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Mineralogical characterization and formation of Fe-Si oxyhydroxide deposits from modern seafloor hydrothermal vents

Zhilei Sun,[1,2] Huaiyang Zhou,[3,*] G.P. Glasby,[1,2] Zhixue Sun,[4] Qunhui Yang,[3] Xijie Yin,[5] and Jiwei Li[6]

[1]Key Laboratory of Marine Hydrocarbon Resources and Environmental Geology, Ministry of Land and Resources, 266071, Qingdao, China
[2]Qingdao Institute of Marine Geology, 266071, Qingdao, China
[3]School of Ocean and Earth Sciences, Tongji University, Shanghai 200092, China
[4]School of Petroleum Engineering, China University of Petroleum, Qingdao, 266555, China
[5]Third Institute of Oceanography State Oceanic Administration, Xiamen, 361005, China
[6]Faculty of Geoscience and Environment Engineering, Southwest Jiaotong University, Chengdu, 614202, China

Abstract

We have studied mineralogical characteristics of Fe-Si oxide precipitates from hydrothermal fields of the Valu Fa Ridge, Lau Basin, especially the role that the neutrophilic Fe-oxidizing bacteria played in their formation, using various analytical techniques (XRD, SEM, EPMA, TG/DTA, and FTIR). According to this examination, the Fe-Si oxide formation can be divided into two stages. At the initial stage, the Fe-oxidizing bacteria bound and oxidized Fe^{2+} into Fe^{3+} to fix CO_2, triggering precipitation of Fe-oxyhydroxide (ferrihydrite) and construction of a loose network of Fe-rich filaments. Subsequently, the decreased porosity of the network resulting from the gradual growth of the filaments led to a decline in the mixing between seawater and the hydrothermal fluids. Then the conductive cooling of the network resulted in saturation of the dissolved Si with respect to amorphous silica. As a result, significant precipitation of opal-A occurred through inorganic polymerization. However, part of the silica was immobilized by bonding to Fe-OH functional groups and yielded unpolymerized silica, which is characterized by Fe-O-Si bond. Owing to the incorporation of Si into the ferrihydrite structure and its adsorption on the ferrihydrite surface, the modern hydrothermal Fe-Si oxides are thermally stable. DSC measurements indicate the full segregation of cristobalite from hematite at about 800 °C in an O_2 atmosphere. These observations indicate that primary alternating Si- and Fe-rich layers may be absent in the Archean ocean and that alternating bands in BIFs represent a diagenetic process; our work thus provides a potential clue that can be used to unravel the precipitation and diagenetic mechanisms of Precambrian banded iron formations (BIF).

Keywords: Lau Basin, hydrothermal Fe-Si oxides, banded iron formations, neutrophilic Fe-oxidizing bacteria