Seabed signatures of gravity flows on subaqueous deltas: recent observations

Charles A. NITTROUER [1*], Andrea S. OGSTON [1], Tina M. DREXLER [1], Cindy M. PALINKAS [2], J.P. WALSH [3] & John S. CROCKETT [4]

[1]School of Oceanography, University of Washington, Seattle, WA 98195 USA
* E-mail: nittroue@ocean.washington.edu
[2]University of Maryland, Cambridge, MD, USA
[3]East Carolina University, Greenville, NC, USA
[4]San Diego State University, San Diego, CA, USA

Rivers that create deltas typically transport large amounts of sediment and have significant vertical relief (e.g., delta-front and foreset regions). These two factors can lead to development of turbid flows with large concentrations of suspended sediment fluid-mud and hyperpycnal flows. Both are important because they transport large amounts of sediment. On broad continental shelves, the flows are responsible for developing morphologic features (e.g., subaqueous deltas, clinoforms), and on narrow shelves they can transport sediment beyond the shelf break. Because the flows have large amounts of sediment, they can dominate the flux of sediment across deltas. The flows also move under the force of gravity and follow different trajectories than sediment transported by physical motions of seawater (e.g., currents and waves). Recent research on deltas has provided knowledge about gravity flows and the resultant signatures recorded in the seabed (e.g., sedimentary structures, radioisotope profiles).

Studies associated with rivers discharging to broad shelves provide insights that are relevant to sediment dispersal associated with large Chinese fluvial systems (Changjiang, Huanghe). On the Amazon continental shelf, energetic tidal and wind-generated currents and waves put much sediment into suspension, and estuarine-like convergent transport creates localized concentrations of suspended sediment that flow from topset to foreset regions as fluid muds (>10 g/l) and cause aggradation and progradation of a clinoform structure. Studies in the Gulf of Papua document the occurrence of similar fluid-mud flows, and delineate the spatial variability of the flows across the clinoform in some cases due to the locations where physical processes focus suspended sediment on the topset, and in other cases where morphologic features (shelf valleys) focus flows on the foreset.

Studies associated with rivers discharging to narrow shelves provide insights that are relevant to the mechanistic operation of gravity flows associated with large Chinese fluvial systems. Intense wave activity can create large concentrations of suspended sediment within a relatively thin boundary layer (cm to tens of cm thick). These turbid waters can then flow down bathymetric gradients, as long as the wave activity keeps the sediment suspended. Such mechanisms have been observed in association with the Eel and Po Rivers. In the former case, most of the sediment discharged is carried to the continental slope (including an adjacent submarine canyon), and in the latter case, much sediment moves to the foreset of the subaqueous delta. In some unusual cases (e.g., river floods), large concentrations of suspended sediment (>40 g/l) may enter the ocean directly (i.e., with freshwater) and flow under the control of gravity. These are more difficult to document, but some studies may be able to demonstrate their existence (associated with the Rhone, Sepik, and Eel Rivers).

Vulnerability assessment of deltas of the Asian monsoonal region

Colin D. WOODROFFE [1]* & Robert J. NICHOLLS [2]

[1] GeoQuest Research Centre, School of Earth and Environmental Science, University of Wollongong, Northfields Ave, Wollongong 2522, Australia
[2] School of Civil Engineering and the Environment, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom
* E-mail: colin@uow.edu.au

Low-lying deltaic coasts are widely recognised to be experiencing coastal erosion and inundation along their ocean margins. The densely populated megadeltas of the Asian monsoonal region are also undergoing rapid changes as a result of human modification of land use both in the catchment and across the coastal plains, including water extraction and diversion. Global climate change presents an additional threat that will make the management of these dynamic systems increasingly difficult.

The potential impacts to which individual megadeltas are exposed are related to the climate drivers and the way in which they are changing, and the susceptibility of different sections of a delta is a function of the geomorphology of the shoreline and the delta distributaries. The adaptive capacity of the population in each delta is relatively low, rendering large numbers of people vulnerable, as tragically demonstrated during Cyclone Nargis. The threat is accentuated as a result of local factors including crustal

flexure, subsidence and compaction, as well as a reduction of resilience that often follows where the natural ecosystems have been transformed for agriculture, aquaculture or urban development.
Subtle geomorphological variations between and within the extensive low-gradient delta plains reflect sedimentation patterns during aggradation and shoreline progradation over the past 6000 years. Substantial impacts result where rivers are dammed and sediment supply is decreased; in some cases, subsidence or compaction exceeds the rate of supply of new sediment, and the longer-term prospect of inundation is increased. The relationship between elevation of the plains surface and flood and storm surge levels is critical for sustainable management of these systems but sediment pathways and the interactions of river, wave and tide processes are rarely understood in sufficient detail.
There are relatively few approaches to assessing the vulnerability of coastlines that are appropriate for application to these multi-stressed sedimentary coasts. Vulnerability in Asian deltas is multi-faceted and assessment needs to address all its dimensions. This paper examines the factors that contribute to vulnerability and reviews the tools that are available to assist the assessment and management of vulnerability.

Cyclonic versus tidal mobilization and sedimentation in the submarine Ganges-Brahmaputra delta, Bangladesh

Hermann KUDRASS [1,4*], Luisa PAMALENGHI [2], Bjoern MACHALETT [3] & Juliane FENNER [4]

[1] MARUM, University Bremen, Leobener Str., 28359 Bremen, Germany
*E-mail: Kudrass@bgr.de
[2] Fachbereich Geowissenschaften, University Bremen, Klagenfurther Str., 28359 Bremen, Germany
[3] Leibniz Institute for Applied Geosciences, Stilleweg 2, 30655 Hannover, Germany
[4]BGR, Stilleweg 2, 30655 Hannover, Germany

The Swatch of No Ground is deeply cut into shelf at the northern Bay of Bengal. The canyon head ends in an amphitheatre-like depression intersecting the prograding foreset beds of the central submarine delta of the Ganges-Brahmaputra. Seismic profiles across the canyon and piston cores from the canyon floor were collected in 1994, 1997, and 2006 using the research vessel SONNE. The canyon floor is covered by several decimeter-thick, parallel-bedded sand-silt-clay sequences draping a slump-derived morphology. Sediments consist of graded, partly laminated fine sand to clay deposited in a mostly anoxic environment. The deep shelf canyon (> 200 m water depth) is therefore a reliable recorder of sediment mobilization and transport at the adjacent shallow (< 20 m water depth) environments of the submarine delta. The high sedimentation rate of up to 50 cm per year allows a correlation of the graded layers with the historic records of tropical cyclones. The repetition of high-resolution seismic profiles and piston coring with a time difference of 12.5 years identifies an additional deposition of 1.75 m in the upper canyon. Detailed analyses of the grain size and the composition of diatom assemblages show that the tropical cyclones are the most effective agent to mobilize, transport, and widely distribute particles from the freshwater/brackish mangrove deposits and from the marine topset beds into the canyon.
In a more general scheme, the results indicate that extreme high-energy events like cyclones exert a much greater influence on the sediment distribution in submarine deltas than daily tidal currents under fair weather conditions.

Megarivers, megadeltas, and the future

John D. MILLIMAN

School of Marine Science, College of William and Mary, Gloucester Point, VA, USA

The ability of a river to create a large delta depends in part on the size of the river, particularly its sediment load. But the extent and growth of a delta also depend on the morphology of the river's watershed, the susceptibility of the river to periodic catastrophic events (such as storms or earthquakes), as well as the preference for floodplain vs. offshore storage, which in part is dictated by regional and local subsidence. Although Amazon River discharges approximately 400 times more sediment annually than the Chao Phyra (1200 vs. 30 (pre-dam) Mt/yr), their deltas are approximately the same size; similarly, the Mekong delta is an order of magnitude larger than the Amazon delta even though it discharges an order of magnitude less sediment.
Superimposed on the geologic and fluvial settings are the impacts of human modification and global climate change, sea-level rise being the most discussed in the popular press, although not necessarily the most critical. High-density urban population centers on the Ganges-Brahmaptura (Calcutta and Dhaka), Nile (Alexandria), Yangtze (Shanghai) and the Mississippi (New Orleans)