

Tsunami geology and its application to tsunami hazard mitigation —summary recommendations

[This report is based on multi-authored reports by different groups who attended the NSF-funded tsunami deposits workshop in June 2005; compiled by J. Bourgeois]

Tsunami geology contributes both to basic science and to hazard analysis; this report focuses on the latter. Of three avenues to consider when addressing tsunami hazards (assessment, mitigation, and warning), tsunami geology applies in particular to probabilistic hazard assessment—for given localities, quantifying recurrence intervals and size estimates of past events. Moreover, tsunami-geology studies can help generate public education and awareness, an important aspect of mitigation efforts.

The June 05 NSF Tsunami Deposits workshop was organized around the following questions, which range from basic science to applications in the public sphere:

How can tsunami deposits be distinguished from hurricane and other storm deposits?

How can properties of tsunami waves be quantified from their deposits?

What are the geomorphic effects of tsunami erosion and deposition?

What is required to construct a database that includes documented historic and prehistoric tsunami deposits and other geologic evidence of tsunamis?

What is the best way to use tsunami geology to constrain coastal hazard maps and help construct probabilistic hazard assessment maps?

How best can the significance of tsunami deposits be explained to the public and used for outreach and education?

Recommendations with Tsunami Hazard Applications:

Tsunami geomorphology:

- Catalogue geomorphic effects—erosion and deposition—of the 26 December 2004 tsunami, taking advantage of remote-sensing technology.
- Study geomorphic effects of older historical tsunamis, particularly where air photos before and after are available.
- Investigate latitudinal and other geographical variations in tsunami effects (e.g., difference between effects on coral reefs vs. deltas; mangroves vs. grassy plains).
- Evaluate claims of tsunami-generated landforms in non-historical cases.

Tsunami deposits—tsunami sedimentology:

- Continue to develop criteria for identifying tsunami deposits and distinguishing them from deposits of other coastal phenomena
 - Tsunami and storm sedimentologists should work collaboratively to understand not only facies differences, but also hydraulic differences between the two phenomena.
 - Focus some research on how muddy and bouldery tsunami deposits might, or might not, be distinguished from other coastal deposits.
 - Develop a cadre of trained tsunami sedimentologists in nations likely to have tsunami deposits—provide post-graduate as well as graduate training.

- Make opportunities, e.g., short courses, for the larger community to understand the current state-of-the-art in reconstructing paleo (pre-historic) tsunamis.
- Generate understanding of the changes that take place in tsunami deposits between the time they are deposited and the time they are discovered
 - Support long-term studies of preservation of depositional extent, thickness, and internal structure of tsunami deposits--not only of the 2004 South Asian tsunami, but also of smaller tsunamis such as 1992 Nicaragua or 1999 Vanuatu.
 - Make comparative studies of preservation factors and effects in different geographical settings (e.g., climate, vegetation, sedimentation rate).
- Investigate the physics of sand deposition by tsunami so that flow conditions that prevailed during deposition (i.e. flow depth and velocity) can be estimated from the deposit alone. Three related avenues of research:
 - Geology--examine modern and ancient deposits and characterize them, including vertical and horizontal structure of the deposit and identification of local topographical features which may have controlled the overland flow behavior.
 - Develop protocol for studying and sampling tsunami deposits in the field
 - Address the following questions:
 - ✓ How does variation in source along shore affect patterns of sorting in tsunami deposits?
 - ✓ Where multiple deposits can be observed at the same location, how are variations in wave structure recorded in the deposit?
 - ✓ What spatial distribution of sediment source do fossils and other tracers record?
 - ✓ Can more-studied event deposits such as turbidites and ignimbrites provide insight into the interpretation of tsunami deposit structure?
 - Sediment transport physics--understand the entrainment, transport, and deposition of sediment in a tsunami, using numerical, experimental, and field studies, addressing the following questions:
 - How unique is the relationship between a given tsunami and the inferred hydrodynamic conditions which created it?
 - How does uncertainty in the tsunami source and the local bathymetry/topography impact the confidence of the deposit interpretation?
 - Hydrodynamic modeling--explain the large-scale propagation of tsunami waves across oceanic basins, the medium-scale bathymetry/topography forcing which can control local tsunami properties, and small-scale turbulence phenomena which drive transport in the nearshore and onto shore
 - Conduct experimental work to look at aspects of tsunami-induced transport. Use of large facilities such as Oregon State's NEES Tsunami Basin would be ideal, and could be utilized to tackle questions such as:
 - ✓ When is the tsunami in an erosive or deposition state, and how does irregular topography control these states?
 - ✓ What is the importance of a bore front with respect to erosion, transport, and deposition?
 - Test various (tsunami) sediment-transport models by experimental cases or well-constrained historical case studies, as has been done for runup modeling.

Tsunami deposits—long-term records

- **Very important for probabilistic tsunami hazard analysis**
- All of above recommendations with regard to tsunami sedimentology are relevant, but with the added challenges of age dating, and of longer-distance correlation
- Develop statistical techniques for evaluating tsunami recurrence and for evaluating spatial and temporal correlations
- Encourage new techniques (such as optically stimulated luminescence) for dating young deposits accurately, especially in the absence of carbon

Tsunami marine geology—offshore marine records and relevant marine-geologic work

- Conduct bathymetric and sea-bottom surveys of tsunami-prone regions
 - Potential for before-and-after studies of erosion and deposition, as well as sources
 - Important for models of tsunami source, propagation, runup and sedimentology
 - Shallow water (<30 m) needs more work – typically not in traditional surveys
- Establish criteria for identifying tsunami deposits offshore -- distinguish, e.g., from flood, storm and turbidity-current deposits
 - Examine the record from recent tsunamis in the offshore
- Improve and develop means to correlate onshore and offshore records
- Collect geotechnical information from regions prone to submarine failure (and hence to tsunami-genesis)

Tsunami deposits—sources other than seismogenic

- **Impact-generated** –
 - No particular hazard-related recommendations [important scientific questions]
- **Volcanogenic and landslide-generated tsunamis**
 - Develop better understanding of the coupling between volcanic and landslide events and their tsunami waves; complexity of volcanic events makes this a particularly challenging problem
 - Investigate possible distinguishing characteristics of volcanogenic and landslide-generated tsunami deposits (vs. seismogenic, e.g., and storms)
 - Characterize wave height and velocity of such tsunamis and improve understanding of erosion and sedimentation associated with very large but more local tsunami waves
 - Calibrate computer models of volcanic and landslide-generated tsunami generation by obtaining field data to check the output of the models.
 - Use improved understanding to evaluate, e.g., arguments and evidence for tsunamis generated by edifice collapse in the Hawaiian and Canary Islands. Can tsunami deposits sufficiently characterize source to be useful in this debate, or other cases where source is a question?

Tsunami geology and geomorphology – database recommendations

- Field geoscientists must be encouraged to cooperate as data providers. The tsunami community should determine which kinds of data should be in the repository.
- The tsunami community must agree on the metadata, field names, and the data structure. Data formats should be carefully selected for long-term preservation and data curation. The tsunami geology community must work together with the IT community to achieve these goals.
- Protections against unethical use of the data should be established.
- A Steering Committee Working Group should be established, including representatives from NEESit, USGS, NGDC, EERI, who should work out areas of genuine cooperation and set goals for each organization.
- Because international collaboration is essential for any tsunami data, there should be an International Summit Meeting. There, a small number of responsive representatives from many countries could meet to work on the data repository.
- A draft data model and data strategies should be presented at a tsunami community workshop for feedback. That input would be considered for incorporation by the Steering Committee Working Group.
- To develop the data repository, we need the following essential supports.
 - a few months of data entry by graduate students.
 - computational and information technology resources
 - for outreach, to encourage better cooperation from the data providers and better inputs from the data users.

Tsunami geology – broader impacts

Saving lives and reducing human suffering

- Support efforts to educate the public about tsunami hazards and response with educational tools developed locally as well as at the national and international level.
- Develop tools and materials with accurate and consistent information that respect and can be readily adapted to diverse cultural settings and audiences.
- Work with and contribute findings to tsunami hazard mapping and tsunami modeling. Understanding of tsunami erosion and deposition can be used to reduce casualties and assist in disaster response.
- Find, publicize and display tsunami deposits - in the context of other tsunami hazard and local traditional cultural information – and present these findings to local communities.
- Make every effort to publicize research results and general tsunami information from all disciplines at a level that is interesting and understandable to the public.
- Disseminate information as broadly as possible in tsunami-prone communities by identifying key local collaborators to collect data and carry on outreach in the community

Limiting economic losses and promoting sustainable development

- Use tsunami geomorphology to inform planners and the public of possible landform changes that can occur during a tsunami.

- Consider tsunamis in offshore and littoral zone development practices that may reduce the buffering effect of coastal barriers such as sand dunes, forests, and coral reefs.
- Research the role of mangroves and other potential vegetation buffers in terms of tree species and characteristics, geologic characteristics that influence root growth, and characteristics of tsunamis likely to impact an area.
- Improve understanding of how non-structural tools such as vegetation management and topographic roughness may absorb wave energy without creating dangerous floating debris.
- Consider how tsunamis may cause long-term changes to the coastal ecosystem. Tsunami erosion can have significant impacts in beach elevation, lagoons, bay and river morphology and man made canals
- Methods of hazardous materials/groundwater pollution confinement and amelioration can be tested and studied in conjunction with tsunami deposit studies.

Promoting interdisciplinary and international scientific collaboration

- Provide information to further scientific knowledge in many areas, including sediment transport, earthquake and tsunami hazard estimation, determination of fault rupture, ecologic restoration, and studies of how the earth's outer layers deform.
- Promote collaboration of scientific researchers in different disciplines and from broad interdisciplinary backgrounds, leading to improved understanding of coastal environments affected by tsunamis.
- Build international science partnerships. The logistics of tsunami deposit studies promote international collaboration and understanding.
- Train a new generation of scientists. The geographic scope and variety of studies undertaken offer field and laboratory research and training opportunities for students from tsunami-affected regions, as well as for any student seeking such training, with its broad interdisciplinary and potential international scope.