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Morphometric assessment of uplifting coral reef sequences, Sumba Island, Indonesia

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Rates and patterns of vertical ground motions constitute a basic framework for understanding the kinematics of the deforming lithosphere. Calibrating morphometric indices with landscape maturity and tectonic deformation requires comparisons with regions of known uplift history. The ability to derive uplift histories from marine or reefal terrace analysis in coastal zones therefore makes such settings ideal for testing morpho-tectonic analysis techniques.

To explore the relationships between uplift rates and landscape morphology, we studied a 300-km-long coastal stretch affected by slow to moderate uplift rates, varying laterally from ≈0.02 to ≈0.6 mm/yr. We exploited the systematic spatial variation in rock uplift rates recorded in well-dated sequences of coral reef terraces of Sumba Island to assess the manner and degree to which the eight morphometric indices selected for this study can be correlated with tectonic forcing. The uniform equatorial climate and lithology (most of the bedrock is composed of Quaternary reefal limestones) across the study area allow us to evaluate which morphometric indices best reflect the spatial variations in Pleistocene coastal uplift rates.

Morphometric indices extracted from digital elevation models include residual relief, incision, stream length index, ksn, hypsometric integral, drainage area, mean relief, and shape factor. We calculated and extracted these indices at three scales: across the whole island, from grouped sequences of coral reef terraces undergoing comparable uplift rates and individual catchments draining mainly the coral reef zones located in the northern part of Sumba Island. We find that SL, hypsometric integral, mean relief and shape factor of catchments positively correlate with uplift rates, whereas incision, residual relief, and ksn do not. Interestingly enough, we find that only the areas that are uplifting at a rate faster than 0.3 mm/yr can yield the extreme values for these indices, implying in turn that these extreme values are powerful indicators of fast uplifting areas. However, the relationship is not bivalent, as we find that any uplift rate can be associated with low values of the same indices. For all indices, the transient conditions of the drainage influence the correlation with Pleistocene mean uplift rates, illustrating the necessity to extract morphometric indices taking into account the choice of catchment scale. This analysis identifies the morphometric indices that are most useful for tectonic analysis in areas of unknown uplift, allowing for an easy identification of short spatial variations of uplift rate and detection areas of relatively fast uplift rates in unstudied coastal zones. Our results suggest that this procedure may be applied to identify rapidly uplifting areas along any given coastal area that includes a sequence of reefal or marine terraces.