In situ observation of dehydration and incongruent dissolution of Serpentine (Antigorite) into aqueous fluids

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Serpentine plays important roles as triggering earthquakes through its dehydration and controlling the rheological coupling between slab/mantle. We heated a natural polycrystalline antigorite ($Mg_{51}Si_{36}O_{90}(OH)_{66}$) in H_2O in the Basset-type externally heated diamond anvil cell [1]. During 600-620°C, we observed that antigorite slightly dissolved into aqueous fluids and then forsterite started crystallizing under a pressure range from 0.27 to 0.64 GPa. The forsterite grew up to about 30 μm across in an hour. According to the previous studies, a dehydration reaction of antigorite = forsterite + talc + H_2O [2] can occur under the present experimental conditions. Nevertheless, talc was not found in our experiments during 1-4 hours. The experimental duration may be too short for antigorite to dehydrate and nucleate talc. Alternatively our observation indicates that antigorite dissolves incongruently into aqueous fluids at the dehydration reaction in the presence of aqueous fluids.

Takahashi *et al.* [3] conducted shear-sliding tests on antigorite gauge at temperature higher than the stability of antigorite under constant pore water pressure of 30MPa at confined pressure of 0.1GPa. They observe forsterite using SEM and trace amounts of talc using XRD in shear-localized zones. The incongruent dissolution of antigorite in our experiments can explain that the dehydration of antigorite forms forsterite, which can cause strengthening and embrittlement of the gouge even at constant pore water pressure. The talc-dissolved aqueous fluids can be silica-rich, and such fluids can migrate upwards to precipitate talc in the plate boundary [4].

[1] Bassett *et al.* (1993) Rev. Sci. Instrum. [2] Evans *et al.* (1976) Schweiz. Mineral. Petrogr. Mitt. [3] Takahashi *et al.* (2011) J. Geophys. Res. [4] Hirauchi *et al.* (2013) Geology

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Physiological and isotopic characteristics of nitrogen fixation by hyperthermophilic methanogens: Implication for nitrogen anabolism of the subseafloor microbial communities on the early Earth

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Hyperthermophilic hydrogenotrophic methanogens are considered to represent one of the most important classes of primary producers in hydrogen (H_2)-abundant hydrothermal environments throughout the history of Earth. Despite extensive studies of methanogenesis, comprehensive research on nutrient anabolism in hyperthermophilic methanogens is limited. This study first investigated the physiological properties and isotopic characteristics of experimental cultures of hyperthermophilic methanogens during the fixation of dinitrogen (N_2), an abundant but less-bioavailable compound in hydrothermal fluids. We found that these hyperthermophilic methanogens actively assimilated N_2 via molybdenum (Mo)-iron (Fe) nitrogenase under broad ranges of Mo and Fe concentrations relevant to present and past oceanic and hydrothermal environments. Furthermore, the methanogens produced more ^{15}N-depleted biomass than that previously reported for diazotrophic photosynthetic prokaryotes. These results indicate that diazotrophic methanogens can be broadly distributed in seafloor and subseafloor hydrothermal environments, where the availability of the transition metals is variable and organic carbon and nitrogen compounds and ammonium are extremely scarce. This perspective may provide key clues to understanding the geological and evolutionary history of the global nitrogen cycle if the nitrogen isotopic ratios of organic matter in the geological records associated with seafloor and subseafloor hydrothermal activities are linked to the potential functions of diazotrophic hyperthermophilic methanogens. The possible emergence and function of diazotrophy coupled with methanogenesis 3.5 billion years before the present may be inferred from the nitrogen and carbon isotopic records of kerogen and fluid inclusions from hydrothermal deposits.

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