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Sedimentological analysis of tsunami deposits along the coast of Peru

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The Peru-Chile-Trench is one of the most active seismic areas in the world (Kulikov et al., 2005). The subduction of the Nasca Plate under the South American Plate causes earthquakes with magnitudes greater than 8 every 5 to 10 years. Consequently, the risk for destructive tsunami along the coast of Peru is very high. The greatest historical tsunami events in this region are the two Arica tsunami in 1604 and 1868 (Okal et al., 2006) and the Chile tsunami in 1960 (Cisternas et al., 2005). The most recent tsunami are the Chimbote tsunami in 1996 (Bourgeois et al., 1999) and the Camaná tsunami in 2001 (Jaffe et al., 2003). Additionally, in 2007, a magnitude 7.9 earthquake 150 kilometres SSE of Lima generated a tsunami with run up heights of 10 m along the southern Paracas Peninsula (Fritz et al., 2008).

Despite a large increase in tsunami studies in the last years, there is still no complete tsunami facies model. Furthermore the hydrodynamical processes leading to deposition of sediment by a tsunami wave are still not well understood. We surveyed various locations along the 2400 km Peruvian coastline to locate deposits of recent and historical tsunami events. Deposits were studied in trenches and boreholes down to depths of 3 m. We separated the foraminifera content for identification and inference of water depths of sediment entrainment by the tsunami. The grain-size distributions of the sampled deposits were optically determined with a PartAn 2001 particle analyser. The grain-size data were used to re-model the flow depths, using the inverse tsunami model of Jaffe & Gelfenbaum (2007).

Recent tsunami deposits of the 2007 event were surveyed in the regions of the Paracas Peninsula and Pisco. At the southern side of the Paracas Peninsula, beige beach sand is overlain by a 25 cm thick more bright coloured layer of shell and gravel, whereas the gravel is sandwiched between layers of sand and shell. This bright material represents the tsunami deposit. The imbricated gravels and shells indicate bedload transport.

30 km north of Pisco the beach sand is overlain by a succession of tsunami layers. The grain size distribution of the beach sand is bimodal with modes at 0.36 mm and 0.56 m. A 3 cm thick layer of coarse sand represents the base of the tsunami deposit. The material shows an irregular grain-size distribution with modes in the field of coarse sand (0.60 mm) and shell material of fine gravel (7.20 mm) size. On the top of the tsunami succession, muddy rip up clasts with a maximum diameter of 29 cm lie in a matrix of sand, which also contains shells. The grain size distribution of the matrix is similar to the one of the subjacent material, but shows an additional mode at a grain size of 4 mm. The main difference between the beach sand and the tsunami sand is the wide size range (0.25 –8 mm) of the tsunami deposits in contrast to a narrower size distribution (0.3-0.7 mm) of the beach sand. The material of the rip up clasts was derived from an agricultural field in a distance of 150 m and was transported seawards by the backwash of the tsunami wave. A 5 cm thick layer of sand represents material deposited after the tsunami.

Paleotsunami deposits were found, for example, in Puerto Casma (northern Peru) and Boca del Rio (southern Peru). At Puerto Casma a 3 cm thick layer of coarse grained material was found in finer grained beach sediment in a depth of 60 cm. The layer has an erosional contact at the base with heavy minerals and contains shell fragments and very fine gravel up to a size of 1.5 cm. Three trenches were dug to track the deposits and to prove a landward fining trend of the grain size within this layer: the mean grain size changes from 0.507 mm in a distance of 10 m from the coastline to 0.424 mm (15 m distance) and finally to 0.415 mm (30 m distance). Furthermore, sorting improves landward, although all three samples are very poorly sorted: the sorting is 2.362 in 10 m distance from the shore, 2.071 in 15 m distance, and 2.025 in 30 m distance. At the site of Boca del Rio two sandy layers with a thickness of 4 cm occur in argillaceous soil. The graded sand layers with shell fragments and fine gravel appear in depths of 30 cm and 40 cm below the surface and seem to represent two palaeotsunami events.

Benthic foraminifera in recent and historical tsunami deposits were only present at two locations. Whereas, at these two locations foraminifera do not only occur in the event deposits, but in the beach sand as well. Planktonic foraminifera were completely absent. The overall condition of the encountered foraminifera can be characterized as very bad. In many cases an identification of the species was not possible. The foraminiferal tests often show abrasion and secondary crystallisation and are broken or dissolved. We assume that the reason for the bad preservation of the tests is not grain to grain abrasion during transportation of sediments but reworking of older sediments. The foraminifera represent post-mortem transport and the reliability is limited. Therefore a statement about the bathymetry is not possible.

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Mantle reference frame and generation of detached- and flat-slab subduction geometries in Caribbean evolution

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Slab dip during subduction is often correlated with the relative buoyancy of the subducting slab with respect to normal oceanic crust. This paper uses the Caribbean region to explore how the motion of the overriding plate relative to the local mantle can control slab dip, as well. Opposing polarities of the Lesser Antilles/Aves Ridge and Middle American arcs prevented the Caribbean Plate from having significant E-W motion in the Indo-Atlantic mantle reference frame while both arcs were active (since Santonian, 85 Ma). During this time, the Americas drifted west relative to the mantle and their Proto-Caribbean margins collided with segments of the stationary Great Caribbean arc at southern Yucatan (70Ma), Ba-