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Hydrodynamic behavior of empty larger foraminiferal tests

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Larger, symbiont-bearing benthic foraminifera are very important producers of carbonate sand in shallow environments of the marine tropics. Today, beach sand in the Indo-Pacific may consist up to 90% of foraminiferal tests and their proportion in the shallow subtidal also remains high peaking at 50%. Because most of the sediments from the eu- and infralittoral are poorly preserved in the geological record due to the extreme water energies acting in these zones, the preservation and selected accumulation of larger foraminiferal shells from the shallowest region in the less dynamic circalittoral must be explained through transport caused by currents or storm events.

Recent investigations of down-slope transport of foraminiferal tests by the authors led to the assumption that differences in response of empty tests to water movement (especially transport by currents) cause accumulation at different places although originating from the same shallow habitat.

Laboratory experiments with a settling tube were exemplified showing differences in sinking behavior (form and velocity). Entrainment from the bottom was investigated using a flume tank with the 2 bottom-conditions ‘smooth’ and ‘rough’ (medium sand) surface. Due to the lower density of foraminiferal tests filled with seawater (~1.2 – 1.7) compared with broken pieces of skeletons and shells consisting of compact calcium carbonate (bivalves, corallinean algae with densities ~ 2.4), sinking velocity is lower than solid carbonate particles of the same size. Additionally, the test form reduces sinking, since spheres and thick discoids show faster sinking than flat discs and blades. Also the rod-like fusiform tests demonstrate slow sinking compared to spheres.

Entrainment of foraminiferal tests is opposite to the sinking behavior. Similar to siliciclastic grains, spherical tests are easier entrained compared to flat discoids and blades. According to differences in Reynolds numbers, sinking velocities, and entrainment, Hjulström diagrams combining sinking velocity and entrainment in relation to test size clearly separate regions with velocities, where tests are entrained, from velocities leading to floating but too weak for entrainment. The third region characterizes velocities, where tests are not floating.

Lenticular peneroplids (*Dendritina*) with higher sinking velocities are easier entrained than flat species (*Peneroplis*) with a lower sinking velocitiy.

The flat soritids (*Sorites*, *Parasorites*, *Amphisorus*) show extremely low sinking velocities (high buoyancy) but weak entrainment. Similar behavior to the lenticular *Dendritina* can be experienced by the fusiform alveolinids (*Alveolinella*), where entrainment depends on the position of the longitudinal axes to the current direction.

Amphisteginids and calcarinids with lenticular to spherical tests behave similar (high sinking velocity - easily entrained). The changing test-diameter/ thickness ratio with growth in nummulitids leads to different behavior against hydrodynamics. While settling velocity is reduced during growth, entrainment is hampered. This explains differences in accumulation of *Nummulites* tests in the geologic past. Because lenticular tests as they are significant for *Nummulites* living in the upper circalittoral (above the storm wave base) are easily entrained and then depth transported, the flat forms (*Planostegina*) occupying the lower circalittoral are less entrained. Therefore, a mixture of species, the one allochthonous and the other semi-autochthonous can be accumulated at the same depths.