Mineralogical markers of highly to ultra-reducing conditions in H2 producing boreholes (Oman Drilling Project Multiborehole Observatory – Samail Ophiolites)

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Résumé

Drilling conducted by the Oman Drilling Project (Oman DP) at Sites BA1, BA3 and BA4 targeted extensively serpentinized peridotites in Wadi Lawayni (Wadi Tayin Massif, south of Samail ophiolites). Recovered cores contain multiple mineralogical indicators of reducing conditions, including calc-silicate phases, sulfides, and native metals, which signify highly reducing environments, which represents an ultra-reducing signature.
The peridotites from the Hole BA3A hosts the reduced most suite of opaque phases- pentlandite (FeNiS), magnetite, awaruite (NiFe), heazlewoodite (NiS), native copper, and covellite (CuS). These minerals mainly occur in the serpentine groundmass or veins, indicating they formed as secondary phases during alteration. In highly serpentinized samples, sulfides appear as ultrafine grains ($< 2\ \mu$m). Pentlandite is the most common sulfide, often associated with magnetite, awaruite, and occasionally native copper. These assemblages suggest low-temperature ($< 200\circ$C) formation under high hydrogen fugacity (aH), consistent with serpentinization-driven redox conditions.

BA3A peridotites are intruded by gabbroic and clinopyroxenitic dikes, which have undergone pronounced hydrothermal alteration to form rodingite-like mineral associations, including hydrogarnet, diopside, phlogopite, xonotlite, pectolite, and vesuvianite. The fibrous to radial habits of xonotlite and pectolite in milky white veins are notable given their rare occurrence globally. Fluid inclusions containing H and CH, observed in pectolite and thermodynamic predictions highlight a strong dependency of alteration mineralogy on the gabbro-peridotite interaction ratio, with Ca-silicates like xonotlite stabilizing under peridotite-dominant, low-fO conditions.
Together, these features indicate robust redox gradients and fluid pathways, with implications for hydrogen production, metal transport, and deep biosphere habitability within serpentinizing oceanic lithosphere.

Mots-Clés: redox gradients, hydrogen, serpentinized peridotites, Oman Drilling Project

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