

## The Art of augering, observing, and connecting processes across threshold landscapes

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### Abstract

We focus here on the soil-mantled landscapes found in high-relief, steeply sloped landscapes typically thought to be at a critical threshold of soil cover. Soil found across such landscapes fits the conceptual framework of a physically mobile layer derived from the underlying parent material with some locally-derived organic content. The extent and persistence of such soils depends on the long-term balance between soil production and erosion. We present cosmogenic Be-10-derived soil production and erosion rates that show that soil production increases with catchment-averaged erosion, suggesting a feedback that enhances soil-cover persistence, even in threshold landscapes [1]. Soil production rates do decline systematically with increasing soil thickness, but hint at the potential for separate soil production functions for different erosional regimes. We also show that a process transition to landslide-dominated erosion results in thinner, patchier soils and rockier topography [2], but find that there is no sudden transition to bedrock landscapes.

These findings focusing on the physical processes of soil production and transport are coupled with extensive measurements of major and trace elements in soils, saprolites and bedrock across different physiographic regimes ranging from low to high gradient in the same field area of the San Gabriel Mountains, California. Connecting the processes shows that average chemical depletion fractions (soil loss relative to parent material) decrease with increasing elevation and decreasing temperature, reflecting a combination of climate influence and potential dust flux. On low-gradient slopes weathering rates increase with increasing erosion rates, reflecting the influence of mineral supply, while on high-gradient slopes both weathering intensity and rates decrease with increasing erosion rate [3].

Finally, we draw an important conclusion connecting the physical processes producing and transporting soil and the chemical processes weathering the parent material by measuring parent material strength. We observe that parent material strength increases with overlying soil thickness and, therefore, the weathered extent of the saprolite. Soil production rates, thus, decrease with increasing parent material competence. These observations highlight the importance of quantifying hillslope hydrologic processes where our multi-faceted measurements are made. Art did it!

[1] Heimsath et al. (2012) *Nature Geoscience* DOI: 10.1038/NGEO1380. [2] DiBiase et al. (2012) *Earth Surface Processes and Landforms* DOI: 10.1002/esp.3205.

[3] Dixon et al. (2012) *Earth and Planetary Science Letters* DOI: 10.1016/j.epsl.2012.01.010.

## Copper partitioning during magmatic-hydrothermal phase separation — revisited: Fluid inclusions in coeval quartz, topaz and garnet

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Recent experimental studies have raised concerns that Cu concentrations in natural quartz-hosted magmatic-hydrothermal fluid and melt inclusions can be modified after entrapment. Li, Cu<sup>+</sup>, Na<sup>+</sup>, Ag<sup>+</sup> and probably H<sup>+</sup> may undergo selective diffusional exchange between inclusions hosted by quartz and the surrounding aqueous fluid [1, 2]. Using LA-ICPMS multi-element analysis including sulfur, we have analysed coexisting brine and vapor inclusions hosted in topaz and garnet, from samples where previous analyses had been obtained from similar and likely coeval inclusions hosted by quartz [3]. We found that the concentration of Cu in the quartz-hosted fluid inclusions deviate from those hosted by garnet or topaz in the same sample. In particular, the selective enrichment of Cu found in quartz-hosted vapor inclusions is not observed in the topaz-hosted counterparts, whereas S and all other metals have overlapping concentrations in each of the samples, irrespective of host mineral.

Our data from natural samples are in line with the experimental study of Lerchbaumer and Audétat [2], indicating selective inward diffusion of copper into the quartz-hosted vapor inclusions after their entrapment and during cooling from ~450°C. Electrolytic diffusion experiments have previously demonstrated that small monovalent cations, such as Li<sup>+</sup> and to lesser degrees Na<sup>+</sup>, can selectively diffuse along the channels oriented parallel to the c-axis of the quartz structure [4].

Post-entrapment modification of natural fluid inclusions depends on a chemical driving force. In cooling magmatic-hydrothermal systems, a chemical potential gradient in  $\mu_{\text{Cu}^+}$  can be established by the high original H<sub>2</sub>S content of magmatic vapor inclusions, in excess relative to chalcophile metals [3] as confirmed by our new data from garnet and topaz inclusions. Cu<sup>+</sup> may be driven to diffuse from a gradually H<sub>2</sub>S-depleted grain-boundary fluid outside the quartz crystals (where Cu<sup>+</sup> activity remains high due to consumption of H<sub>2</sub>S by reaction with ferromagnesian silicates to pyrite) towards the vapor inclusions in which Cu<sup>+</sup> activity gradually decreases by precipitation of a daughter crystal of chalcopyrite, CuFeS<sub>2</sub>. This S-driven exchange mechanism explains why S/Cu ratios in natural fluid inclusions are commonly close to the stoichiometric proportion of Cu:S = 1:2, as in chalcopyrite [3].

[1] Zajacz Z., Hanley J.J., Heinrich C.A., Halter W.E., Guillong M. (2009) *Geochimica et Cosmochimica Acta* **73**, 3013-3027.

[2] Lerchbaumer L. and Audétat A. (2011) *European Geophysical Union General Assembly*, Vienna: **EGU2011**, 11906.

[3] Seo J.H., Guillong M. and Heinrich C.A. (2009) *Earth and Planetary Science Letters* **282**, 323-328. [4] Harris, P.M. and Waring, C.E. (1937) *Journal of Physical Chemistry* **41**, 1077-1085