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2- and 3-D hierarchical fracturing driven by hydration reactions

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Hierarchical fracture patterns are the result of a slowly driven fracturing process that successively divides the rocks into smaller domains. In quasi-2D systems, such fracture patterns are characterized by four sided domains, and T-junctions where new fractures stop at right angles to pre-existing fractures. We describe fracturing of mm to dm thick enstatite layers in a dunite matrix from the Leka ophiolite complex in Norway. The fracturing process is driven by expansion of the dunite matrix during serpentinization. The resulting fracture patterns have all the characteristic feature of 2-D hierarchical patterns, including a power-law distribution of cumulative fracture lengths for lengths $>$ layer thickness.

Spectacular examples of 3-D hierarchical fracture patterns form during the weathering of basaltic intrusions (dolerites). Incipient chemical weathering of dolerites in the Karoo Basin in South Africa occurs around water-filled fractures, originally produced by thermal contraction or by externally imposed stresses. This chemical weathering causes local expansion of the rock matrix and generates elastic stresses. On a mm to cm scale, these stresses lead to mechanical layer-by-layer spalling, producing the characteristic spheroidal weathering patterns. However, our field observations and computer simulations demonstrate that in confined environments, the spalling process is unable to relieve the elastic stresses. In such cases, chemical weathering drives a much larger scale hierarchical fracturing process in which fresh dolerite undergoes a continuous domain division that effectively regenerates fresh surfaces. This process produces the characteristic weathering patterns seen both in Karoo and a wide-range of other geological environments.

In summary, hierarchical fracturing leads to a continuous production of fresh reactive

surface area during hydration processes such as serpentinization and weathering, and provides first-order rate control during both serptinization and weathering. It thus has wide ranging implications for global geochemical budgets, landscape evolution, and a number of other important geological features.