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Chronology of extreme coastal events: In situ produced cosmogenic nuclides to date erratic boulders in Ryukyu and Taiwan islands

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Displaced boulders along coastlines can serve as significant geomorphic evidence of coastal extreme events, e.g., tsunamis or storm waves. Beyond the problem of distinguishing between these two major hydrodynamic processes, accurately dating the timing of boulder dislocation is another challenge. In this study, we specifically employed concentrations of in situ produced cosmogenic Chlorine-36 to determine the duration of exposure to cosmic rays post-dating the deposition of coastal boulders. While radiocarbon dating and other techniques, such as optically stimulated luminescence or 230Th/U, have been previously used on coastal boulders, the use of cosmogenic isotopes in such sedimentary context is still innovative. We focused on coastal boulders in Ishigaki (Yaeyama, Japan) and Taiwan (main island and Lanyu), which are regions prone to intense seismic activity and potential tsunamis. The in situ produced cosmogenic Chlorine-36 database, measured in carbonate rocks of coral origin includes 96 samples, and is completed using Beryllium-10 and Aluminum-26 where quartz material were available. This allows determining the exposure duration of 34 individual boulders and discussing timing and recurrence for coastal extreme events in a context of convergent plate boundaries associated to frequent typhoons. Samples were taken from the coastal boulders themselves, as well as from the marine terraces on which they now stand a few meters above the present-day sea level. In the southern tip of Taiwan main island, terrace samples yielded Chlorine-36 minimum exposure ages (MEA) ranging from 1420±135 to 2270±100 years, which are consistent with those on the order of 1390±90 years determined in the Pacific island of Lanyu. Along the southern and western coast of Ishigaki, samples taken from cemented beach-rock and coral fragments at sea level yielded MEA on the order of 775±50 years, whereas samples taken from the uplifted Holocene terrace yielded 11180±154 years. This systematic dating of coastal terraces at sea level or above unsure that the erratic boulders have been displaced and abandoned onshore during the last 2500 years. It also helps distinguishing between actual erratic and terrace-derived boulders. In Ishigaki, dislocated boulders are distributed into two main MEA groups of 380±20 and 790±40 years. Since the younger group of exposure ages is most probably related to the latest 1771 tsunami, the roughly 140±20 years shift has to be discussed accounting for underwater inheritance acquired in the source area and thermal neutron activation due to a systematic high natural chlorine content in coral material at sea level. In Ishigaki, the Chlorine-36 database also suggests a recurrence interval ranging from 410 to 850 years. In Southeastern Taiwan and Lanyu, samples taken on overturned boulders and their environment indicate that the extreme coastal events responsible for their emplacement occurred during the last 1000 years.

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