11-14-2010

Subsurface Images Shed Light on Past Tsunamis in India

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The 2004 Indian Ocean tsunami caused massive devastation and left a lasting impact along many of the major coastal regions in South Asia, including the coast of Tamil Nadu, a state in the southeastern tip of India. Following the event, sand deposits draped the low-lying areas and buried the muddy sediments of the coastal plain [*Babu et al.,* 2007; *Srinivasalu et al.,* 2007]. In addition, erosional features related to the tsunami, such as channels and scarps, have been observed along many parts of the coast (Figure 1a). This tsunami, along with a recorded history of intense monsoons, has highlighted the need for focused research on the role of extreme events in shaping the geological character of India's coastal plains.

Research on the geological signatures of tsunamis has advanced over the past decades [*Nanayama et al.,* 2003; *Rajendran et al.,* 2006; *Monecke et al.,* 2008; *MacInnes et al.,* 2009] and includes attempts to date paleo-tsunamis [*Meyers et al.,* 1996; *Huntley and Clague,* 1996]. However, few reconstructions of extreme phenomena have a recent analog with which to compare the morphological and sedimentological signatures of a past event [*Babu et al.,* 2007]. Because of its orientation relative to tsunamigenic regions of the Indian Ocean, the southeastern Indian coast presents an ideal region in which to compare both depositional and erosional features of the 2004 tsunami to those within the sedimentary record of prograded coastal plains.

In particular, sedimentary deposits attributed to past tsunamis have been described by *Rajendran et al.* [2006] in the Mahabalipuram region, a prograded coastal plain 55 kilometers south of the city of Chennai in southeastern India (Figure 1). Subsurface investigations of ancient beach deposits reveal erosional signatures of a probable tsunami origin and shed new light on a rich geological archive of past erosional events in this part of the world.

The key to finding past tsunami deposits is first to locate erosional disconformities that truncate normal marine deposits across broad areas. These can be identified and mapped using near-surface geophysics. Ground-penetrating-radar (GPR) imaging has proven to be a successful tool for identifying and mapping sand-rich coastal sequences by providing high-resolution images of the extent and geometry of various boundaries of different rock and sediment types [*Meyers et al.,* 1996; *Babu et al.,* 2007; *Buynevich et al.,* 2007]. GPR sections taken perpendicular to Mahabalipuram Beach reveal a series of three prominent, steep (10°–15°), seaward dipping reflectors, which are interpreted as buried disconformities resulting from past erosional events (Figure 1b). By using geophysical

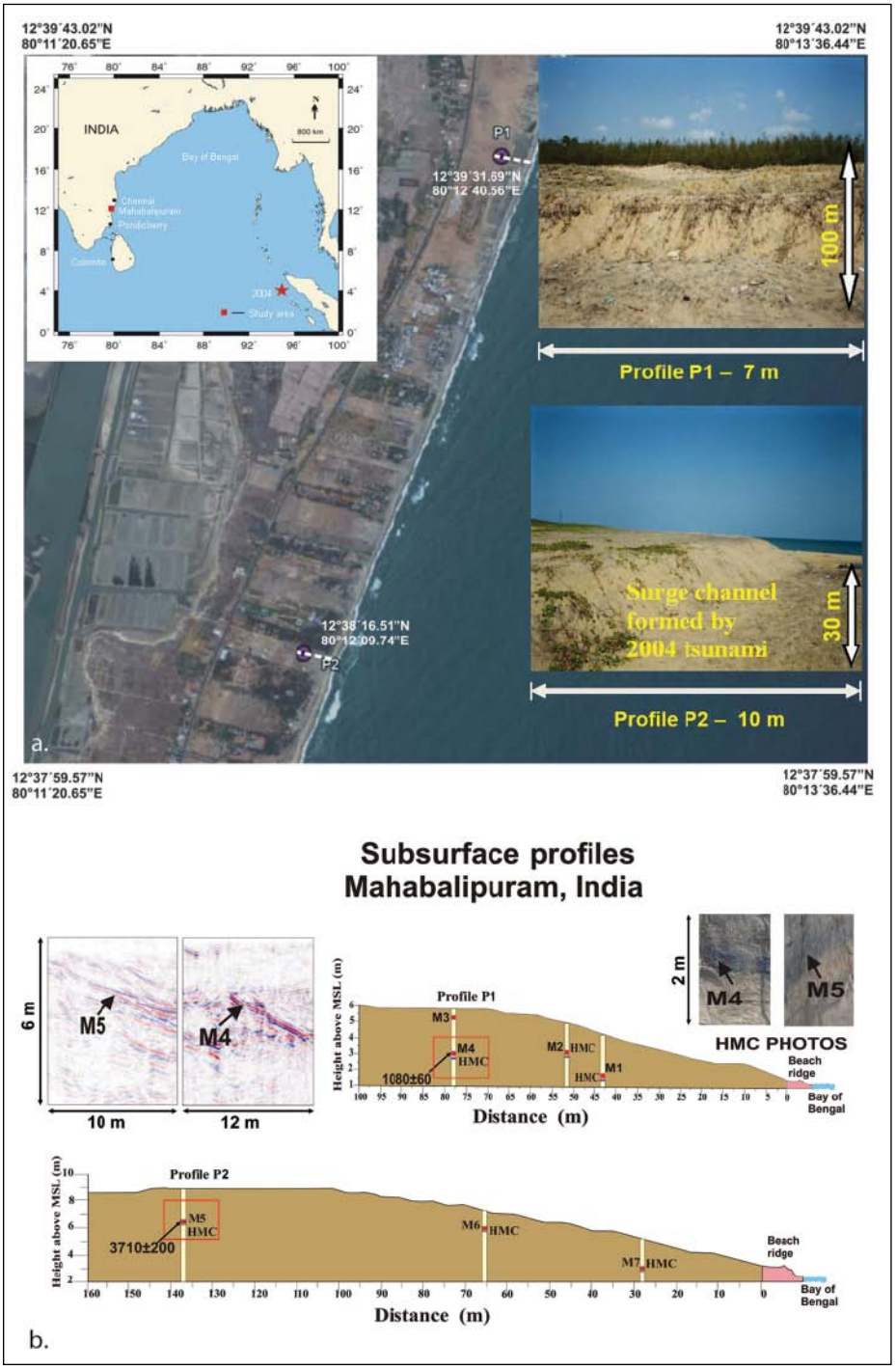

Fig. 1. (a) Study area at Mahabalipuram, with inset at top left showing its location in the Bay of Bengal. The channels pictured in the insets at right are features created by the 2004 Indian Ocean tsunami. (b) Topographic profiles and subsurface data of transect P1 and P2, taken perpendicular to the shore. Also shown are locations of high heavy-mineral concentrations (HMCs; blue lines) and locations of optical dates (red boxes labeled M1—M7, each representing a different unconformity) obtained on sands immediately overlying the HMCs. Segments of the Geophysical Survey Systems Inc. (GSSI) ground-penetrating-radar profiles at top left and right highlight prominent reflections in the upper part of the coastal plain sequence, as outlined by red rectangles in the profiles, which are interpreted as erosional disconformities. The optically stimulated luminescence (OSL) ages of samples associated with anomalies M4 and M5 are indicated in years before 2009. MSL is mean sea level.

surveys, these erosional features are shown to extend laterally over much of the coastline. The broad, lateral extent of these features indicates that erosion was caused by a widespread event rather than by a rogue wave here and there.

Each disconformity coincides with a high concentration of heavy minerals in sediment cores [*Nair et al.,* 2010; *Vijaya Lakshmi et al.,* 2010], the GPR response being due primarily to a high magnetite content (>10%) at these layers. These high heavy-mineral concentrations (HMCs) result from particles that marginally resist erosion because of their weight. Textural properties of the sediments at these disconformities, such as pits and crescents in individual grains, suggest deposition by high-energy events [*Vijaya Lakshmi et al.,* 2010]. Optical dates of sands immediately overlying the imaged erosional scarps point to erosional episodes that took place approximately 1000 and 3700 years ago (Figure 1b).

But how can scientists know that either of these represents a tsunami? The younger date, similar to that obtained locally by *Rajendran et al.* [2006], is also the date of disconformities documented at other points across the Indian Ocean basin [*Monecke et al.,* 2008]. This strongly suggests a likely basin-wide tsunami impact rather than a storm. Similar basin-wide comparisons will be necessary to distinguish between a tsunami and more localized storm impacts for these erosional events. Such studies are crucial when reconstructing the past history of tectonically triggered versus climatically related phenomena. These findings provide the first step toward establishing an integrated geophysical and chronological database of erosional events along the southeastern coast of India and pave the way for a regional correlation of erosion horizons along the northern margin of the Indian Ocean.

Acknowledgments

Indian National Centre for Ocean Information Services grant 283/2007/2909 mainly funded this work, with partial support from Indian Department of Science and Technology grant SR/S4/ES-317/2008.

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NEWS

Budget Realities Could Put Damper on Some NOAA Programs

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The fall meeting of the National Oceanic and Atmospheric Administration's (NOAA) Science Advisory Board was in part a study in contrasts: discussing the agency's vision, goals, and recent successes while facing the harsh economic and political landscape that will make it difficult for NOAA to receive sufficient funding for the current fiscal year (FY 2011) to do little more than tread water toward reaching some of those goals.

During a 30 November presentation, NOAA administrator Jane Lubchenco provided an overview of NOAA's Next Generation Strategic Plan. The document focuses on four long-term goals: climate adaptation and mitigation, a weather-ready nation, resilient coastal communities and economies, and healthy oceans.

These key areas "are central to what we are all about," Lubchenco said, adding that the plan acknowledges "that the health, prosperity, and well-being of Americans depend intimately on the health and resilience of coupled human-natural systems and on people having access to timely and usable information to enable them to make good decisions."

Lubchenco also discussed highlights from the agency's annual guidance memorandum, which she called "our marching orders for focused activities for the coming year." These activities include implementing a climate service and the National Ocean Policy, defining the future of NOAA's weather and water services, eliminating overfishing and rebuilding depleted fish stocks, and strengthening science. In that area, Lubchenco said the agency is working toward establishing scientific integrity and conduct policies and also is working on efforts to retain and diversify NOAA's workforce.

The memorandum also includes two place-based foci: the Gulf of Mexico and the Arctic. NOAA will continue work in the gulf related to the BP Deepwater Horizon oil spill, including analyzing data from the monitoring of subsurface oil, assessing damage, and participating on an interagency team focused on restoration. Regarding satellite systems, Lubchenco noted that the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project is on track for launch in 2011 and that the transition from NPOESS to the Joint Polar Satellite System (JPSS) is proceeding, with three of five major JPSS contracts now in place.

However, some of the agency's goals may need to be tempered, according to Lubchenco and Maureen Wylie, NOAA's chief financial officer. Wylie told NOAA's Science