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On the preservation potential of tsunami deposits

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Tsunamigenic earthquakes belong to the ambient noise of plate tectonics. A large part of the record of this activity is stored in the sediments tsunamis leave behind especially in coastal lowlands and their sedimentary successions. Recent tsunami records show that a tsunami which deposits sediment onshore occurs every two years, on average. Consequently, tsunami deposits should be very frequent in coastal lowland successions. A large number of respective studies show that, in fact, they are not.

In the last decades numerous post-tsunami surveys resulted in the recognition of a set of sedimentary and erosional structures typical of but not unique to onshore tsunami deposits. The absence of unique tsunami depositional structures hampers the unequivocal recognition of paleotsunami deposits in the geological record. Consequently, tsunami sediments can only be distinguished from other types of event deposits, such as storms deposits, if the climatic, seismological, depositional and geologcial background is considered.

The style and potential of preservation of such deposits depends on climate, syn- and post-seismic geomorphic changes, the burial history and, ultimately, diagenesis. The interaction of these processes, and potentially others not named here, continues to be poorly understood. This information gap can only be filled by repeated re-surveys during the years following a tsunami event which document even small changes affecting the deposits (Szczucinski, 2012; Spiske et al., 2013; Bahlburg and Spiske, 2015). But even this approach is very limited due to the geologically short human life span.

We combine here results of some of our studies concerned with the preservation potential of Recent tsunami deposits laid down on the coasts of Peru and central Chile (Spiske et al., 2013; Benavente et al., 2015; Bahlburg and Spiske, 2015, and unpublished data). The Peruvian record includes the events at Chimbote (1996), Camaná (2001) and Pisco-Paracas (2007), which we resurveyed in 2007 and 2008. In central Chile our study site is on Isla Mocha, to the south of Concepción. Here, the original deposits formed by the February 27, 2010, tsunami. We re-surveyed the sediments in 2012, 2015 and 2017.

At Chimbote, all traces of the tsunami have been removed or reworked by flash floods and ocean waves. 0.5 m of co-seismic uplift was insufficient to protect a tsunami sand sheet that had mantled a coastal marsh from removal by ocean waves. At Camaná, rip-up clasts of soil which had been deposited on the coastal plain from tsunami-backwash began to be rounded and abraded by eolian sands immediately after the event. Only the largest clasts suvived. Eolian processes also smoothed and filled tsunami scours. Some muddy tsunami deposits escaped erosion by wind in certain areas, probably because of their greater cohesion. The spatial distribution and thickness of the sediments laid down by the Pisco-Paracas tsunami in 2007 had already decreased considerably in 2008. Still, we recognized multiple layers, ripup clasts, shell accumulations, imbricated gravel layers, small concrete boulders and mud caps. The maximum sediment thickness was about 44 cm. Both run-up and backwash sediments, as well as scours by the backwash were observed one year after the event.

The Peruvian examples reviewed here show that the preservation of tsunami deposits at arid-coast depends on interactions that are more complex that hitherto perceived. These involve sediment type, grain size, depositional setting, co-seismic movement, bioturbation, winds, and anthropogenic modification.

The Chilean examples were deposited in a region near the southern limit of the subtropical climate zone characterized by frequently elevated wind speeds and considerable rainfall. On Isla Mocha in 2012, relatively dense vegetation consisting mainly of grass and thistles, specifically of invasive members of the family Asteraceae had covered the 2010 tsunami deposits. Since 2010, sediment beyond 200 m from the coast had been removed by a combination of surface processes and grazing cattle. Grain-size distributions of the preserved sediment show an increase of the sand fraction at the expense of the coarser grain sizes. Boulders moved by the 2010 tsunami are very common. They consist of weakly indurated clay-rich and fine grained sandstones. They developed patterns resembling mud cracks on the surface and disintegrated into smaller fragments of cobble and pebble size, and sand. Veneers of dried algae documenting the derivation of the boulders from the tidal zones had flaked off partly or completely from most rock surfaces. At the northern, wind-facing coast of the island a c. 130 m long and 1.2 m high beach ridge had accumulated, most likely from reworked tsunami sediment.

Boulders deposited by tsunamis are commonly assigned a high preservation potential. We demonstrated for the first time that such boulders may in fact disintegrate rapidly and disappear from the record over short geological time scales, given a lithology susceptible to weathering.

The degree of modification to the lsla Mocha tsunami boulders and the finer grained deposits strongly questions the applicability of inverse models using paleotsunami deposit thickness and grain-size distributions to infer parameters and magnitudes of the causative tsunamis. Inverse models would consequently underestimate tsunami flow parameters and may result in the inference of erroneous transport modes and event magnitudes.

We consider our data strong evidence in support of re-survey studies following the deposition of tsunami sediments by tracing and quantifying the changes affecting them. We conclude that the preservation potential of tsunami deposits is low and that the available historic and pre-historic tsunami record is highly fragmentary. Calculations of recurrence intervals based on pre-historic successions are consequently minimum estimates at best which suggest an apparent hazard potential significantly lower than the real danger.

REFERENCES

Bahlburg, H., Spiske[1], M. (2015): Styles of early diagenesis and the preservation potential of onshore tsunami deposits - a re-survey of Isla Mocha, Central Chile, two years after the February 27, 2010 Maule tsunami. Sedimentary Geology 326, 33-44.

Benavente, C., Spiske, M., Delgado, F., Bahlburg, H. (2015): Depósitos de paleotsunamis en la costa central y sur del Perú. INGEMMET Boletín, Serie C, Geodinámica e Ingeniería Geológica 62, 185 p.

Spiske, M., Piepenbreier[3], J., Benavente, C., Bahlburg, H. (2013): The onshore preservation potential of siliciclastic tsunami deposits in arid climate regions. Earth-Science Reviews 126, 58-73.

Szczucinski, W. (2012): The post-depositional changes of the onshore 2004 tsunami deposits on the Andaman Sea coast of Thailand. Natural Hazards 60, 115–133.