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Disentangling serpentinization events at the massif scale through microstructural and B isotope characterization.

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The process of peridotite hydration, or serpentinization, is known to generate reducing conditions through the production of H₂-CH₄-rich fluids. The release of these abiotic energy sources has attracted a broad scientific attention spanning natural energy research, carbon cycling, and deep subsurface microbiology and astrobiology. Serpentinization is documented at various geological settings including sub-seafloor hydrothermal systems and at much higher pressures and temperatures in subduction zones. Determining the conditions at which serpentinization and H₂ release occur is crucial to comprehensively understand the geochemical cycle of life-essential, redox-sensitive elements such as C in subduction zones and the potential supply of energy to the deep subsurface biosphere. However, especially at convergent margins, ultramafic rocks may record multiple serpentinization events ranging from seafloor to subduction metamorphic conditions, which challenges the study of this key geological process. Petrographic and geochemical tracers, such as $\delta^{11}\text{B}$, have been used to disentangle multiple serpentinization events taking place at different geodynamic settings and/or from different fluid sources. However, petrographic features may be of ambiguous interpretation, and boron isotope data may show significant overlap among different serpentinization conditions.

To tackle these open questions, we adopted a high-resolution approach at the massif scale within the blueschist-facies Monte Maggiore ultramafic body, Alpine Corsica, France. This massif recorded the critical conditions of the lizardite/antigorite transition, which makes it an ideal case to study preserved and structurally controlled serpentinization events. We collected more than 150 samples of partially to fully serpentinized peridotites over an area of about 1Km². The samples were selected and processed for petrographic analysis, Raman Spectroscopy, major and trace elements and $\delta^{11}\text{B}$ with the aim of reconstructing a massif-scale distribution of multiple serpentinization events. Four main serpentine generations were identified: lizardite/chrysotile, lizardite/antigorite, sole antigorite, and late chrysotile. These generations show characteristic and systematic features, and their association defines a limited number of sample types at the massif

scale. Bulk $\delta^{11}\text{B}$ analyses show a wide range of values, from -2.51 to 23.33 ‰, which overlap with both slab and ocean derived fluids. When compared with petrographic data, it appears that samples belonging to the same sample type, therefore sharing common mineralogical and microstructural features characteristic of a specific serpentinization process, show substantially different boron isotopic values.

Our results indicate that large petrographic and $\delta^{11}\text{B}$ variability may exist within a single serpentinized ultramafic massif, and also among samples plausibly belonging to the same serpentinization event. This high-resolution study of serpentinization events at the massif scale calls for caution while interpreting large-scale serpentinization processes through the study of individual samples or small sample sets inferred to represent large geodynamic contexts.