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Why are Mediterranean carbonate mountains high and steep? Climatic and tectonic controls on carbonate landscape evolution

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In the Mediterranean, carbonate massifs occupy many of the highest mountains, whereas quartzofeldspathic units are often associated with more subdued topographic relief. In contrast, carbonates occupy valley bottoms, and quartzofeldspathic bedrock forms ridgelines in more humid and tectonically quiescent regions, such as the eastern United States and Ireland. This observation implies changes in the pace and style of denudation associated with climate and tectonic regime. Denudation in carbonates is traditionally thought to be controlled by dissolution; however, this paradigm has not been quantitatively vetted. Here we present new results of cosmogenic basin-average denudation rate measurements from both ¹⁰Be and ³⁶Cl in meta-clastic and carbonate bedrock catchments on Crete, Greece, compile all existing ³⁶Cl denudation measurements globally, and calculate dissolution rates from water chemistry and satellite-derived water flux data to improve understanding of landscape evolution and the partitioning between physical and chemical denudation in carbonates in the Mediterranean and elsewhere. In Crete, basin average erosion rates in meta-clastic and carbonate catchments are similar, with mean values of 0.10 and 0.13 mm/a, respectively, but the total relief is almost double in carbonates relative to meta-clastic bedrock. Results show that both carbonates and meta-clastic units on Crete are dominated by physical denudation with < 10% and ~40% of total denudation attributed to dissolution, respectively. Water mass-balance analysis shows that 40-90% of surface runoff is lost to groundwater infiltration in carbonates due to the development of mature karst hydrology. We incorporate chemical weathering and infiltration into a simple one-dimensional landscape evolution model based on the widely used stream power model and show that relief production in carbonates in Crete is largely due to reduced erosive power associated with water lost to infiltration into karst. Relief production in carbonates results in enhanced slope-dependent erosion, allowing carbonate denudation rates to keep pace with those in the meta-clastic catchments. From a global perspective, we observed a strong relationship between total denudation rate and physical erosion rate, but a weak scaling with dissolution rate. This observation implies that slope-dependent erosion becomes progressively more important as erosion rates increase, whereas rates of dissolution are limited by other effects, such as water flux. These findings lead to a new conceptual model where there is a dissolution speed limit in

carbonates due to available water and acid such that areas of high local uplift require substantial mechanical erosion to balance uplift and form steep slopes. In contrast, areas experiencing low uplift rates with sufficient water availability (e.g. humid climate) can balance uplift entirely with dissolution resulting in subdued carbonate landscapes.

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