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Feedbacks between erosion, climate and uplift in the Gongga granite on the eastern margin of the Tibetan Plateau

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In regions such as the Himalayan syntaxes, feedbacks between high rates of erosion, extremely rapid exhumation, and hot and weak crust have been proposed, where high erosion rates lead to thermal weakening of the crust, which leads to focused deformation and uplift, high topography, focused precipitation, and continued rapid erosion. However, there remains much debate about the initiation of such systems and the extent to which feedbacks exist, and it is not clear whether orographic precipitation, rapid erosion, and thermal weakening are necessary drivers or merely a response to tectonically driven uplift. To help elucidate these interactions, we turn to a system where spatial variations in climate, topography, exhumation, and crustal properties allow for an improved understanding of the factors leading to the combination of high topography, rapid erosion, and rapid uplift. Gongga Shan, a 7556 m peak on the eastern margin of the Tibetan Plateau, caps an area of localized anomalous topography that soars ∼3000 m above the plateau. Gongga Shan sits at the southern end of the Gonnga Shan granite, a Cenozoic intrusive body about 120 km long that roughly parallels the NNW-SSE strike-slip Xianshuihe Fault. Cosmogenic 10Be basin wide erosion rates show a distinct pattern of extremely high rates (> 5 mm/yr) in the Gongga region with rates decreasing in all directions to as low as 0.1 mm/yr over a distance of ∼30 km. Erosion rates are generally consistent with topography, published thermochronology ages and modern geodetic uplift rates, suggesting a stable pattern over the past 2-3 My. This system resembles the rapidly uplifting syntaxes; however at Gongga Shan many of the distinctive features of such systems predated rapid uplift. U-Pb zircon ages from the Gongga granite indicate a prolonged history of emplacement from ∼30 Ma to 4 Ma. The generation of melt and its emplacement at shallow depths indicate that the crust in this region has been relatively hot and likely weak since ∼30 Ma. Gongga Shan is located on the plateau margin where elevations rise rapidly from the Sichuan Basin, creating an orographic barrier and a zone of enhanced precipitation that has likely existed since middle Miocene time. The highest topography is also adjacent to the deeply incised Dadu River. The incision of the Dadu at 10-12 Ma created substantial local relief, enabling enhanced erosion even prior to the development of the anomalous topography. We propose that this combination of focused precipitation, preexisting relief, and hot weak rocks in the southern part of the granite set into motion a series of feedbacks between erosion, uplift, and orographic precipitation that has resulted in the extremely high topography and rapid erosion rates seen today. Only where all three of the driving factors are present do we observe the topographic and erosional extremes, and each of these driving factors was likely present prior to the initiation of extremely rapid uplift. Gongga Shan therefore represents a clear case of erosion-climate-tectonic coupling.