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Subcritical crack growth and mechanical weathering: a new consideration of how moisture influences rock erosion rates.

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The contributions of moisture to the mechanical aspects of rock weathering and regolith production are poorly quantified. In particular, geomorphologists have largely overlooked the role of subcritical crack growth processes in physical weathering and the fact that moisture strongly influences the rates of those processes. This influence is irrespective of the function that moisture plays in stress loading mechanisms like freezing or hydration. Here we present a simple numerical model that explores the efficacy of subcritical crack growth in granite rock subaerially exposed under a range of moisture conditions. Because most weathering-related stress loading for rocks found at, or near, Earth's surface (hereafter surface rocks) is cyclic, we modeled crack growth using a novel combination of Paris' Law and Charles' Law. This combination allowed us to apply existing empirically-derived data for the stress corrosion index of Charles' Law to fatigue cracking. For stress, we focused on the relatively straightforward case of intergranular stresses that arise during solar-induced thermal cycling by conductive heat transfer, making the assumption that such stresses represent a universal minimum weathering stress experienced by all surface rocks. Because all other tensile weathering-related stresses would be additive in the context of crack growth, however, our model can be adapted to include other stress loading mechanisms. We validated our calculations using recently published thermal-stress-induced cracking rates. Our results demonstrate that 1) weathering-induced stresses as modeled herein, and as published by others, are sufficient to propagate fractures subcritically over long timescales with or without the presence of water 2) fracture propagation rates increase exponentially with respect to moisture, specifically relative humidity 3) fracture propagation rates driven by thermal cycling are strongly dependent on the magnitude of diurnal temperature ranges and the average contrast in thermal properties of adjacent minerals, and 4) cracking is suppressed with increasing depth at meter scales due to increasing confining pressure, and decreasing range of temperature cycling. We incorporated our crack growth model into a simple rock erosion model, describing only the case of intergranular cracking and associated granular disaggregation and spalling. Using this rock erosion model and local climate data, we will compare rock erosion rates calculated for different localities and rock types with those independently derived from 10Be cosmogenic radionuclide analysis of bedrock outcrops. Our analysis will potentially provide some of the first quantification of mechanistic links between mechanical weathering rates and climate at Earth's surface.