Sulfide mineralization is induced by shallow intrusion on the ultraslow-spreading Southwest Indian Ridge: Sulfide mineralogy and geochemistry evidence from the Longqi-3 hydrothermal field

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The newly discovered Longqi-3 hydrothermal field (HF) is located on the ultraslow-spreading Southwest Indian Ridge. Sulfide-rich samples collected from this field exhibit stockwork mineralization, which is primarily seen on ultraslow-spreading ridges, presenting an opportunity to understand the subsurface mineralization characteristics and diversity of the hydrothermal activity in ultraslow-spreading ridges. Sulfide mineralization in this field can be divided into stockwork, semi-massive, and oxidation stages. The stockwork stage mainly comprised pyrite, chalcopyrite, magnetite, hematite, and ilmenite. However, the semi-massive stage mainly comprised chalcopyrite, pyrite, pyrrhotite, and minor sphalerite. The Cu contents of the sulfide-rich samples were in the range of 0.02–2.88 wt.% with an average of 0.37 wt.%, and the Zn content was generally below 0.01 wt.%. The chemical compositions of the sulfide-rich samples suggested that the ore-forming elements were probably of basaltic origin. The sulfur isotopes content in the sulfide-rich samples was 4.42–11.28‰ and averaged 7.61‰. The mineral assemblages and sulfur isotope features indicated that the deep part of the hydrothermal system is in an oxidation environment and has a high permeability that allows large quantities of seawater to enter. During the ore-forming process, the conditions shifted from relatively oxidizing to more reducing conditions and, accordingly, the seawater-derived sulfur in the system deceased from 46.41% to 41.90% and subsequently to 31.85%. Hence, the Longqi-3 HF probably formed by the intrusion of a shallow dike into the normal fault system. This finding implies that HFs that are controlled by shallow heat sources may have developed on other ultraslow-spreading ridges.