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The origin and dynamics of a boulder deposit on a low-lying rocky promontory in the Northern Adriatic Sea

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This study investigates a coastal boulder deposit that was recently identified along the Northern Adriatic coast (Premantura Promontory, Istria, Croatia). Accumulations of large boulders have not previously been reported in the North Adriatic Sea, which is a semi-enclosed basin elongated in the SE-NW direction. In particular, we devoted our attention to the mechanisms that may be responsible for the detachment and transport of these large limestone fragments from the emergent part of the coast and from the sea bed towards inland areas. We adopted a multidisciplinary approach including geological and geomorphological surveys, climate analysis, hydrodynamic modelling together with the use of an Unmanned Aerial Vehicle (UAV). Moreover, 14C AMS datings have been made in order to possibly constrain the age of the studied boulders.
The deposit is composed of 950 clasts and lies on a low-lying limestone promontory where the topography, together with the bedding planes and dense joint pattern constitute the predisposing factors for boulder size and detachment.
We focused our attention on an isolated boulder characterized by fresh marine carbonate encrustations. Its arrival was reconstructed by means of historical satellite images, wave data and hydrodynamic models and was ascribed to a severe storm which occurred during early 2014. Concerning the remaining boulders, thanks to 14C AMS datings, their deposition can be explained by multiple past extreme wave events.
We explained the boulders detachment mechanism as due to frost and salt weathering during severe bora conditions, when air temperatures are below 0°C and waves and associated sea spray fill limestone cracks with water. The freezing and subsequent thawing caused further ruptures and eventually detachment of limestone fragments. Then, the boulders are carried onshore during major sirocco events when much longer and higher waves are generated. We estimate that sirocco generated wave heights can exceed ∼15 m, which is enough to transport most of observed boulders to their present day location, according to hydrodynamic equations results. We hypothesize that the boulder detachment mechanism was more effective during the past, when the coastal slope was intact and the boulders were progressively removed and thrown onto the upper storm berm that represents the maximum inundation limit reached by the boulders. Through the centuries the coast has been eroded through the removal of rocks and has been shaped by truncations of the gently dipping limestone beds that acted as ramps for boulder movements along channels delimited by scarps. The mechanism might have also been favoured over the centuries by slow sea level rise inundating new portions of the rocky coast, bringing seawater into contact with limestone beds that were previously stable, in a subaerial environment, causing their resizing and rupture.