High pressure serpentinization and abiotic methanogenesis in metaperidotite from the Appalachian subduction, northern Vermont

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Serpentinization is the process of hydroxylation of olivine-rich ultramafic rocks to produce minerals such as serpentine, brucite, magnetite, and may release $\text{H}_2$. The hydrogen produced through serpentinization reactions can be involved in abiotic reaction pathways leading to the genesis of abiotic light hydrocarbons such as methane ($\text{CH}_4$). Examples of this phenomenon exist at the seafloor, such as at the serpentinite-hosted Lost City hydrothermal field, and on land in ophiolites at relatively shallow depths. However, the possibility for serpentinization to occur at greater depths, especially in subduction zones, raises new questions on the genesis of abiotic hydrocarbons at convergent margin and its impact on the deep carbon cycle. High-pressure ultramafic bodies exhumed in metamorphic belts can provide insights on the mechanisms of high-pressure serpentinization in subduction zones and on the chemistry of the resulting fluids. This study focuses on the ultramafic Belvidere Mountain complex belonging to the Appalachian belt of northern Vermont, USA. Microstructures show overgrowth of olivine by delicate antigorite crystals, suggesting olivine serpentinization at high-temperature consistent with the subduction evolution of the Belvidere Mountain complex. Fluid inclusion trails cross-cutting the primary olivine relics suggest their formation during the antigorite serpentinization event. MicroRaman spectroscopy on the fluid inclusions reveals a $\text{CH}_4$-rich gaseous composition, with trace of $\text{N}_2$, $\text{NH}_3$ and S-H compound. Moreover, the precipitation of daughter minerals of lizardite and brucite in the fluid inclusions indicate the initial presence of $\text{H}_2\text{O}$ in the fluid. Secondary olivine is observed at the rim of pseudomorphosed primary pyroxenes (bastite), and has higher forsterite (Fo$_{95}$) content with respect to the primary olivine (Fo$_{92}$), suggesting either a syn-serpentinization olivine precipitation in the subduction zone, or a successive partial dehydration of the antigorite during metamorphism. Decreasing oxygen fugacity during serpentinization and related abiotic reduction of carbon at high-pressure conditions is proposed at the origin of methane in the fluid inclusions. This potentially places the Belvidere Mountain complex as an example of deep serpentinization related to high-pressure genesis of abiotic methane.