Variations in chemical weathering contributions to landscape lowering across a retreating escarpment

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The removal of mass loss from hill slopes occurs via two distinct mechanisms: physical removal of material off of hill slopes into streams, and dissolution of minerals by water moving through the system. In this study we are comparing the contributions of these processes to landscape lowering across the escarpment in south eastern NSW, Australia. Profiles at the base and top of the escarpment are developed in the Bemboka granodiorite.

Regions at the base of the escarpment (NR) are homogenously deeply weathered, in places to depths greater than 10m. Bulk geochemical analyses were completed at a variety of soil transport distances and at different depths within the soil profile and upper saprolite at the NR site. Because zirconium behaved as an immobile element, it was used as a geochemical tracer to monitor the degree of mass loss relative to the parent material. These data indicate that ~30% mass loss occurs in the granite prior to soil formation at the NR site. The degree of mass loss increases as soil is transported down the hill slope. By the time soils reach the convergent region of the hill slope as much as ~60% of the mass of the original parent material has been removed via solution. The NR profiles are characterized by high degrees of sulfur accumulation near the soil surface. The distribution of lanthanide elements in these weathering profiles is controlled by secondary lanthanide aluminum phosphate minerals. These highly insoluble lanthanide phosphate minerals are dissolved in the soil and all lanthanides (including Ce) accumulate deeper in the profile. We attribute this to microbially enhanced dissolution of phosphate minerals in shallow soils, and organic ligand complexation of lanthanides.

The site at the top of the escarpment (BMtn) is characterized by several features that distinguish it from the NR site. Zirconium does not behave as a conservative tracer. However, Ce is oxidized to form cerianite; it is conserved within the saprolite and strongly accumulated in the soil (Taunton et al., 2000). Unlike at NR, there is no evidence of sulfur accumulation in the soil at BMtn. All other geochemical data indicate that the soils are very highly weathered. Using Ce as a conservative tracer, we estimate up to 90% mass loss via dissolution. These results are consistent with escarpment retreat through an old and deeply weathered landscape.

References:
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Nebular oxidation of iron

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The mole fraction fayalite, X_{Fa}, in olivine (olv) of H-, L- and LL- chondrites averages 0.18, 0.23 and 0.29, resp. At 10^{-3}-10^{-6} bars, forsterite (Fo) condenses at 1450-1250K from a solar gas [1], which is so reducing that significant Fe^{2+} is stable only at T<600K [2] as fayalite (Fa). Equilibrium solar nebular condensation of FeO thus requires Fe^{2+} diffusion into pre-existing Fo grains. But at such low T, Fe^{2+} diffusion is so slow that this means of FeO stabilization is unlikely. The nebula began as a cold cloud, solar in composition overall, of gas and dust, with all condensable elements in the dust. If dust concentrates relative to gas in regions which then totally vaporize, gas volumes enriched in condensables and O relative to C and H compared to solar composition are created where condensation occurs at higher fO_2 than a solar gas. This stabilizes Fe^{2+} at high enough T for it to diffuse into the cores of pre-existing Fo grains on nebular time-scales. Olv with X_{Fa} typical of ordinary chondrites condenses at T> 1200K in systems enriched in dust of C1 composition by factors of 400-900 relative to solar composition [3]. But in dynamical models of the solar nebula, it is hard to enrich dust by factors >100 *via* coagulation and settling [4]. What minimum dust enrichment yields such X_{Fa} at high enough T for diffusion to allow equilibration on nebular time-scales? To answer this, we did equilibrium condensation calculations to 500K with the same program and input data as [1], except for new, lower, photospheric abundances of C and O [5]. Solar gas and systems enriched in C1 dust [3] or anhydrous (OC) dust [1] were studied. In solar gas, $\log fO_2$ rises from IW-6.5 at 900K to IW-4.4 at 550K, driving X_{Fa} from ~0 to 0.27. Fe-Mg interdiffusion rates in Fa~10 [6] and their T- and fO_2-dependence [7] were used with the fO_2-T path for solar gas to compute the lowest T at which 1 and 10µ olv grains equilibrate in 10^4 yr, and thus the highest X_{Fa} attainable for likely condensate grain sizes and nebular time-scales. This maximum X_{Fa}=0.005 at T=830K. Enrichments of even 1000X in OC dust fail to yield the whole range of X_{Fa} in ordinary chondrites: $\log fO_2$ falls from IW-3 at 1000K to IW-4 at 600K, giving maximum X_{Fa}=0.15 at 920K for 10µ and 0.20 at 800K for 1µ grains. Much lower enrichments of C1 dust suffice: at only 75X, well within the range in dynamic models, $\log fO_2$ rises from IW-3 at 1000K to IW-1 at 500K. In such gas, 10µ grains equilibrate in 10^4 yr at 920K, where X_{Fa}=0.18; 1µ grains at 800K, where X_{Fa}=0.26.

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