Occurrence and formation process of kaolin minerals in seafloor hydrothermal fields in the Okinawa Trough

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Abundant and diverse occurrence of hydrothermal clay minerals has been documented for seafloor hydrothermal fields in the Okinawa Trough, where the fluid discharge zone develops within thick sediment layer. Previous studies on clay minerals in sediments collected during IODP Expedition 331 conducted in 2010 revealed zonal distribution of alteration minerals, which was characterized by dominant occurrence of smectite - chlorite - illite along the depth beneath the seafloor of Iheya North Knoll. Another noteworthy was identification of kaolinite in shallow layer (shallower than 15 mbsf: meters below seafloor), because it suggests acidic alteration as well as high temperature alteration has occurred in the hydrothermal environment. We found occurrence of kaolin minerals in drilling sediment cores recently obtained from other sites in Iheya North Knoll. We studied their detailed occurrence and characteristics using XRD analysis and SEM-EDS observation, with a view to understanding their formation process.

The one sediment core was obtained from Site 9016B (27º46.6' N, 126º54.6' E, depth = 1124 m) during CK14-02 cruise conducted in 2014 using *D/V CHIKYU*. Site 9016B is located ~1 km apart from the activity center of Aki Site. Among the drilling core of 140 m total length, kaolin minerals were identified mainly recognized as at a depth from 8.5 to 11.0 mbsf, where alteration was visually observed as white colored. Within this range, dominant kaolin minerals changed along the depth; halloysite of fine spherules (~1 μm) at 8.7 mbsf, halloysite of tubular shape and kaolinite of hexagonal plates at 9.1 mbsf, dickite of block morphology (~15 μm) at 10.8 mbsf. Kaolin minerals were minor in the sediment from 11.0 mbsf and not identified in 11.4 mbsf, where illite and anhydrite appeared as dominant altered minerals. Together with recognition of unaltered volcanic material even in 9.1 mbsf, this change would reflect steep gradient of physical and/or chemical condition below the seafloor according to expected formation temperature of each kaolin mineral.

The other sediment core was obtained from Site BMSI-4 (27º47.4' N, 126º53.9' E, depth = 1048 m) by shallow drilling during BMS11 cruise conducted in 2011 using *R/V Hakurei No.2* . Site BMSI-4 is located about 300 m apart from the activity center of Original Site. Over most part of the obtained core of ~4.0 m length, occurrence of kaolinite was identified in sediment intensely altered as white gray colored. Within the 4 m range, amount of kaolinite increased along the depth, likely replacing smectite that was dominant in the layer shallower than 1.9 mbsf. Whereas neither halloysite nor dickite were identified. With recognition of sandy sediment without alteration in the surface (<0.05 mbsf) and induration of altered sediment including dolomite at 3.6 mbsf, abundance of kaolinite may reflect steep gradient physical and/or chemical condition below the seafloor.

Alteration zones of kaolin minerals recognized in these two sediments are commonly characterized by limited thickness of a few meters, and by subadjacent indurated sediment layer (anhydrite at Site 9016B and dolomite at BMSI-4) probably formed by high temperature alteration. Formation of kaolin minerals in these vertical profiles is difficult to be attributed to hydrothermal interaction related to mixing between upflow of the hydrothermal fluid component and seawater-like porewater. Rather, focused lateral flow of acidic fluid is more likely to explain well steep gradient in the

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divergence or abundance of kaolin minerals. It is notable that occurrence of sulfide minerals such as sphalerite was recognized in both the upper and lower boundaries of the kaolin minerals alteration zone. The lateral flow of acidic fluid may play an important role in transportation of metal elements in subseafloor sediment layers.

Keywords: acid hydrothermal alteration, scientific ocean floor drilling, seafloor hydrothermal system, kaolinite, Okinawa Trough

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