pumice contents, overall low in uti and l/h-hm, composed of lithofacies B turbidites. The vertical provenance pattern shows that the Pandora Trough samples (MV 23, 33, 54) were entirely pathway 1 during the time period 44-17 Ka, while Moresby Trough received sediment via pathway 1 (MV-25, 29) and pathway 2 (MV-22), gradually shifting to pathway 3 from late Pleistocene to the middle Holocene. We also suggest that the Gazzi Dickinson scheme be re-evaluated in light of powerful new automated MLA techniques, to allow better sample discrimination in fine-grained lithic and felsic sands typical of our study area, and many other deep-water basins.

Shaw, John B.

Tracking the distal extent and character of distributary channels on the Wax Lake Delta, Louisiana, USA

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We investigate delta-front bathymetry to determine the extent and character of distributary channels beyond their region of sub-aerial definition. Our field site is the Wax Lake Delta in Louisiana, USA; a river delta prograding quickly (~100 m/yr) into a shallow (~3 m) basin. The delta-front is the zone where delta bathymetry transitions from proximal islands bordering distributary channels to a distal, non-channelized surface. We have mapped 40 km² of delta front bathymetry immediately seaward of two sub-aerial distributary channels at the Wax Lake Delta; Gadwell Pass and Main Pass. The subaqueous channel that is Gadwell Pass extends 2.0 km seaward of its subaerial portion before

bifurcating into at least 4 channels of equal depth over a streamwise distance of 0.8 km. Over this distance, channel depths shoal from -3 m to -1.2 m (all elevations relative to MLLW). Beyond these bifurcations, bathymetry transitions from channelized to flat over the next 1.0 km and begins to gradually dip seaward with a bed slope of $7E-4$ until the tapered deposit pinches out against the pre-existing floor of the bay. The subaqueous channel that is Main Pass extends 2.8 km beyond its subaerial extent before losing definition. The bed of this channel begins at -3 m as well, but never shoals above -1.8 m. There is a single bifurcation at 1.5 km beyond the subaerial exposure and the two channels are not of similar depth. The deeper channel remains defined even as regional, delta-front bathymetry dips towards the bay floor. Distributary channels on the Wax Lake Delta extend well beyond their subaerial definition before terminating. The channels tend to shoal and bifurcate in the subaqueous zone, although different channels exhibit different bifurcation character and frequency. We will compare field data against predictions of channel growth from models describing delta progradation and discuss the implications of long subaqueous channels defining the leading edge of a delta distributary network.

Sheets, Benjamin A.

Linking terrestrial and submarine processes: a preliminary bathymetric and sub-bottom survey of the Stehekin Delta, Lake Chelan, WA

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Geologists have long recognized the importance of both river deltas and deep-ocean sedimentary fans as major sinks for large quantities of land-derived sediment, and as important components in the integrated source to sink transit of terrestrial sediments. Indeed, studies too numerous to count have addressed these depositional systems individually. Relatively few studies, however, have directed their attention at the linkage between the two. This linkage is key to our ability to model and understand sedimentation in both environments, as these dynamics provide an important boundary condition for terrestrial and marine models, and represent a critical interface in the integrated source to sink system. This project is a preliminary study of the relationship between deltaic and deep-water sedimentation in Lake Chelan, WA, where the external forces acting on the system are relatively well-constrained, and the river is directly linked to deeper water. Detailed bathymetric and sub-bottom data, including lake bed grab samples, gravity cores and CHIRP sonar, were collected in order to characterize the transport and fate of sediment. Preliminary data analysis suggests the presence of large scale bedforms on the lake floor, presumably the product of density currents produced during high river

flows or as a consequence of failure on the delta front. Grainsize and isotopic analysis of the cores and grab samples should constrain the mechanisms by which deep marine flows are generated, and provide a valuable baseline from which future monitoring studies can be designed.

Shobe, Jim

Terrestrial sediment flux across a fringing reef in Moloka'i, Hawai'i

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In environments with fringing reefs, terrestrial sediment must pass across the reef in order to reach its ultimate sink. While on the reef, this sediment can increase coral stress. Sediment particles that settle on coral interfere with photosynthesis and feeding while turbidity resulting from suspended sediment decreases incident light levels. As an example of processes in this type of environment, we present suspended sediment concentration (SSC) and sediment flux data from measurements taken on a fringing reef off south-central Moloka'i, Hawai'i. Terrestrial sediment enters this reef via an eroding gulch just east of our study area. In spring of 2005, 2007, and 2010 seasonal trade winds were the primary driver for resuspension and advecting sediment along and across the reef. These currents were generally westward alongshore with a smaller offshore component. SSC was highest at the easternmost transect (proximal to the deltaic source of sediment) and decreased to nearly half at 4.5 km westward along the reef flat. In addition, a clear concentration gradient was evident as we moved offshore; SSC was highest on the reef flat near shore and decreased towards the reef crest. In the absence of trade winds, for example in spring of 2009, tides were the main driver of currents on the reef. These tidal currents were weaker and had less uniformity in direction than those generated by trade winds. In these conditions, SSC levels were significantly lower but still had the same characteristic of highest concentrations onshore and to the east. These data allow us to assess terms in the sediment budget over a period of time under which management practices have attempted to reduce terrestrial sediment to the reef. These data do not show a clear effect of these practices on the reef. While terrestrial sediment delivery rates may have been reduced, previous high rates created accumulated storage in deltaic deposits that continue to be resuspended by waves and currents and redistributed along and across the reef.

Simms, Alexander R.

The importance of winds in controlling deposition and reconstructing climate within the estuaries of the Gulf Coast

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The unmixed estuaries of the Gulf of Mexico provide an economic and ecologically important stepping stone along the source to sink pathway connecting the interior Southern High Plains and the Edwards Plateau of the central US to the shelf of the northwestern Gulf of Mexico. These small temporary sediment sinks provide a useful archive of past coastal processes. Previous studies have documented the importance of sea-level and climate changes on these systems. Despite previous work illuminating the importance of winds on estuaries, the impact of and records of changing winds on these systems has not been determined. Here we use grain size as a proxy for former wind strength along the northwestern Gulf of Mexico. After correcting for the impacts of a steadily increasing fetch, floods, and tropical storms through time, we reconstruct past wind energy along the northwestern Gulf of Mexico. Our proxy suggests the mid Holocene from approximate 5.5 ka to 4.2 ka was the windiest time along the central Gulf of Mexico. Our study reiterates the often overlooked impact of wind energy on sediment deposition within estuaries.

Slingerland, Rudy L.

Modification of Sediment Fluxes by the Transfer Fluvial System

Slingerland, Rudy L.¹

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Predicting the stratigraphic record for a given set of boundary and initial conditions in the source terrain requires a description of transformations from 'upstream' dynamics and surface sediment fluxes and types to preserved stratigraphy in the basin. Within the transfer fluvial system we need to define the processes that attenuate or amplify a sediment signal and the resulting characteristic response times and buffer distances. If sediment transport in a river of length L is diffusive, then the characteristic reaction time is L^2/K where K is the diffusivity, a function of sediment mobility and unit water discharge. The distance over which a periodic disturbance of amplitude A and period λ decreases by $1/e$ (e -folding distance) is given by $d = \sqrt{K\lambda/\pi}$. It seems inescapable that sediment fluxes reaching a coast through

long transfer rivers are strongly damped and frequency-filtered. But this conclusion is at odds with advection solutions for the propagation of a sediment bed wave in which the bed wave celerity is $u/[(1-p)(1-Fr^2)h]dq_s/du$, where u is the mean flow velocity, p is bed porosity, Fr is the flow Froude number, and q_s is the sediment transport rate per unit width. Furthermore, in both cases washload is ignored. This talk will explore the extent to which rivers of various characteristics transmit either diffusive or advective sediment signals to an adjacent basin.

Spiess, Volkhard

The partial decoupling of source and sink in the current-controlled sediment dispersal systems on the East African and Northern Madagascar continental margin

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The relationship between a sedimentary deposit and the source of its accumulated particles is intimately linked to the processes of transport. While classical river-delta-slope systems are quite common, the presence of coast- and slope-parallel current systems can modify sediment dispersal pattern significantly. In front of river systems, shelf currents may lead to non-deposition on the shelf, may result in a shift of maximum sediment transport across the shelf break and again in a slope-parallel shift of the depocenter on the upper slope. As a function of current patterns on shelf and slope, current strength, sea level, shelf morphology and riverine sediment input, the resulting dispersal pattern can reveal a high degree of complexity. It may even lead to an almost complete decoupling of sediment source and depocenters on shelf, slope and in basins. As a result of a recent IODP pre-site survey (SAFARI, Hall, Zahn et al.) on the East African continental margin off Mozambique and Madagascar during R/V Meteor Cruises M63/1 and M75/3, sedimentary deposits were investigated with high-resolution multichannel seismics, sediment echosounder, multibeam and acoustic water column imaging to study the impact of the Agulhas and Madagascar currents on the slope sedimentation. Widespread contourite bodies on the upper and middle slope as well as semi-stationary eddy systems related to the continental margin structure have controlled presence and shifts of depocenters during the last 15 million years, revealing a rich history of current activity as part of the global conveyor belt in conjunction with the storage of terrestrial signals from riverine sources. Deciphering these archives, however, will require an advanced understanding of the sediment dispersal from seismoacoustic mapping of sedimentary units. First results from several study areas reveal also an intimate link between changes in sea level and sediment dispersal, being further complicated by the persistence of widespread continuous Pleistocene dune fields on the inner shelf off Limpolo, which seem to a larger extent

inhibit sedimentation on the upper slope, guiding sediment onto an outer terrace, where sedimentation occurs under strong control of the Agulhas current. Off the Zambezi river, a wider shelf, starved of sediments, supports the NE-directed sediment transport, feeding the Mozambique Channel as well as the Madagascar contour current, which in turn builds up widespread contourites in front of the Zambezi river. While the contourites accumulate mainly due to the shape of the shelf break, they lack a causal relationship to the riverine input. On the Northern Madagascar slope, strongest interaction of terrigenous sediment input occurs in intermediate water depths, where complex drift bodies develop in the vicinity of major canyon systems.

Storlazzi, Curt D.

Spatial and Temporal Variability in Coastal Grain Size due to River Floods and Storm Waves

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Surficial sediment grain size was sampled using US Geological Survey “Eyeball” digital grain-size cameras at 8 beach and 42 seabed sites spaced every 400 m in a 2.4 km-wide grid off the mouth of the San Lorenzo River in northern Monterey Bay, CA, USA. The goal of this effort was to determine the impact of river floods and winter storm waves on the temporal and spatial variability in surficial seabed sediment grain size during the 2008 and 2009 winters. Northern Monterey Bay is an energetic (wave heights 1-9 m), emergent, rocky coastline where small, steep rivers and streams drain faulted sedimentary rocks; the San Lorenzo River discharged approximately 6,500 metric tons of sediment during the 2008-2009 winter, almost all of which came during three floods in a 20-day period. Mean grain size at the beach and nearshore sites ranged from 203 to 1055 μm and within-site variability ranged from 62 to 1284 μm . Overall, mean grain size and grain-size variability from the beach out to depths of 20 m were greatest during the winter when large storm waves were eroding the beaches and impacting the seabed, and lower across the study area in the quiescent summer; there did, however, appear to be a decrease in grain size between the 5 m and 20 m isobaths following river discharge events. Mean grain size and grain-size variability decreased from the beach out to water depths of 5-10 m, however these parameters increased between the 10-20 m isobaths. Although the decrease from the shoreline out to the 10 m isobath follows the trend of decreasing grain size with decreasing wave energy, the increase at greater depths suggests seabed stratigraphy influenced surficial sediment grain size, with a finer-grained sedimentary layer on the order of 300 μm thinning offshore and periodically exposing an underlying coarse-grained lag on the order of 900 μm . The increase in grain size and grain-size variability during the winter can be explained by the finer-grained surficial sediment layer being resuspended by energetic

waves and advected offshore, resulting in the exposure of the coarser-grained lag. These findings highlight (a) the response of the beach and inner shelf to discharges from a small mountain river, where the sediment is generally discharged concurrently with energetic oceanographic conditions, and (b) the widely temporally- and spatially-varying sedimentary nature of energetic emergent shorelines that characterize much of the Pacific basin. Given that the inner shelf is the conduit between the coast and mid-shelf depocenters, documenting the sedimentologic nature of these environments is key to understanding the linkages between terrestrial sediment sources and marine sinks.

Straub, Kyle M.

Scale dependant compensational stacking of channelized sedimentary deposits

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Compensational stacking, the tendency for sediment transport systems to preferentially fill topographic lows, thus smoothing out topographic relief is a concept used in the interpretation of the stratigraphic record. Recently, a metric was developed to quantify the strength of compensation in sedimentary basins by comparing observed stacking patterns to what would be expected from simple, uncorrelated stacking. This method uses the rate of decay of spatial variability in sedimentation between picked depositional horizons with increasing vertical stratigraphic averaging distance. We explore how this metric varies as a function of stratigraphic scale using data from a physical experiment, stratigraphy exposed in outcrops, and numerical models. In an experiment conducted at Tulane University’s Sediment Dynamics Laboratory, the topography of a channelized delta formed by weakly cohesive sediment was monitored along flow-perpendicular transects at a high temporal resolution relative to channel kinematics. Over the course of this experiment a uniform relative subsidence pattern, designed to isolate autogenic processes, resulted in the construction of a stratigraphic package that is 25 times as thick as the depth of the experimental channels. We observe a scale-dependence on the compensational stacking of deposits set by the system’s avulsion time-scale. Above the avulsion time-scale deposits stack purely compensationally, but below this time-scale deposits stack somewhere between randomly and deterministically. The well-exposed Ferris Formation (Cretaceous/Paleogene, Hanna Basin, Wyoming, USA) also shows scale-dependant stratigraphic organization which appears to be set by an avulsion time-scale. Finally, we utilize simple object based models to illustrate how channel avulsions influence compensation in alluvial basins.

Syvitski, James P.

Source to Sink Numerical Modeling of Whole Dispersal Systems

Syvitski, James P.¹

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Numerical earth-surface models come in all shapes and sizes, depending on the intended goals, scales of interest (space and time), and the processes and parameters to be simulated. Three approaches are common: 1) Landscape and/or stratigraphic evolution models (LEM or SEM) are used to simulate longer geological time and space scales. Often LEM or SEM models involve geophysical feedbacks such as isostasy, eustasy, faulting and other tectonics, and climate change. Often these model incorporate post-depositional process such as compaction and cementation. These models may be steady state (e.g. diffusive in nature), or event-based scaled to deal with geological scales. The models may be limited to siliciclastic or carbonate regimes, and be either abiotic or biotic in nature. Source-to-sink LEM & SEM models provide quantitative evaluations on the material fluxes from highlands to the deepwater, including production, transport and sequestration. 2) Morphodynamic (MD) models simulate the evolution of the transport pathway (e.g. surface elevation changes) with dynamical feedback to fluid transport processes. MD models involve fluid dynamics, geodynamics and ecodynamics, with and without human interaction. At their simplest, MD models may employ advection-diffusion schemes such as the St. Venant shallow water equation. MD models are used to model complex Newtonian to non-Newtonian fluids. MD models are useful in signal tracing, and the transmission and attenuation of perturbations. 3) Sediment transport (ST) models are used to simulate a single event or otherwise short term events. Here the emphasis is on the dynamics of the flow and the material flux along a pathway. Complicated transport models may include multiple domains such as fluvial, coastal and marine environments. ST models involve computational fluid dynamics (CFD) such as Reynolds-averaged numerical simulators, large-eddy simulators, and direct numerical simulators where all the scales of turbulence are considered. ST models may involve a complex array of CFD concepts including Boussinesq and non-hydrostatic approximations, finite difference, finite volume and finite element modeling of explicit and implicit solutions, and Eulerian, Lagrangian or particle-in-cell approaches. ST models have been used to better understand the role of coherency between terrestrial and marine forcing (e.g. river floods and ocean storms). The Community Surface Dynamics Modeling System (CSDMS) develops, integrates, disseminates & archives software to define the earth's surface dynamics by simulating the movement of fluids, sediment & solutes through landscapes, seascapes, and their sedimentary basins. CSDMS produces protocols for an international repository (> 150 models, 3.5 million lines of source code) of community-generated, evolving, open software, and provides the cyber-infrastructure to rapidly distribute its software tools and models in aid of application

and education uses. Importantly CSDMS offers S2S scientists a complete modeling environment with its model coupling tool allowing language interoperability for unstructured, structured and object-oriented code, framework interoperability, structured and unstructured grids.

Sømme, Tor O.

Use of source-to-sink concepts to provide insight to the stratigraphic record

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Studies of modern and ancient stratigraphic sections provide only little and restricted information on the sediment transport system that was involved in its formation. Better understanding of paleo sediment routing systems may increase our knowledge of how, where and when sediment is dispersed from catchments, via coastal plains and shelves, to the deep oceans; and how the dynamic interaction between the different source-to-sink segments controls the preserved stratigraphy. Robust understanding of the link between the segments constituting the source-to-sink system is important when considering all time-scales, and may help understand problems related to: (i) the nature of climatic and tectonic signals generated in catchments; (ii) longer-term patterns of sediment storage and release between onshore- and offshore segments; (iii) “reconstruction” of ancient source-to-sink systems in terms of segment morphology and sediment routing guided by modern analogues. Here we will focus on the longer term problems (thousands to millions of years), which are associated with the generation of stratigraphy using examples from the Quaternary Mediterranean and the Cretaceous North Sea. On the scale of thousands of years, sediment is stored and released from the catchment and shelf segments as local intrinsic thresholds are met, causing the system to change its mode of sediment dispersal. This is done by alluvial aggradation and shallow marine progradation followed by subsequent erosion, incision and basinward sediment remobilisation. On such short time scales, climatic and eustatic forcings are key factors controlling onshore-offshore sediment dispersal. On the scale of millions of years, tectonics is the main controlling factor determining sediment generation and preservation. Understanding the paleo landscape back in time may provide information on regional drainage and main sediment transport routes. In addition, it may also provide more detailed information on the type of deposits expected to be present in the basin. For example, a first-order

reconstruction of a paleo catchment may provide information on the transport capacity of the ancient river system, and thereby also the mode of sediment delivery to the ocean basin. In ancient subsurface systems where little data is available, such information may be important for understanding reservoir distribution and internal architecture in depositional units.

Tanabe, Susumu

Strata formation in a tectonically subsiding incised valley: a latest Pleistocene to Holocene example from the Shinano River incised-valley fills, Echigo Plain, central Japan

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The Echigo Plain is on the Japan Sea coast of the island of Honshu and is bounded to the west by the Echigo Plain Western Margin Fault Zone. The Shinano River incised valley lies east of the bounding fault zone and runs seaward, approximately parallel to it. The incised valley deepens to more than 160 m below mean sea level near the coast, deeper than sea-level fall during the Last Glacial Maximum, because of subsidence governed by the fault. The valley is filled with sediments deposited during the last deglacial sea-level rise and mid-Holocene highstand. In this study, we examined the sediment stacking patterns of the incised-valley fill at 1000-year scale by analyzing sedimentary facies and radiocarbon ages from three sediment cores from the Echigo Plain. The latest Pleistocene to Holocene Shinano River incised-valley fill sediments unconformably overlie a basement of late Pleistocene floodplain sediments. The fill sequence comprises sediments of meandering river (~12 cal kyr BP), estuarine (13–9 cal kyr BP), and barrier–lagoon (9–0 cal kyr BP) systems, in ascending order. We identified a maximum flooding surface between the estuarine and barrier–lagoon sediments. Thousand-year isochrons based on radiocarbon ages show that the meandering river and estuarine systems were deposited aggradationally and retrogradationally and the barrier–lagoon system was deposited progradationally and aggradationally. These sediment stacking patterns resemble those of other incised-valley fill sequences in East and Southeast Asia, which indicates that during the last deglacial eustasy was a major factor controlling incised-valley fill sediment stacking patterns in these regions. However, aggradational sedimentation in all three depositional systems is unique to the Echigo Plain and suggests that long-term subsidence at 2.6–3.7 mm/yr is an important factor controlling the 1000-year scale sediment stacking pattern in this tectonically subsiding incised valley.

Upton, Phaedra

Modeling Source-to-Sink systems in New Zealand: The Waipaoa and the Waitaki catchments

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The Waipaoa River catchment on New Zealand's northeastern coast has one of the highest mean sediment yields on Earth of 6780 t km⁻² yr⁻¹ resulting from a vigorous maritime climate, and extremely erodible mudstone argillite lithologies. Over the last 700 years of human settlement these have combined to produce a 7 times increase in landscape erosion. Today's yield is the highest the Waipaoa River has ever carried. Sediment from the Waipaoa River is trapped in actively subsiding tectonic basins on the shelf and mid-slope and one of the challenges of the modeling project is how to correlate modeled sediment yield to offshore records gleaned from cores. Waipaoa River water and sediment discharge have been modeled for the past 3000 years using HydroTrend, a climate-driven hydrological model, and the results compared with floodplain and shelf sediment records (Kettner et al., 2007; 2009). We extend the existing HydroTrend model back to the Last Glacial Maximum (LGM) and investigate changes in suspended sediment load since that time. During the LGM the Waipaoa River catchment covered approximately twice the area, with the river mouth located near the current shelf break. LGM gravels in terraces and in relict shelf deposits indicate that the river had a coarser-grained bedload than during the Holocene highstand phases. Climate proxies suggest that during the LGM and early transgression the region was colder and drier than present (Drost et al., 2007), consistent with the presence of loess and recycled pollen (Berryman et al. 2000; McGlone, 2001). The LGM vegetation was dominated by semi-alpine scrub and grassland (McGlone et al. 1984; McGlone, 2001) with only partial forests, leaving the catchment vulnerable to erosion although not as vulnerable as open pasture today. The LGM to full forest cover transition is a potential window into future millennial-scale landscape response. Preliminary HydroTrend simulations predict that, given a cover of grass and scrub, the suspended sediment flux yielded from the LGM Waipaoa catchment was only 40–50% of modern pasture cover. The larger catchment size is offset by a drier, cooler climate with lower erodibility. Our results suggest that landscape erodibility has been more significant than climate variability with respect to riverine sediment flux to the coast. Current climate-change predictions suggest drier, more variable conditions, in concert with an increase in climatically driven events such droughts and floods. Such events are of significant economical and societal impact but this and earlier studies indicate that greater sediment loads in the Waipaoa can be offset by strategic increases in forest cover. In the Waitaki River catchment, South Island, New Zealand, we

are utilizing ~80 years of historical water discharge readings, climate measurements, sediment rating curves and some short cores from Lake Ohau to calibrate a HydroTrend model of the large glacial valleys and lakes that make up the upper Waitaki catchment. We will then use paleoclimate proxies to extend the models back in time. Our preliminary models suggest that the Lake Ohau record is dominated by events, mostly large northwesterly storms, rather than by seasonal variation.

Verstraeten, Gert

The changing anthropogenic impact on sediment source-to-sink transfers since the introduction of agriculture

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From the introduction of agriculture, humans have impacted the processes and intensities of sediment production, transport and storage. Throughout the Holocene, this external driver has become more and more the dominant control on the sediment dynamics of the hillslope-fluvial system, overwhelming the impact of other external controls. However, no linear relation between the intensity of human presence and the magnitude of change in sediment dynamics can be observed due to the importance of intrinsic controls on sediment propagation. Especially the buffering capacity of slopes and floodplains can be held responsible for this non-linearity, as both sinks store the produced sediment temporarily. Several concepts have been developed over the last few decades to explain the complex behavior of sediment transfers in the combined hillslope-fluvial system. However, none of these concepts seems to hold universally when reconstructing historical sediment dynamics for contrasting environments, as is illustrated with case-studies from a range of environments in Belgium, Turkey and the USA. The sediment cascade model suggests that sediment is transferred from one sink to another, slowly moving down the landscape. This can be valid in the case of a single disturbance event (e.g. in the USA), but it fails to explain sediment transfers in a landscape with persisting pressure. Here, the time lag between colluvial and alluvial sediment storage can often be explained by an increased slope-channel coupling related to land use (e.g. in Belgium). However, for Turkey, persistent land use did not result in similar sediment dynamics due to soil exhaustion. Field data also show that sediment delivery ratios changed through time, questioning the use of constant SDR-values.

Furthermore, the complexity of human impact on fluvial systems has clearly increased through time. In the past, it was mainly aerial land use change that controlled sediment fluxes, but through time localized interventions became dominant. For instance, increased construction of reservoirs

and levees (decoupling rivers and floodplains) in the 20th century made that - on a global scale - reservoirs have replaced floodplains as the major sediment sink in river basins. As a result, unraveling the human impact from current-day sediment archives and predicting the impact of future human disturbances on river and sediment behavior remains a major challenge. This has important implications for interpreting the marine and deltaic sediment stratigraphy, as well as contemporary sediment yields, in terms of changes in the drivers of environmental change. For instance, our European sediment budget suggests that agricultural land use is no longer the dominant source of sediment export to the ocean, contrary to what is often suggested. Numerical modeling of past and future sediment fluxes in response to spatially and temporarily varying patterns of human impact, climate change or other controlling factors, in combination with multi-temporal sediment budgets, may provide a solution as case-studies from Belgium and Turkey illustrate.

Vis, Geert-Jan

From floodplain to abyssal plain: depocentre migration of a large European river

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Studies of sediment depocenter migration in late Quaternary fluvial-marine depositional systems provide thorough insights in sea level, tectonic and climatic controls of sedimentation patterns in depositional systems at continental margins. Here we present the first quantification of sediment depocenter shifts of the Tagus River (a major southwest European river) controlled by large relative sea-level changes and mid Holocene climatic aridification. The Lower Tagus River is located in a bedrock-confined setting and debouches into the Atlantic Ocean. Offshore, there is a narrow continental shelf (30 km), which is connected by submarine canyons to a vast abyssal plain. We used an extensive sedimentological and paleoenvironmental dataset derived from 385 terrestrial and 11 marine cores, constrained by a well-calibrated chronology based on 127 radiocarbon dates. Using Schlumberger Petrel 2009 software, the volume of fluvial and marine deposits was calculated for sediment budgeting across the Tagus fluvial-marine system for the last 12 ka. The quantitative reconstruction of 4D sediment volume (distribution in time and space) shows that in different parts of the Tagus fluvial-marine depositional system: (1) during the last glacial period, when relative sea level was low, sediment bypass favored sedimentation on the Tagus Abyssal Plain; (2) during relative sea-level rise, the main sediment depocenter shifted towards the shelf, where it arrived at 13.5 ka. Soon after, at about 12 ka, the main depocenter migrated to the Lower Tagus Valley; and (3)

during relative sea-level highstand, the main depocenter was located in the Lower Tagus Valley with a dramatic higher (up to 2.5 times) sediment flux and storage, favored by more arid climate conditions and land-use changes. The main conclusions which can be drawn from this study are that: (1) the deep incision of the Lower Tagus Valley and the efficient sediment bypass show that besides catchment size (upstream control) and sea level (downstream control) the width of the shelf is an important downstream control on incision depth and width through fluvial gradient and landward extent of regressive erosion; (2) the utilized multi-disciplinary and multi-proxy approach has clearly demonstrated the shelf region—being at the confluence of terrestrial and marine processes—to be extremely sensitive to developments in the terrestrial and marine realms. The detailed study of sediment depocentres migrating from the deep-marine abyssal plain to the inland river valley and seaward again has shown to be of great value for the interpretation of sedimentary successions on the continental shelf; and (3) a (semi-) quantitative approach using sediment budgets provides a 4D reconstruction of sediment supply and deposition. Sediment budgeting is a powerful tool to link erosion with deposition on a basin scale, to identify its changes through time and to link land and ocean depocentres. This underlines the importance of an integrated land-ocean study and the quantification of fluvial-marine sediment fluxes to identify effects of e.g. climate change and human impact on depositional systems from source to sink.

Voigt, Ines

A submarine canyon as sink in the interplay of down-slope and along-slope processes – The Mar del Plata Canyon offshore Argentina

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Submarine canyon systems are common morphological features on continental margins. They are both, important natural conduits for the transfer of terrigenous sediments to the deep sea, but also considerable (temporary) sinks. Thereby they significantly control the depositional patterns and transport processes on continental slopes. The Mar del Plata Canyon is located at the continental margin off Argentina in a setting which is characterized (1) by the huge sediment discharge of the Rio de la Plata, (2) by a key location in the intermediate and deep-water global conveyor belt, with both having a major impact on the overall architectural evolution of this margin segment and (3) by the Malvinas–Brazil Current confluence (BMC). This setting causes that the canyon is incorporated into a significant contourite depositional system (CDS) and therefore affected by both, down-slope and along-slope transport and sedimentation processes. To understand the interaction of these processes, the canyon was studied by means of coring

and seismo-acoustic surveys. The Mar del Plata Canyon is a relatively straight, deeply incised feature. The canyon head is located on a major terrace at a water depth of ~ 1000 m. From there on, the canyon extends for ~ 110 km down to a water depth of ~ 3900 m. Seismo-acoustic profiles crossing the canyon show dominant erosive processes at its flanks, but well-layered sedimentary units on a small terrace in the north-eastern part. Nearby that small terrace the sediment cores from the thalweg of the canyon show unusual high accumulation rates up to 100cm/kyr during the Holocene. Presumably in that area the canyon interacts with the deep-water circulation and the sediment material is mainly derived from contourites and related deposits. Moreover in the same sediment cores intercalation of (cyclic) fine-grained turbidites reveal climate controlled shifts in the sediment supply during the Holocene and could be related to changes of the erosion/weathering regime in the hinterland. Therefore, the Mar del Plata canyon allows to evaluate the sedimentary imprints of the interplay between gravity-driven and current-driven transport mechanism and to decipher the dominant processes in relation to climate changes. This information can be used to improve the basic understanding of submarine canyons as a sink in the interplay of paleoclimate and/or paleoceanographic variations.

Walsh, John P.

Strata Development on the Poverty Bay Margin: Insights from Sedimentological, Radiochemical and Geophysical Data

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3. School of Oceanography, University of Washington, Seattle, WA, USA

Margins with high sediment supply can produce thick sequences that contain detailed information on the controlling sedimentary processes. However, the stratigraphic record must be unravelled to understand the terrestrial and marine processes influencing sedimentation. As part of a recently initiated NSF Margins Source-to-Sink project, a combination of sediment-transport observations, coring and numerical modeling is being used on the Poverty Bay margin in northeastern New Zealand to examine strata development. This is a tectonically active and oceanographically energetic margin with a significant sediment supply (~ 15 Mt/y), and here, the source and sink are anticipated to be closely coupled because of the severity of flooding and the short river course. Previous research shows that the Waipaoa fluvial sediment load is stored in one outer shelf and two mid-shelf depocenters, building thick (>40 m) deposits, and a fraction of the load is escaping to the surrounding slope. A comprehensive dataset of core,

chirp-seismic, and multibeam information helps explain how this complex system has developed. Decadal (Pb-210) and millennial (seismic-derived) sediment accumulation rates illustrate morphologic evolution of the margin while x-radiograph images reveal the stratigraphy in high-resolution. Integration of available data indicates that across- and off-shelf sediment transport and accumulation has occurred throughout the Holocene as tectonic activity has altered the margin. Variable but rapid (>0.3 cm/y) rates of sediment accumulation in shelf and upper slope areas suggest continuous and possibly accelerated accretion. A field effort was initiated in 2010 to make measurements of in situ sediment transport and stratal development over 12 months using deployed instrumentation and time-series coring. Preliminary results from multicores collected on three of four planned research cruises reveal that strata reflect a complex interplay of fluvial supply and oceanographic processes. Short-lived radionuclide data (Be-7, Th-234) indicate deposition is consistent with decadal and millennial rates of storage. However, tripod measurements show short-term seabed dynamics (i.e., locally measured bed elevation changes) may differ dramatically from longer-term sedimentation patterns. The complete dataset will give valuable insights into the sequencing of sedimentary processes.

Wang, Houjie

Hyperpycnal flows at the Mouth of Huanghe (Yellow River): Past, Present and Future

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Rapid increase in the Huanghe (Yellow River) sediment yield from the Loess Plateau at 3000 yr BP was caused by the human interventions. As a result, the sediment load delivered to the sea increased to approximately ten folds of the pristine level (100 MT/yr) with suspended sediment concentration (SSC) high up to 25 kg/m³ at the river mouth that is favorable for the formation of hyperpycnal flows in the coastal environment. Results from cruises in the 1980s and 1995 suggest that hyperpycnal flows off the Huanghe mouth are maintained by high concentration of river sediment and modulated by tides. The hyperpycnal flows start at the slack before high water, and during the developing stage the bottom suspended sediment concentration increases rapidly while the salinity drastically decreases and the median grain size of suspended particles within the hyperpycnal layer increases, creating a sediment-stratified water column due to the straining effect from tides. Because of the momentum dissipation, they begin attenuating at the slack before low water while the stratification of the water column becomes collapsed owing to the enhanced tidal mixing. As a result, both the sediment concentration and median grain size of suspended particles

within bottom layer decreases. As coarser sediment particles are dumped on the seafloor, the hyperpycnal flows are no longer maintained because of density loss. Nearly 90% of the river-laden sediment is delivered to the sea during the period when the hyperpycnal flows are prominent. Given the extremely high SSC at the river mouth during the past thousands of years, hyperpycnal flows have been a dominant pattern for the terrestrial sediment dispersal in the coastal ocean. During the past several decades, construction of large reservoirs and soil-conservation practices within the river basin have reduced the sediment flux to the sea by ~90% and increased the grain size of suspended sediment delivered to the sea (30 μm now versus 18 μm before in median grain size). Scouring of the channel in the lower reaches has added a new sediment source to those derived from the loess region of the middle reaches. Those conditions are unfavorable for the formation of hyperpycnal flows at the river mouth. Observations from cruises after the operations of the Xiaolangdi Reservoir, suggest that buoyant hypopycnal plumes, rather than hyperpycnal plumes, have occurred at the river mouth since the dramatic changes in concentration and grain size of suspended sediment discharged to the sea. Climate change (ENSO events impacted regional precipitation) and human activities in the river basin have altered the 'Source-to-Sink' pattern of the Huanghe sediment as indicated by the infrequency of hyperpycnal flows at the river mouth. The Huanghe has become an artificially regulated river, and the delta, similar to the example of the Nile, will be starved. As a result, the delta erosion by monsoon activities will probably be a dominant source for sediment exporting to the distal mud deposition on the continental shelf. The perturbations from climate change and human activities propagate throughout the sediment dispersal system from source to sink.

Warrick, Jonathan A.

A Summary of the Source-to-Sink Sediment System of the Semiarid Santa Barbara Channel, California

Warrick, Jonathan A.¹

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The Santa Barbara Channel is an appealing – yet challenging – region to investigate sediment source-to-sink, owing to its active tectonic setting, small mountainous watersheds, episodic delivery of sediment, and accumulation of sediment in several marine settings. Sediment yield in the drainages of the Western Transverse Ranges is up to an order of magnitude greater than other drainages of Southern California, which is attributed to rapid rates of uplift (1 to >5 mm/yr), weak lithology, and impacts from land use changes such as cattle grazing. Episodic events define sediment export to the sea, and over half of the 20th and 21st century sediment load has been discharged during events with recurrence intervals greater than 10 yr. These rare, yet important, events are commonly related to El Niño–Southern Oscillation (ENSO) conditions, and annual rates of sediment export can exceed 50 Mt. These large, rare events produce massive deltaic deposits of sand and gravel at the Santa Clara River mouth, and these topographic bulges (or

“waves”) of sediment exhibit both advective and diffusive morphologic changes with time after the event. Coarse sediment is eventually transported down the littoral cell to the Hueneme and Mugu Canyons, which have numerous violent turbidity currents each year and export into the Santa Monica Basin. Fine sediment from episodic river pulses can be observed in positively buoyant (hypopycnal) turbid plumes extending tens of kilometers from the river mouths. However, observations suggest most of the fine sediment load settles rapidly toward the seafloor and forms negatively buoyant (hyperpycnal) gravity currents. These hyperpycnal plumes have been observed immediately offshore of the Santa Clara River mouth, which discharges over half of its sediment load at suspended sediment concentrations >40 g/L, and >95% of its load at >1 g/L. The shelf offshore of the Ventura and Santa Clara Rivers is broad and low sloped (less than 0.004), which suggests that fluid-mud gravity currents could transport across this shelf, albeit slowly (~10 cm/s) and only with adequate wave-generated shear stress and sediment loading. In light of this, there is considerable fine sediment accumulation both on the shelf and within the Santa Barbara Basin.

Weight, Robert R.

THE HOLOCENE TEXAS MUD BLANKET: A RECORD OF MAJOR CHANGES IN SEDIMENT DELIVERY AND REDISTRIBUTION

Weight, Robert R.¹; Anderson, John B.¹; Fernandez, Rodrigo¹

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The Texas Mud Blanket (TMB) is a large (~300 km³) depocenter that formed after the last (LGM – MIS 2) eustatic lowstand on the central Texas shelf, an area where no large rivers occur. The evolution of the TMB is determined from 26 new radiocarbon dates and from ~3000 km of high-resolution 2D seismic data. Sediment flux (km³/ka) was calculated from this combined dataset. XRD analysis reveals that the origin of sediments accumulated in the TMB are mainly local, coming mostly from the Colorado and Brazos rivers, with the Mississippi River having been a secondary source. A large depression between the MIS 3 shoreline on the west and a linear reef trend on the east created accommodation for the TMB. The ancestral Colorado and Rio Grande deltas are the northern and southern boundaries, respectively. Between LGM and ~17 ka, terrestrial and lagoonal sediments filled the deepest parts of the depocenter. From ~17 to ~9 ka was a time of rapid eustatic rise and low sedimentation (flux= 0.4 km³/ka). At ~9 ka, sediment flux to the mud blanket dramatically increased to 41 km³/ka. During this time, older, falling stage Brazos and Colorado deltas were being ravaged, producing an estimated 61 km³ of sediment, of which an estimated 58.3 km³ was silt and clay and contributed to growth of the TMB. By ~5.5 ka, Texas was experiencing maximum temperature and minimum precipitation for the Holocene, which led to a reduction in sediment accumulation in the TMB. During the last 3.5 ka the mud blanket experienced remarkable growth, having accumulated 172 km³ of

sediment, accounting for 57% of its volume. Mineralogical data indicate that most of this sediment that comprises the TMB was derived from the Colorado and Brazos rivers and did not vary significantly over the time of its evolution. This calls for a dramatic increase in the sediment yields of these rivers during the late Holocene, which is best explained by a more variable climate at this time and elimination of accommodation space within the river valleys as they were filled to capacity.

Wheatcroft, Robert

Timing is Everything: The Role of River-Ocean Coincidence in Ocean Sediment Dispersal and Accumulation

Wheatcroft, Robert¹

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The concept of river-ocean coherence, whereby peaks in fluvial sediment export coincide with specific oceanic forcing, provides a powerful means to understand the dispersal and accumulation of sediment in the coastal ocean. Although river basin size is the overarching determinant of coherence (large river = low coherence and vice versa), other factors play an important role. For example, by slowing fluvial sediment flux to the ocean, river impoundments have the effect of decreasing coherence. In contrast, a high storm frequency essentially expands the time window that leads to coincidence. This talk will examine generic controls on river-ocean coherence and review several well-studied dispersal systems around the world that will collectively highlight the importance of timing.

Wiberg, Patricia L.

Mechanisms for Entrapment of Sediment Reaching the Coastal Ocean

Wiberg, Patricia L.¹

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Transfer of sediment from rivers to the ocean is regulated by several mechanisms that trap and store sediment in the coastal ocean (inner-mid continental shelf). Specific mechanisms depend on the way that sediment is delivered to the coastal ocean, e.g., sediment concentrations and durations of river discharge to the ocean; coherence of river flooding and ocean wave and current conditions; shelf morphology; and storm/flood frequency. On the sandier inner shelf, fine sediment can be trapped by migrating bedforms and sand deposition. Armoring processes contribute to retention of this fine sediment in the high-energy conditions of the inner shelf. Recent studies suggest that large quantities of fine sediment reaching the muddier mid shelf are likely to be delivered by wave-supported sediment gravity flows that follow large river discharge events. Consolidation of the resulting deposits can allow fine sediment to persist at shelf depths that experience at least episodic, relatively high-energy conditions – depths much shallower than “storm wave base”. Whatever the trapping

mechanism, timing and magnitude of subsequent depositional and reworking events is critical to long-term retention of fine-grained sediment in the inner-mid shelf.

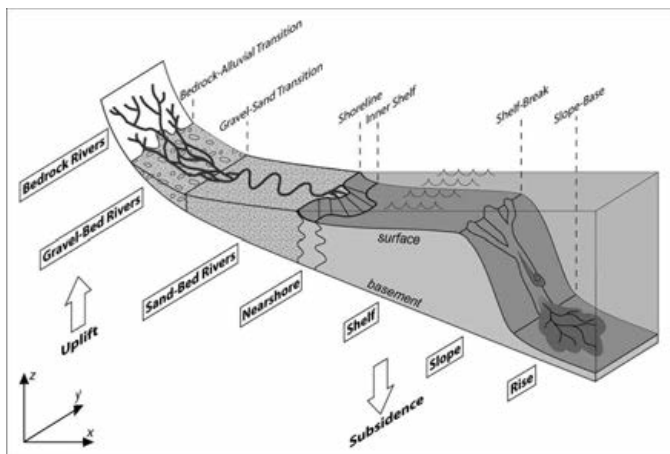
Wolinsky, Matthew A.

Source to Sink Sediment Dynamics: Making Models Talk to Data

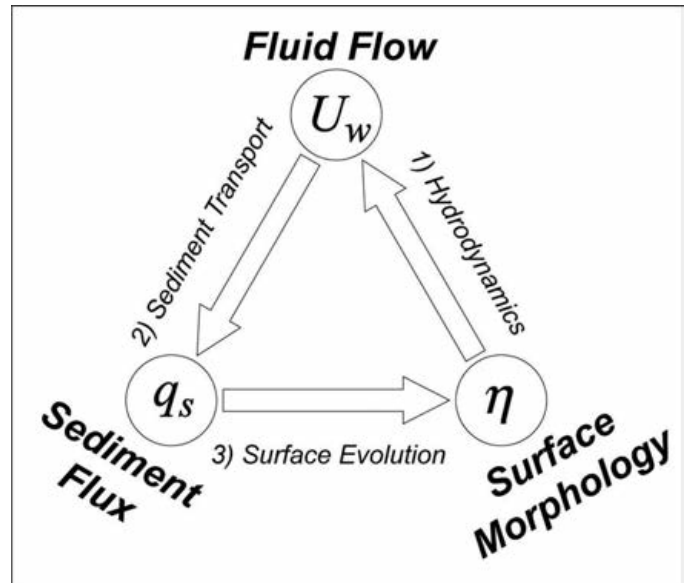
Wolinsky, Matthew A.^{1, 2}; Swenson, John B.²; Paola, Christopher²; Voller, Vaughan R.²

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2. University of Minnesota, Minneapolis/Duluth, MN, USA

Source to sink (S2S) systems at continent scale form a linked array of environments (Fig. 1), and system-wide coupling is essential to problems ranging from geodynamics on Myr timescales to event-response on annual timescales. Modeling is a powerful tool to attack these problems, but unless models are accessible to data their results may be only pretty pictures. Here we develop a S2S model for terrestrial (bedrock, alluvial) environments sculpted by rivers and marine (shelf, deepwater) environments shaped by waves and currents. Our event-based morphodynamic approach upscales hydrodynamics and sediment transport into flux laws governing surface evolution on geologic timescales (Fig. 2). Upscaling makes geodynamic-scale problems accessible to modest computational needs, but also expresses model parameters in terms of fundamental observables rather than “transport coefficients” (making the model accessible to data). We use extensive data from two extant S2S systems, the Amazon and Waipaoa, to illustrate how models can be calibrated at event-to-Holocene scale and then used to predict response to tectonic-climatic forcing on scales up to Myr.



S2S Environments, Processes, and Boundaries. (Note: A preliminary version of this figure appeared in the GeoPRISMS Science Plan.)



Fundamental morphodynamic feedback loop. Geomorphic transport laws can sometimes reduce to a closed system for surface evolution. However fluid-flow and sediment-flux indicators are often far better preserved in the sedimentary record than is paleotopography.

Xu, Jingping

Modes of Suspended Sediment Transport in Hueneme Submarine Canyon, Southern California

Xu, Jingping¹

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Submarine canyons are known conduits for transporting sediment and other particles from coastal waters to ocean basins, thus playing a key role in source-to-sink systems. Two ADCPs (one upward-looking and another downward) measuring velocity profiles at 190 m water depth for 6 months (September 2007 - March 2008) in Hueneme Canyon provided data to characterize the three modes of suspended sediment transport (mean, tidal, and turbidity currents) along the canyon. Below the canyon rims, the mean (time average of the 6-month time-series data) current of <3 cm/s is generally downcanyon and becomes nearly insignificant near the canyon floor. The co-spectra of along-canyon tidal currents and sediment concentrations indicate an upcanyon transport at the dominant semi-diurnal frequency, contradicting the asymmetry of the semi-diurnal currents near the canyon floor that appears to favor downcanyon transport. This discrepancy seems to be caused by the phase lag between tidal currents and the timing of the turbid plumes. Impulsive sediment transport events resembling turbidity currents were observed four times during the 6-month period. The maximum speed of these turbidity currents reached almost 300 cm/s. Within the 2-hour duration of one turbidity current event, a total of 69,000 metric tons (46,000 m³) of sediment was transported downcanyon through the bottom 20 m (turbidity current thickness) of the 160 m wide thalweg at the mooring site. The transport during this single event is more than double the mean transport through the cross-section of the whole thalweg for the entire 6-month deployment (33,000 metric

tons), of which the majority are lighter particles (e.g., biological flocs) that tend to stay in suspension for a long period of time.

Yang, Rick

The temporal variability of particle composition in the river plume of a small mountainous river

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River plumes are important pathways for particulate terrestrial matters to enter the sea. Studying how the suspended particle composition of the river plume influenced by the tide, wave, wind and discharge is an important issue in the Source-to-Sink research. This study tries to find out the particulate component variability of river plume when the river water enters the sea. The component of river plume was observed by using a CTD and LISST-100 on board R/V Ocean Researcher III at the Gaoping River mouth from August 27 to 28, 2006 and May 23 to 24, 2008. We collected upper-column data and used the EOF technique to analyze the correlations among the structures of grain-size groups of 32 suspended sediment particles (between 1.25-250 μm), salinity and water temperature on the hourly basis. The EOF method can effectively distinguish different modes of the grain-size variability in the river plume affected by different environmental factors. Since in the 2006 data set the 1st two eigenmodes explain over 90% of the correlations, only these two modes are presented in this abstract. The first eigenmode explains about 70 % of the correlations. This mode distinguishes the grain-sizes classes into two groups. The coarser (3-250 μm) group is associated with the high water temperature and low salinity. In this scenario, the river effluent lowers the salinity and increases the water temperature. This mode suggests that the coarser group is of terrestrial origin, and is associated with the river plume. And we used the eigenweight's zero-crossings from the first eigenmode to determine the thickness of the river plume as co-defined by grain size, salinity and temperature. The second eigenmode accounts for about 20 % of the correlations. This mode describes the dominant influence of water temperature affecting the finest grain-size classes (< 3 μm). When the colder water from submarine canyon wells up, the surface water temperature decreases, but the concentrations of the finest grain-size classes increase. We also used the eigenweight's zero-crossings from the second eigenmode to determine the upper boundary of the influence of the submarine canyon water. Similar results appeared in the 2008 data set. Sometimes the sampling station was not affected by the river plume. In this case, the 1st eigenmode describes the dominant influence of water temperature affecting the finest grain-size classes. The 2nd eigenmode is the submarine canyon mode similar to that of 2006. We used the eigenweight's zero-crossing from the river plume mode and the submarine canyon mode, to determine the lower boundary of the plume domain and the upper boundary of the submarine canyon domain. The results

suggest that the grain size classes coarser than 3 μm size-classes are terrestrial suspended sediment exported by the river plume. The thickness of the river plume ranges from 2 to 15 m affected by the tide and discharge. The river plume in 2006 is thicker than that of 2008, because the discharge in 2006, 2008 were 210.4 and 71.97 (cms), respectively. The grain sizes finer than 3 μm size-classes in the water column come from the submarine canyon below, whose effect can reach as shallow as 10 m below the surface especially under the offshore-directed wind condition.

Yang, Shouye

The sediment source-to-sink patterns in large drainage basins and marginal seas: the Changjiang (Yangtze River) example

Yang, Shouye¹

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The mega-rivers originated from the Himalayan-Tibetan Plateau transport huge amount of particulate and dissolved matters eroded from the plateau and its surrounding regions into the marginal seas of Asia and, therefore, exert a great control on marine sedimentation and biogeochemical cycle. The Changjiang (Yangtze River) is the third longest river in the world and the fourth largest one in terms of its water discharge. It is obvious that the sediment source-to-sink (S2S) pattern of the Changjiang is significantly different from those of well-known MARGINS sites (New Guinea and New Zealand), and widely-documented island rivers such as the Kaoping River in Taiwan. The sediments transported by the Changjiang are mostly trapped in the delta and estuarine area and some escape to the inner shelf of the East China Sea by coastal current. Nevertheless, the sediment S2S process of the Changjiang has been significantly changed because of rapidly increasing human impacts on the drainage system over the last decades, such as the water impoundment of the Three Gorges Reservoir. The recognition of flux and fate of the Changjiang-derived sediment into the East Asian marginal seas is therefore of great significance for the understanding of the global S2S pattern of terrigenous materials into the sea and the river-sea interactions. Over the past decade, we have investigated the sediment production and transport in the Changjiang drainage basin at present and in the Quaternary, and tectono-climate control on the river sediment S2S process. The sediment S2S processes in the present-day's Changjiang drainage basin and marginal seas were examined, and the ultimate sources of the fluvial sediments were identified by using various sedimentological and geochemical proxies including REE and Sr-Nd isotopic compositions and age patterns of detrital zircon and monazite grains. Our research results revealed that source rock compositions and chemical weathering intensities in the drainage basin account for the compositional variations of the modern Changjiang sediments. The bulk Sr-Nd isotopic compositions and age spectrum of zircon and monazite from the Changjiang sediments provide good constraints on sediment recycling and evolution of

weathered upper continental crust in the Yangtze Craton. The core data from the East China Sea revealed that the Changjiang-derived sediments played an important role in the formation of sedimentary strata in the East China Sea during the late Quaternary, forming one of the largest deltas and of the widest continental shelf in the world. The combined influences of climatic variability, sea-level changes, oceanic circulation and anthropogenic activities on the production, transport, deposition and preservation of the Changjiang sediment in the East China Sea were recognized, and thus, the late Quaternary S2S pattern of the Changjiang sediment was reconstructed.

Yang, Zuosheng

Sediment transport and deposition off the Huanghe (Yellow River) Delta and in the adjacent Bohai Sea and seasonal comparison

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The sediment discharge from the Huanghe (Yellow River) to the sea had been historically about 1.0×10^9 tons annually. Sediment transport and deposition off the Huanghe Delta and in the adjacent Bohai Sea and seasonal comparison were studied based on the hydrographic data collected in winter, 2006 and in summer, 2007 along three transects at three time-series stations off the delta, and at 24 stations in the adjacent Bohai Sea. The summer survey was conducted during the Huanghe artificial flood period. The vertical structure of the water column illustrated that the waters was highly stratified. The Huanghe diluted water from the river mouth in the upper water layer dispersed widely, covering most part of the southeastern Bohai Sea, but was limited within 20 km off the coast in the middle and bottom layers. The suspended sediment concentration (SSC) < 5 mg/L occupied most of the study area. The SSC > 10 mg/L had very limited zonal distribution along the coast. Two centers of high SSC were found in the present river mouth and around the abandoned mouth. The high SSC around the present mouth was caused by the river sediment input. The high SSC around the abandoned mouth was caused by bottom resuspension. The limited dispersion of the high SSC is explained by the barrier effect of the tidal shear fronts along the coast and the highly stratified water bodies in summer. The suspended sediment fluxes (SSF) off the delta coast were 2.4–0.04 kg/m/s in general. The northeastward directed SSF indicated that northeastward transport of the coastal sediment is dominated in summer. The winter survey was conducted during low water and sediment discharges. Before the survey the winter storms with strong northerly winds happened. The homogeneous vertical structure of the water column indicated waters was well-mixed. A zone of high SSC > 100 mg/L with a width of 35 km was found along the coast. Three centers of highest SSC were found around the

abandoned mouths and the present mouth. The SSC in the bottom layer was significantly higher than that in the surface and middle layer, indicating its resuspension origin. The resuspension origin of the three highest SSC centers was caused by the winter storm waves, partially by tidal currents. These three highest SSC centers become sediment sources in winter. SSF off the coast were 36–2.8 kg/m/s. The SSF directed northeastward off the northwest part of the delta, but southeastward along the coast of the recent delta lobe in winter. The SSC and SSF were higher in winter than summer by 1.7–27.1 and 2–122.5 times, respectively. This comparison indicates that the intensity of sediment transport in winter is much stronger than in summer. The massive Huanghe sediment was accumulated in a narrow coastal area in summer, and then resuspended in winter and transported to the offshore area. The coastal area off the Huanghe delta acts as a sediment sink in summer and converted to be a sediment source in winter in response to the seasonal variation of the East Asian monsoon in this region.

Yin, Hang

Effects of Salinity on the Size and Strength of Clay-biopolymer Floccs

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In riverine and coastal environments, sediment transport involves a transition from fresh water to aquatic environments with varying salinity. Moreover, sediments, particularly clay mineral particles, usually interact extensively with the organic substances (e.g., extracellular polymeric substances (EPS) or exopolymers, humic acids, transparent exopolymer particles) to form tenuous, fragile, and porous floccs, via complex clay-polymer interactions (e.g., hydrogen bonding, Coulombic forces, cation bridging, van der Waals attraction, cross-linking). Upon the variation in salinity and ionic strength during the transition, these interactions will result in disturbance to the flocculation-dispersion equilibrium established in fresh water, leading to changes in floc size and strength. This in turn influences sediment transport and dynamics in turbulent waters. A series of laboratory experiments have been designed to investigate how varying salinity affects the floc size and strength by a particle size analyzer that simultaneously enables floc formation and measures their size via a closed fluid circulation system of tunable flow velocity. The floc strength is indirectly estimated from the flow velocity. Two clay minerals, kaolinite and illite, and two biopolymers, xanthan gum and guar gum, are selected as model materials to simulate the naturally water-borne particles. The salinity of the background solution varies from 0 to 10 psu, while two different clay and biopolymers concentrations are selected, 0.02 and 0.05 wt.%, to vary the total suspended sediment concentration (TSSC) in water. It was observed that both floc size and strength generally increase with salinity for the two tested clay. Also, prolonged shearing in

high velocity flows leads to relatively denser flocs with higher strength. These results have their unique practical significance for the prediction and modeling of sediment transport: after entering salt water, the flocs are more resistant to breakup by turbidity and hence settle faster. Larger size and higher density also contribute to fast settling and deposition in the fresh-salt water transition zone. This study provides a more quantitative basis to prior observations.

Youngs, Penny M.

Geochemical fingerprints unravel complex source-to-sink behavior under a variety of forcing conditions: Unparalleled insights from the Ganges-Brahmaputra Delta

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The Ganges-Brahmaputra Delta is part of the largest source-to-sink system in the world, connecting the Himalayan mountain source-terrain with its deep-sea sink, the Bengal Fan. Together the rivers drain 2/3 of the Himalayan range and presently combine to transport > 1 Gt of sediment to the tectonically active continental margin. Two-thirds of this load is sequestered on the subaerial and subaqueous portions of the delta, with the remaining sediment accumulating in the Swatch of No Ground canyon. The dynamic nature of this system – highlighted by two large, avulsive, braided rivers, active tectonic deformation, and variable monsoon climate – means that traditional facies and volumetric analyses alone are not enough to

understand how interacting source-to-sink components have evolved together under a variety of forcing mechanisms. To unravel these mixed source-to-sink processes, we have conducted a variety of geochemical analyses to investigate their use in interpreting changing source inputs, channel avulsions, and the origin of geomorphic features. We present the results of Sr geochemistry ($^{87}\text{Sr}/^{86}\text{Sr}$ and $[\text{Sr}]$), Nd isotopes, elemental analyses, and U-Pb dating of detrital zircons to show that deltaic sediments are not a simple mixture of source inputs. From a variety of geochemical tracers, river channel migration and avulsion history can be discerned as well as episodic sediment inputs from more localized source terrains, all of which are associated with changes in behavior of the mainstem river systems. These data reveal a complex history of sedimentation and delta response to spatial heterogeneity in catchment erosion, temporal climate shifts, and changes in accommodation due to tectonic subsidence. For instance sediments in the subsiding Sylhet Basin are primarily sourced from the Brahmaputra, except when the river avulses to its western path where sediments derived from local sources infill the available accommodation. In addition, damming of the Tibetan reach of the Brahmaputra by glacial ice results in a relative increase of sediments from Himalayan-dominated tributaries such as the Tista. Apparent flood burst deposits, also of Himalayan origin, are also recorded in the delta and must play a role in the geomorphic evolution of that system. Geochemical signatures can be further applied to calculate more precise sediment budgets and determining how sediments loads are partitioned across the continental margin. Overall this work underscores the importance of using multiple geochemical analyses to fully understand the dynamics of source-to-sink components and the linkages between them.