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An Allegre-ian Perspective on Why Weathering Rates Slow with Age

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Claude Allegre's research career resulted in highly-cited papers and books on topics spanning from the age of the Earth to formation of the atmosphere and evolution of Earth's surface. One set of topics he investigated with colleagues and students since at least the 1990s included the lithological and erosional controls on weathering. Global weathering is important to understand because silicate mineral dissolution removes carbon dioxide from the atmosphere at the same time that it creates pores that store or mobilize ground water in the subsurface. We can understand these processes by measuring them in the laboratory but weathering and porosity growth rates both decrease with duration of weathering, making extrapolation from lab to field difficult. Some of the causes of weathering rate decreases are similar for basalts and granites but some differ for the two lithologies. Both lithologies show evidence of rate limitation by mineral-water reaction kinetics when studied in small systems over short timescales but show evidence of transport limitation in large systems over long timescales. Especially for the less-reactive granitic lithologies, kinetic limitation may still be observed in cool, wet, fast-eroding watersheds. As exposure time for any system increases, however, weathering rates slow because the most reactive minerals disappear and porosity and flow paths change. For example, primary porosities (pores, vugs, fractures) in active volcanic systems tend to be large and heterogeneous, allowing deep infiltration. But when basaltic watersheds are exposed for longer time periods, deeply-sourced springs tend to disappear and shallow flowpaths increasingly dominate. Although weathering fluxes also decrease in granites with increasing exposure time, the trends in flow and weathering location may differ substantially. For example, porosity is generally low in granitic-composition rock before weathering commences, but porosity can grow with weathering (often by weathering-induced fracturing). The result is deeper regolith on granitic than basaltic rock. An open question is whether the rate of diminution of weathering with time is the same or different for the two lithologies as they move toward steady state, and how these differences in evolution of weathering may affect global responses to perturbation, including isotopes in the rock record.