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A TEM study on serpentinized peridotite from the Southwest Indian Ridge and implications for the deep ocean hydrothermal system

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In this work, TEM was used to establish the mineralogy of a sample collected from a hydrothermal field in the Southwest Indian Ridge (SWIR). The mineral assemblages revealed in this sample shed new light on earth mantle hydration and flow. Abyssal peridotites generate at mid-ocean ridges where they can undergo hydration reactions to become serpentinite minerals, especially in slow to ultraslow spreading mid-ocean ridges. The SWIR is one of the two ultraslow spreading ridges in the world. The serpentinized peridotite sample studied in this work was collected by the 21st Voyage of the Chinese oceanic research ship Dayang Yihao (aka Ocean No. 1) from a hydrothermal field (63.5°E, 28.0°S, and 3660 m deep) in SWIR.

The reaction of peridotites to serpentinite has attracted increasing attention as it can provide information regarding mantle hydration and water cycles in the deep Earth. For example, among the main types of serpentinite, antigorite forms at T > 300 °C, lizardite forms at T < 200 °C, and chrysotile forms at intermediate temperatures [1].

The mineral assemblages of the SWIR serpentinized peridotite determined by petrography and XRD techniques were found to be lizardite, chrysotile, olivine, orthopyroxene, clinopyroxene, spinel, magnetite, and chlorite. SEM and TEM revealed serpentinized olivine and orthopyroxene were transformed to chrysotile (Figure 1). In addition, lizardite was found coexisting with chrysotile in clinopyroxene. From nanobeam SAED and TEM analysis, it was observed that the topological structure between lizardite and clinopyroxene is $[100]_{cpx}//[001]_{liz}$ (Figure 2), while there is no topological relationship between chrysotile and clinopyroxene. A little chlorite was observed in the serpentine vein, and some nanometer-sized amphibole was observed existing at the side of serpentine vein with $[100]_{cpx}//[001]_{amp}$ (Figure 3).

The existence of chlorite and amphibole suggest a hydration temperature reaching greenschist facies conditions, which indicates the hydrothermal metamorphic reaction with pre-serpentinization was above 300 ℃ in the east part of SWIR [1, 2]. But the temperature decreased rapidly because of watercooling. The remnant lizardite indicates the serpentinization started below 200 °C . However, chrysotile is the dominant serpentine mineral composition in this sample, which is different from most seafloor serpentinized peridotite [2]. Because serpentinization is an exothermic reaction, the coexistence of chrysotile and lizardite indicates the hydration temperature of serpentinization was mainly below 300 °C. These observations suggest that the easternmost part of SWIR had undergone multiple stages of hydrothermal metamorphic reactions.

References

[1] O'Hanley, D.S. Serpentinites. 1984.
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[3] This work was supported by NSFC (41172050) and CSC. The electron microscopy was accomplished at the Electron Microscopy Center at Argonne National Laboratory, a U.S. Department of Energy Office of Science Laboratory operated under Contract No. DE-AC02-06CH11357 by UChicago Argonne, LLC.

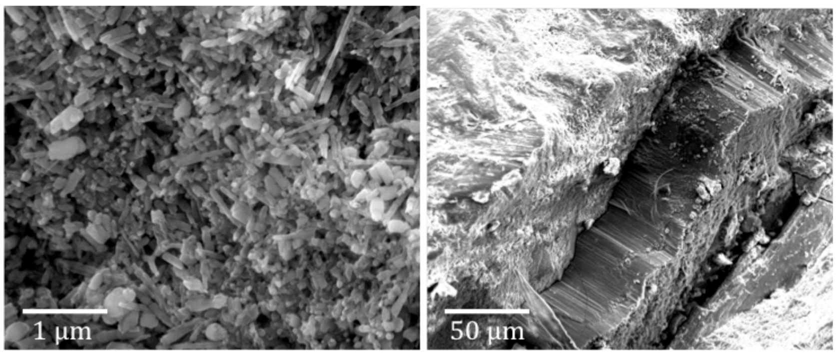

Figure 1. Serpentinized olivine (a) and orthopyroxene (b) were found changed to chrysotile with different morphology.

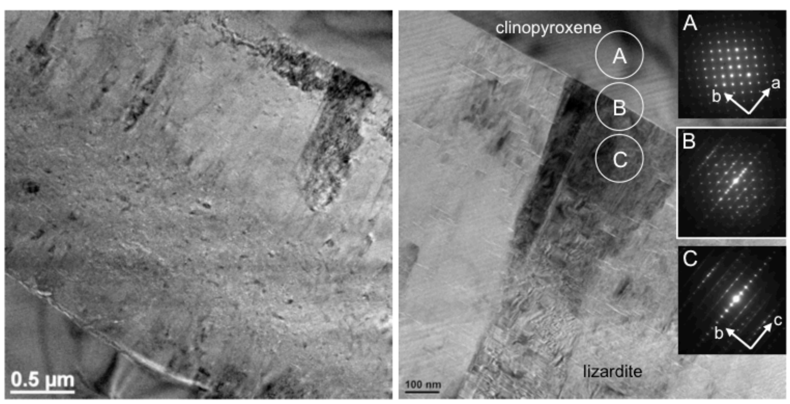

Figure 2. Serpentinite vein observed in clinopyroxene. The outer vein consists of lizardite. The topological structure between lizadite and clinopyroxene is $[100]_{cpx}//[001]_{liz.}$ The inner vein is filled with chrysotile.

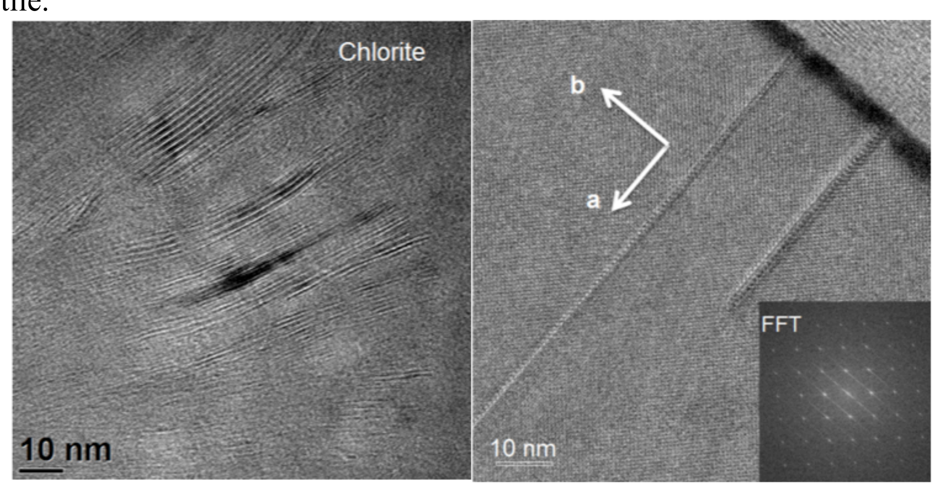

Figure 3. Chlorite was observed in serpentine vein (a), and some nanometer-sized amphibole was observed existing at the side of serpentine vein with $[100]_{cpx}//[001]_{amp.}$

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