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What tors tell us about controls on bedrock jointing and spatial variability in regolith formation

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Tors are striking features of many granitic landscapes that offer windows into processes of regolith formation that otherwise frequently remain inaccessible. In this study, we combine measurements of tor volumes, joint spacing, feldspar, quartz and biotite crystal lengths, and ground surface convexities with geochemical analyses to determine petrological and structural controls on differential weathering and the formation of granitic regolith and tors in the Cairngorm Mountains, Scotland. Our results show that the tors have formed in spatially defined kernels of widely jointed, relatively coarse grained granite surrounded by finer grained, more densely jointed granite, in which regolith mantles have developed. It further appears that this wide joint spacing was largely established by slow cooling of intruded melts, thereby revealing a control on bedrock joint spacing, and subsequent rates of regolith formation, that is little recognized in geomorphology. Sheet jointing is variably developed in the Cairngorms tors, with better developed sheet jointing on relatively high convexity surfaces. This variability strongly influences tor morphologies and indicates that the regional compressive stresses necessary for the formation of sheet jointing were of lower magnitude than in locations where sheet jointing displays less spatial variability, such as in the Sierra Nevada mountains of California. Although the source of this compressive stress remains uncertain, the presence of sheet jointing reaffirms that the Cairngorm tors have likely emerged from a thin regolith. This important implication of sheet jointing has been previously unrecognized in the tor literature and probably also applies to sheeted tors elsewhere. The location of tors in coarse grained granites, characterized by wide joint spacing but high matrix effective porosity, and regolith on finer grained granites, characterized by more closely spaced joints and lower matrix effective porosity, highlights the dominance of fracture porosity over matrix porosity in differential weathering and regolith formation. Controls on differential weathering are, however, frequently relative and, therefore, local, thereby confounding attempts at identifying universal controls on the development of tors and regolith zones.