Clay Minerals: a key for Deciphering Fluid/Sediment Interactions in Oceanic Hydrothermal Systems

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Hydrothermal fluid circulation in oceanic environments plays a major role in the heat transfer within the oceanic crust and the chemical budget of the ocean. Mineralizations formed at the crust-sea-water interface are better preserved when sediment is present, because it limit heat and mass transfer between the crust and the open ocean and provide chemical elements for authigenic phases.

Clay minerals and oxy-hydroxydes are common mineralogical phases in these enveronments. Because they generally consist on nano sized particles, their mineralogical investigation needs the combination of in situ observation and analyses (SEM, TEM, HRTEM, EDX) with spectroscopic methods (i. e. EXAFS analyses). The origin of the fluids can be determined from geochemical analyses (REE and isotopic analyes) of the authigenic minerals.

In this study we discuss how phyllosilicates and oxy-hydroxydes can record present-day and past circulation of fluid in high and low temperature hydrothermal systems. The examples of Juan de Fuca Ridge (JF) and Costa Rica (CR) margin are presented.

At Middle Valley (northern JF Ridge), a sequence of Mg- and Fe-rich phyllosilicates are associated with the production of extensive massive sulphide deposits in an area of high heat flow and active fluid venting. In the discharge area, saponite, corrensite (Fig. 1) and chlorite associated with authigenic quartz and pyrite form pure hydrothermal layers in the detrital sedimentary cover (Buatier et al. 1995). Their texture and isotopic composition suggest that they precipitated directly in the sediments. Highly altered fluids of about 270°C circulating upward and laterally through the sedimentary column permit the precipitation of these authigenic phases (Lackshewitz et al., 2000). Reactions in both the basaltic basement and the sediments control silicate and sulphide mineral chemistries.

In contrast, phyllosilicate formation at the Eastern flank of the JF Ridge is controlled by the circulation of weakly altered seawater at low temperature (about 70°C) and is limited to the interface between the sedimentary cover and the cooling basaltic crust (Buatier et al., 2001). Zones of fluid discharge are restricted to topographic highs where the sedimentary cover is thin. Fe-Mg rich smectite (Fig. 2) sometimes associated with Ca-Na zeolites precipitates in the coccolithe rich sediments located at less than one meter from the basaltic crust.

Mn and Fe oxides are also common mineralizations in ridge flank hydrothermal system. Detailed mineralogical investigations on altered sediments and concretions from Flank of Juan de Fuca ridge and Costa Rica margin indicate several stages for the formation of Mn oxides with a progressive oxidation of Mn and increase in cristallinity (Buatier et al., 2004). The initial step in this process is the precipitation of Mn, Fe and Si amorphous phase around bacteria and siliceous fossil remains. These amorphous phases serves as precursors for birnessite and todorokite

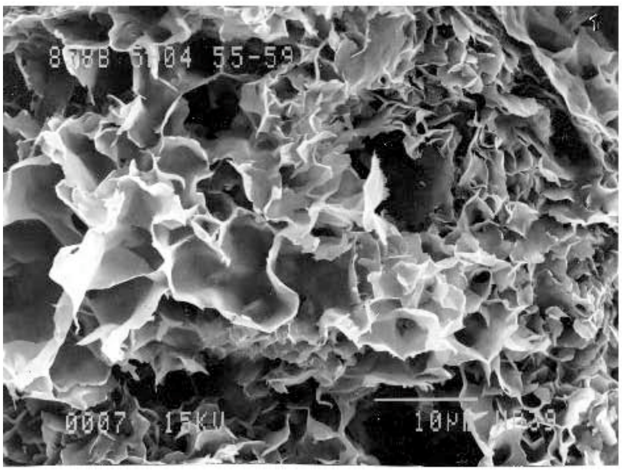

fig 1. Corrensite formed in Middle valley (Juan de Fuca Ridge).

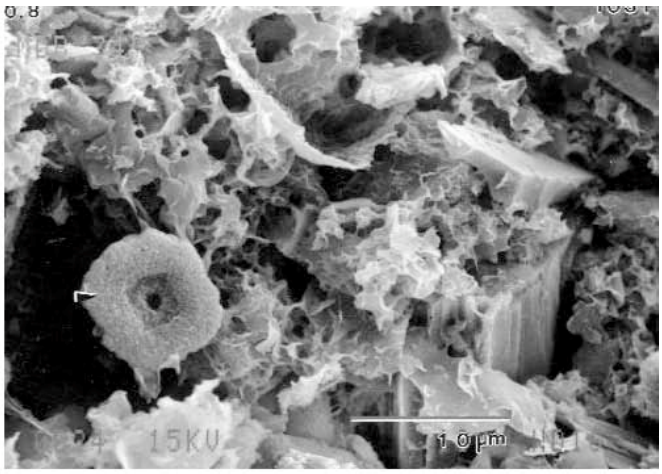

fig 2. Fe-montmorillonite formed in the flank of Juan de Fuca Ridge.

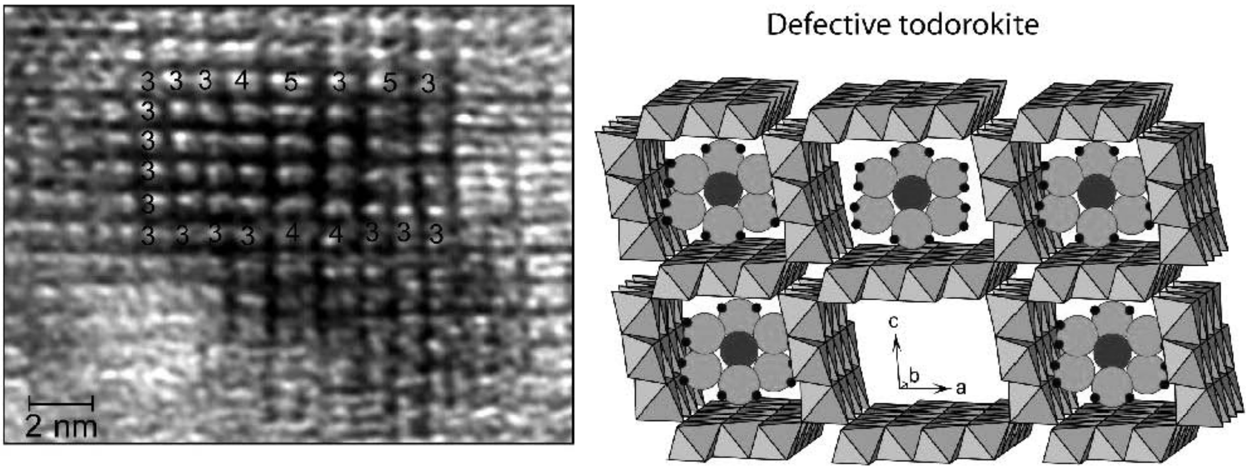

fig 3. HRTEM image of defective todorokite from the Costa Rica margin. The numbers of octahedra are indicated. The structure model is presented on the right (Bodei, et. al., 2008).

crystallization. Hydrothermal todorokite (fig. 3) can also formed from phyllomanganate precursor. A control of the precursor phase on the structure of todorokite is suggested by high resolution transmission eclectron microscope images (Bodei et al., 2007, 2008)) (Fig 3).

The nature of the authigenic minerals and their mechanisms of formation on sedimented oceanic environments depends on the conditions prevaling during their formation. Such mineralizations are good proxies of past and present hydrothermal fluid circulation.

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