

Polyphase serpentinization history of Mariana forearc mantle: Observations on ultramafic clasts from ODP Leg 195, Site 1200

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In the forearc of the Mariana subduction zone system, abundant seamounts form from extrusion of blueschist and serpentine mud. ODP Leg 195 drilled the South Chamorro seamount, where ultramafic clasts occur within the mud matrix. These clasts show a complex serpentinization history, which bears the potential for tracking the fluid history during uplift and cooling of mantle wedge rocks to the seafloor.

Highly serpentinized harzburgites, which are crosscut by different generations of late-stage veins, were examined. Preserved primary minerals include olivine ($X_{Mg}=0.91-0.92$) and orthopyroxene ($X_{Mg}\approx 0.92$). Magnesium-rich ($X_{Mg}=0.92-0.95$) clinopyroxene is present as exsolution lamellae in orthopyroxene and in symplectitic intergrowths with spinel ($X_{Cr}=0.48-0.59$).

Multiple serpentinization steps are documented: (I) Pervasive serpentinization led to ubiquitous breakdown of olivine and formation of serpentine ($X_{Mg}=0.92-0.94$) and magnetite. Orthopyroxene was replaced to lesser extent by serpentine ($X_{Mg}\approx 0.90$). Clinopyroxene remained stable during this stage. (II) The second hydration stage was bound to fractures crosscutting earlier serpentinization textures and is manifested as veins consisting of Mg-rich serpentine ($X_{Mg}=0.90-0.93$). (III) Veins from stage II were re-activated and overprinted by serpentine + brucite assemblages. Replacement of magnetite is observed, leading to brucite with $X_{Mg}\approx 0.80$ and serpentine with $X_{Mg}< 0.90$. Furthermore, clinopyroxene breaks down and Fe-rich brucite ($X_{Mg}\approx 0.60$) forms. (IV) Finally, late discontinuous serpentine veins formed perpendicular to the stage II and III veins.

Pervasive serpentinization (stage I) likely marks a comparatively high-T (i.e. $T=250-350^{\circ}\text{C}$) hydration that took place within the mantle wedge. The lower density of the hydrated rocks led to diapiric rise and associated fracture-bound serpentine formation (stage II). Formation of Fe-rich brucite as well as breakdown of magnetite and clinopyroxene (stage III) occurred after considerable cooling ($T\ll 200^{\circ}\text{C}$) during uplift. Petrography and mineral chemistry point to low-temperature demagnetization, which is in agreement with density-susceptibility relations and results of reaction-path modelling.

Incomplete recovery of mineral-bound lignin phenols

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Intimate associations with minerals is one mechanism involved in the accumulation and stabilisation of organic matter (OM) in soils. Phenolic compounds derived from partial degradation of polyphenols such as lignin are among the most surface-reactive organic compounds. However, we still do not know to which extent lignin-derived phenols associated with soil minerals can be analytically assessed.

Here, we tested the extractability of mineral-bound lignin-derived phenols by alkaline CuO oxidation.

We used tree aqueous litter (blue oak, pine, annual grass) leachates and five minerals (ferrihydrite, goethite, kaolinite, illite, montmorillonite). In a first step, we determined the sorption capacity for dissolved organic carbon for each mineral, as well as the changes in specific UV absorption during the sorptive interaction between organic matter and minerals. Then, we produced organic–mineral associations under conditions well below the sorption maximum of the contained mineral. The mineral–organic associations, the dried out leachates and the equilibrium solutions were then subjected to CuO oxidation. The amount of sorbed and not CuO-extractable lignin-derived phenols were calculated by difference.

CuO-oxidation extracted lignin-derived phenols bound to ferrihydrite completely and without changes in composition, presumably due to complete dissolution of the mineral. For all other minerals, up to 44% of the bound phenols could not be extracted. The incomplete recovery of sorbed phenolic compounds was accompanied by different ratios of extracted individual phenols, suggesting different bonding strengths.

The results show that a substantial portion of lignin-derived phenols binds irreversibly to minerals, even escaping harsh extraction unless the mineral is completely dissolved. The difference in extractability of individual phenols suggests that abiotic processes, such as sorption/desorption, should be taken into account when using CuO oxidation data for assessing organic matter transformation in mineral matrixes.