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Multistage serpentinisation at the ocean floor revealed by *in situ* analysis

CORALIE VESIN[1], PROF. DANIELA RUBATTO[1,2], THOMAS PETTKE[1] AND ETIENNE DELOULE[3]

[1]University of Bern
[2]University of Lausanne
[3]CRPG, CNRS - Université de Lorraine, F-54000 Nancy
Presenting Author: coralie.vesin@geo.unibe.ch

Serpentinisation is the main hydration reaction of the oceanic lithosphere and plays an important role in the Earth's water cycle. The crystallization of serpentine in defined textural sites after the mantle minerals (mesh rim and mesh centre after olivine, and bastite after orthopyroxene) provides a guide for the study of hydration stages. We used *in situ* analysis of oxygen isotopes (SIMS) and trace elements (LA–ICP–MS) to study the variability of temperature and fluid composition during the successive water uptake into peridotites. The investigated samples are from the extended passive margin (Newfoundland and Iberia, ODP Leg 210 Site 1277 and Leg 173 Site 1070, respectively), and mid-ocean ridges (MOR, Mid-Atlantic Ridge, Leg 209 Sites 1272A & 1274A and Hess Deep Leg 147 Sites 895D & 895E).

Transition metal (V, Sc, Co, Zn, Mn) concentrations provide insights into the redistribution of elements between textural sites during serpentinisation. Serpentine from MOR and the Iberia margin preserve transition metal compositions in mesh and bastite characteristic of mantle precursor minerals, suggesting sequential, closed system serpentinisation of the mineral domains. In contrast, samples from Newfoundland show chemical exchanges between serpentine textures, suggesting a simultaneous serpentinisation of olivine and orthopyroxene.

The $\delta^{18}O$ value of serpentine is temperature dependent, whereas chlorine and boron concentrations were used as proxies for the extent of water/rock interaction. The correlation of Cl/B with $\delta^{18}O_{serpentine}$ helps to decipher the temperature from the fluid evolution effect. The fluid involved in the serpentinisation of the MOR samples was more saline with Cl/B of 25–200 compared to serpentine in the passive margin samples with Cl/B below 25. The lowest Cl/B measured in serpentine is interpreted to represent fluid-rock interaction with the least evolved fluid composition, i.e., seawater composition, allowing the use of $\delta^{18}O_{fluid}$ = 0 ‰ to calculate serpentinisation temperatures. The $\delta^{18}O_{serpentine}$ of the MOR samples indicates temperatures between 150–290°C, whereas most of the passive margin samples were serpentinised at lower temperature from 190 to 100°C. One sample from the Iberia margin shows $\delta^{18}O_{serpentine}$ variation of ~10 ‰ between the textural sites, which indicates prolonged serpentinization during cooling from 190 to 75°C.