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Low-temperature plate boundary serpentinization post-dates subduction initiation and facilitates obduction of an Appalachian ophiolite

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Geodynamic models suggest that formation of plate boundary shear zones requires a mechanically weak material. Serpentinites are commonly credited for lithosphere-scale strain localization and considered prerequisites for subduction initiation. However, geologic observations suggest that proto-interface temperatures exceed 550˚C at 20-30 km, making conditions too hot for serpentine to form. Thus, serpentine's contribution to plate boundary formation is unclear. Here we present structural and geochemical data constraining the mechanical and metasomatic evolution of a fossilized subduction interface exposed on Mont Albert (Québec, Canada) to evaluate the relative timing, extent, and effects of serpentinization across a developing interface.

Mont Albert is an incomplete Ordovician ophiolite complex that records subduction initiation and obduction onto the Laurentian margin during the Taconian Orogeny (~450-500 Ma). Across an ~80 m structurally thick moderately south-dipping section, meta-oceanic crust is underthrust beneath sheared basal mantle rocks. The "contact zone" in the upper plate mantle comprises ~10-20 m of serpentinite (75-95%) mylonites recording top-N, thrust-sense of shear; stretching lineations in the underlying crust and mantle mylonites are similar. Contact mylonites are characterized by sub-mm to cm-scale intercalations of fine-grained lizardite (confirmed with Raman spectroscopy), Fe-oxide-rich (hematite), and relict olivine-rich layers. No antigorite was identified. Sheared mesh textures show that serpentinization occurred during progressive contact mylonitization. Mantle rocks grade into less serpentinized (90-50%) porphyroclastic peridotites ~20-60 m above the contact that exhibit older, pre-serpentinization dynamic recrystallization textures. Geochemical analyses across the 60m mantle transect (n=9) and farther away (+300-800m, n=4) show very limited trends with distance from the contact or degree of serpentinization. Major elements and HREE demonstrate variable melt depletion (~5-15%) of the mantle protolith; Ce, Sr, and Pb are only subtly enriched at the contact compared to structurally distal samples; and LREE and other fluid mobile elements do not vary systematically between samples. Overall, this supports minimal chemical overprinting during serpentinization, and that limited fluid flow occurred late in the shear zone history at low temperatures (<300˚C). Serpentinites therefore did not facilitate initial strain localization during plate boundary development, but rather followed from focused fluid flow along an established lithosphere-scale structure and accommodated late-stage obduction-related thrusting.