

## **Tsunami-geology training in southeast and northwest India**

*A trip report for the U.S. Indian Ocean Tsunami Warning System Program*

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### **SUMMARY**

A full-day workshop and two weeks of field work provided a total of 86 person days of capacity building in identifying the geologic records of tsunamis. Most of the scientists served are Indian but others came from Indonesia, Sri Lanka, and Thailand. From the Americas I was joined by a U.S. authority on Indian flood deposits and Chile's leading tsunami geologist. Non-USAID contributions of salary and services, adjusted to U.S. prices, approach \$25,000 and include about \$18,000 from Indian sources.

Most of the work took place in Tamil Nadu, among communities still recovering from the 2004 tsunami. Additional work took place in Gujarat, where the most recent large tsunami occurred in 1945.

The activities in Tamil Nadu proved timely for two groups of Indian scientists who have recently won support, from Indian sources, to seek ancient sand layers as guides to the recurrence of tsunamis like the one in 2004. Their job is made difficult by grading and plowing of coastal plains, burrowing crabs in mangrove soils, shifting shorelines, and government regulation of possession and use of coastal topographic maps.

In Gujarat, home of fast-expanding ports at Kandla and Mundra, the tsunami threat from the Arabian Sea receives little attention despite reports of a 10-meter runup in 1945 and of preceding tsunamis as early as the 4th century B.C. A four-person, four-day reconnaissance, hosted by a geology professor in Bhuj, turned up no obvious tsunami deposits but identified salt flats as promising places to seek geologic histories of repeated tsunamis. Interviews with elderly coastal residents yielded a second-hand account of the "sea gone mad" in 1945 and hearsay about an associated loss of cattle.

### **ACTION ITEMS**

*Southeast coast.* Assist the difficult hunt for paleotsunami traces in Tamil Nadu by providing leading Indian scientists with field experience elsewhere, such as Thai paleotsunami work slated for late February and early March, 2007. Funding from my USAID project and, if possible, the US IOTWS Program Integrator.

*Northwest coast.* Increase awareness of tsunami hazards in Gujarat and neighboring Maharashtra by collecting and publishing accounts, written and oral, of the 1945 tsunami. This effort, probably never before attempted, should extend to Mumbai, where the 1945 tsunami is said to have taken 15 lives. There is no time to waste in the search for eyewitnesses; a teenager in 1945 would now be in his or her late 70s. I am working with the Bhuj professor, Mahesh Thakkar, to get this project underway.

### **APPENDICES**

Activities (p. 2-6), Statistics (p. 7), Index maps (p. 8), and References (p. 9)

## APPENDIX 1 — Activities

### 1. Tsunami-geology workshop (Chennai; November 30)

*Program:* Talks by scientists from Chile (1 talk), India (10), Thailand (1), and U.S. (2). Attendees included 20 students from Anna University and University of Madras. Organized by Seshachalam Srinivasalu (Anna University).

*Outcome:* The content and comraderie of the workshop, and of the ensuing field work, has promoted collaborations both within India and internationally. For example, one of the U.S. participants, Lisa Ely (Central Washington University; upper left in lower photo), is now planning to apply for a grant jointly with at least two of the workshop's Indian participants (see p. 3).



*Above,* scientists gather in Chennai to exchange findings on the geologic signatures of tsunamis. From left, Marco Cisternas (Chile), Brian Atwater (United States), Starin Fernando (Sri Lanka), Kruawun Jankaew (Thailand), and hosts Seshachalam Srinivasalu and Kusala Rajendran (India). *Below,* most of the workshop speakers.

## 2. Field review of 2004 tsunami geology on the Tamil Nadu coast (December 2-3)

*Program:* Two-day reconnaissance of sites near Cuddalore, Vellaru River, Nagapattinam, Velankanni, Vilumdamavadi, and Vedaranniyam. Led by Seshachalam Srinivasalu (Anna University), V. Ram Mohan (University of Madras), P. Seralathan (Cochin University of Science and Technology), and S.R. Singarasubramanian (Annamalai University)

*Outcomes:* (1) Visiting geologists from Chile, Indonesia, Sri Lanka, Thailand, and the United States learned from their Indian hosts, and vice versa, about how to identify tsunami deposits in environments like those of India's east coast. (2) The U.S. visitors donated equipment that may aid in finding the deposits of pre-2004 tsunamis: World War II folding shovels, Japanese weeders (*nejirigama*), and soil augers. (3) Visitor Lisa Ely (Central Washington University) is planning to seek a Small Grant for Exploratory Research from the National Science Foundation, in collaboration with the two Indian geologists in the foreground below. If successful, this proposal will help sustain the US IOTWS paleotsunami agenda beyond September 2007.



Geologists explore sandy deposits near Cuddalore, Tamil Nadu, in an area overrun by the 2004 tsunami. Debating in foreground are Hema Achyuthan (left) and Seshachalam Srinivasalu, both of Anna University. Dr. Srinivasalu holds foreign tools that aid in exposing sedimentary structures in the sand: an American shovel and a Japanese weeder. Others in the group include P. Aravazhi (Archaeological Survey of India, Bangalore Circle, second from left), Mahesh Thakkar (Shri R.R. Lalan College, Bhuj; shooting photo), and Starin Fernando (Sri Lanka; taking notes).

3. Search for geologic signs of tsunami recurrence in Tamil Nadu (December 1 and 4-6)

*Program:* Field work at active archaeological excavation near Mahabalipuram and at archaeological sites near Poombuhar. Led by Terry Machado and C.P. Rajendran (Centre for Earth Science Studies [CESS], Trivandrum), under a project supported by India's Department of Science and Technology.

*Outcome:* (1) Visiting geologists from Chile, Indonesia, Sri Lanka, Thailand, and the United States learned how Indian scientists are using 1000-year-old cultural horizons to narrow their search for geologic signs of a sea flood that is cited in ancient writings. (2) Several of the visitors provided constructive criticism of this tsunami-recurrence investigation. Their advice includes greater use of coastal landforms and modern tsunami deposits as guides to locating and identifying the deposits of pre-2004 tsunamis.



Indian geologist Terry Machado (with notebook) talks with villagers in Kidangal, near Poombuhar, Tamil Nadu, about his efforts to learn how often tsunamis flood this part of India.

### 3. Public workshop in Vanagiri, Tamil Nadu (December 4)

*Program:* Presentations by scientists from Chile, India, Indonesia, Thailand, and United States before an audience of 35 villagers, including elected officials, followed by half-hour Q and A. Moderated and translated by Terry Machado.

*Outcome:* For the foreigners, appreciation of the villagers' tsunami losses (approximately 70 lives). For the villagers, understanding of the visitors' field work, including follow-up discussions at field sites on December 5 and 6 (as in the photo on p. 4).



*Above*, during a public workshop in rural Tamil Nadu state, a villager discusses tsunamis with moderator Terry Machado (standing at left). *Below*, in foreground, Dr. Machado (at right) and his colleague C.P. Rajendran (second from left), join villagers for a group photo. Village officials bestowed the shawls on the four overseas visitors, from left: Kruawun Jankaew (Thailand), Brian Atwater (United States), Eko Yulianto (Indonesia), and Marco Cisternas (Chile).

4. Informational meetings with Joseph Ravikumar (tsunami recovery specialist, USAID, Chennai; December 8 and 9)

*Program:* At the request of Peter Collier (US IOTWS Program, Bangkok), Brian Atwater met with Mr. Ravikumar. A follow-up meeting included CESS seismologist Kusala Rajendran, who is an editor of *Current Science* and served the field work's chief coordinator (CESS).

*Outcome:* Mr. Ravikumar learned about the activities reported here on pages 2-5, and he described some of USAID's roles in tsunami relief in India.

5. Reconnaissance of tsunami history and preparedness in Gujarat (December 11-14)

*Program:* Field search for evidence of the 1945 tsunami and 1998 cyclone in Kachchh. Localities: Arabian Sea coast near Jakhan; Gulf of Kachchh near the ports of Kandla and Munddra. Participants: Mahesh Thakkar (R.R. Lalan College, Bhuj), Kusala Rajendran, Brian Atwater (USGS), and Marco Cisternas (Univ. Católica de Valparaíso, Chile).

*Outcome:* Initial plan to collect and publish written and oral accounts of the 1945 tsunami, to spur tsunami preparedness on India's northwest coast



A fisherman (left), interviewed by geologist Mahesh Thakkar (right), recounts a 1998 cyclone that took a thousand lives in Kandla (background). A tsunami in 1945, before Kandla's development, probably overran the site of today's fishing village and the grounds of the tanks and cranes on the skyline. Kandla is now India's fifth largest port, not far behind Visakhapatnam, Chennai, Kolkata, and Mumbai in total tonnage handled between April and November 2006 (<http://www.ipa.nic.in>).

APPENDIX 2 — Statistics

Indian institutions receiving technical assistance: 5

Anna University (Chennai, Tamil Nadu)  
 Annamalai University (Annamalainagar, Tamil Nadu)  
 Centre for Earth Science Studies (Thiruvananthapuram, Kerala)  
 Cochin University of Science and Technology (Cochin, Kerala)  
 University of Madras (Chennai, Tamil Nadu)

Non-Indian institutions receiving technical assistance: 3

Chulalongkorn University (Thailand)  
 Geological Survey and Mines Bureau (Sri Lanka)  
 Indonesian Institute of Science (LIPI) (Indonesia)

Person days of geologic training for scientists from Indian Ocean countries: 86

Event	Date	Place	Indians	Others
Workshop	11/30	Chennai	30	2
Field work	12/2-12/7	Tamil Nadu	28	13
Field work	12/9-12/14	Tamil Nadu	3	2
Field work	12/11-12/14	Gujarat	8	0
TOTAL			69	17

Additional trainees: 35 villagers in an evening workshop in Vanagiri, Tamil Nadu

Non-USAID contributions: about \$10,200 nominal; \$24,600 adjusted to U.S. prices

Country	Source	Contribution	Nominal	Adjusted
India	Anna University	<i>Workshop:</i> booklets of abstracts, binders, banner, refreshments	\$200	\$500
India	University of Madras	<i>Lodging:</i> subsidized rooms at university guest house	300	600
India	Centre for Earth Science Studies	<i>Field expenses:</i> supported by Department of Science and Technology; includes vehicle rental and trench digging	2,200	5,000
India	Six institutes	<i>Salary:</i> 90 person days, professors and Ph.D. researchers	3,000	12,000
Chile	Universidad Católica de Valparaíso	<i>Salary:</i> 20 days, professor who served as tsunami-geology trainer and role model	1,000	3,000
United States	Central Washington University	<i>Salary:</i> 20 days, professor who served as geology trainer	3,500	3,500
TOTAL			\$10,200	\$24,600

### APPENDIX 3 — Index maps

Fault-rupture areas (red) known to produce deadly tsunamis in India

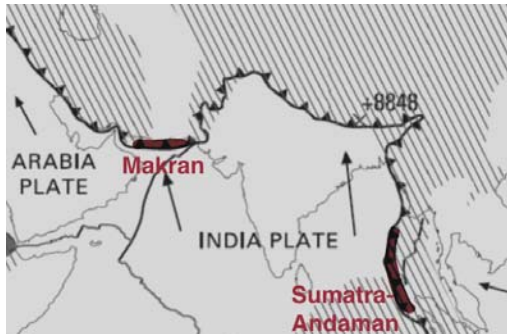
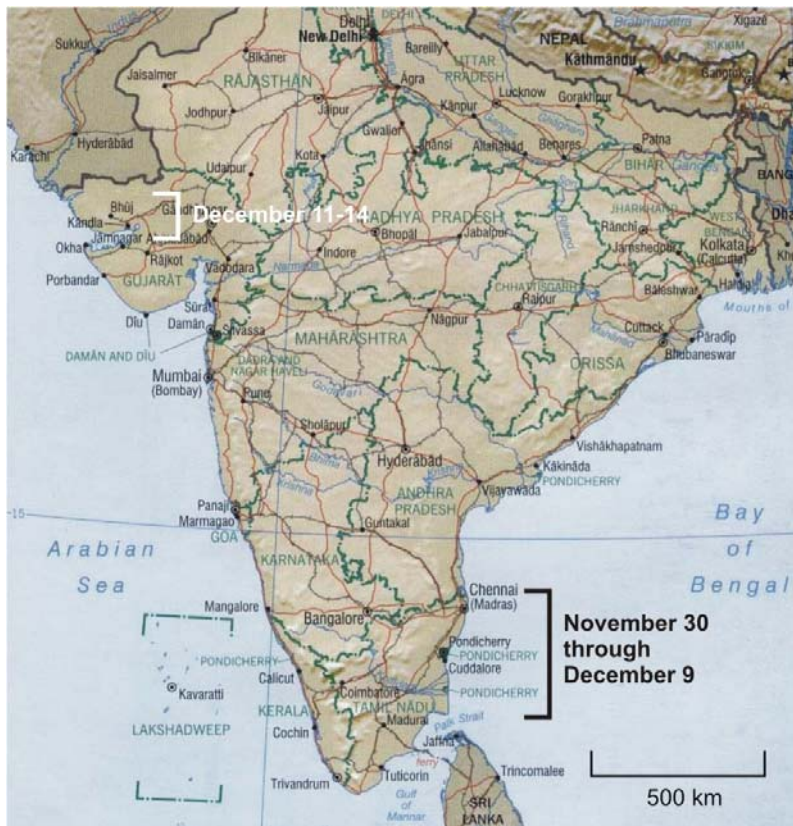


Plate-tectonic base map from "This Dynamic Planet"  
(<http://pubs.usgs.gov/imap/2800/>)

Coastwise extent of activities described in Appendix 1



Base map from University of Texas Libraries  
([www.lib.utexas.edu/maps/india.html](http://www.lib.utexas.edu/maps/india.html))



APPENDIX 4 — Selected references on tsunamis and tsunami geology in India

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