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# Enhanced weathering in the seabed: Rapid olivine dissolution and iron sulfide formation in submarine volcanic ash

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## Abstract

In basaltic volcanic ash recovered from a seamount at 3000 m water depth, we discovered marcasite and pyrite precipitation within cavities that formed by partial to complete dissolution of olivine. In places, these cavities are reminiscent of negative crystal shapes; elsewhere they apparently continue along cracks. In strong contrast, adjacent volcanic glass shows little, if any, evidence for dissolution. The $FeS_2$ precipitates were commonly found to be conjoined and planar aggregates, occurring in the center of the voids. Their maximum volume fraction in relation to the void space as determined by 2D and 3D imaging techniques corresponds to the amount of iron released by olivine dissolution. Almost all occurrences of $FeS_2$ precipitation are related to Cr-spinel inclusions in the former olivine. We propose that rapid olivine dissolution was initiated by reduced $H_2S$-bearing fluids at olivine grain boundaries or surfaces exposed by cracks. Many of these cracks are connected to spinel grains, where the iron liberated from olivine is mineralized as $FeS_2$, initially facilitated by heterogeneous nucleation. Subsequent pyrite and/or marcasite precipitation occurred as overgrowths on existing $FeS_2$ aggregates. The particular chemical environment of low-pH, hydrogen sulfide-bearing fluids may have enhanced olivine dissolution by (1) keeping Fe in solution and (2) sequestering important quantities of Fe as $FeS_2$. The in situ oxidation of ferrous Fe and precipitation of ferric hydroxides at the olivine surface commonly observed in oxic environments were obviously impeded. It would have slowed down olivine dissolution to rates more similar to the dissolution of basaltic glass. We have no direct indication that the process of rapid olivine dissolution was aided by subseafloor life. However, the presence of fibrous structures with small sulfide particles could indicate late colonization of sulfate-reducing bacteria that may add an additional path of iron fixation.

**Keywords:** Olivine, pyrite, marcasite, seamount, Canary Islands, dissolution, alteration, X-ray microscopy