Geochemistry and deep geothermal processes of geothermal springs along the Xianshui River fault zone, Western Sichuan plateau, China

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Keywords: Deep geothermal processes; Xianshui River fault; Heat-controlling structure

ABSTRACT

The eastern margin of the Qinghai-Tibet Plateau, which located in the border of Songpan-Ganzi, Sichuan-Yunnan and South China blocks, is one of the most intense Cenozoic tectonic activity areas in Chinese mainland. The eastern margin of the Qinghai-Tibet Plateau has a high heat flow background related to Cenozoic plate interaction, high-temperature geothermal manifestations such as boiling springs, fumaroles, hydrothermal explosions and geysers are occurred on the surface, and are mainly distributed in the Xianshui River fault zone (XSF), Litang fault zone and Jinshajiang fault zone. In recent, with the support of "The National Key Research and Development Plan of Deep Resources Exploration and Mining (No.2017YFC0601205)", a systematic geological survey and evaluation of hot springs in western Sichuan was carried out. Therefore, combining with the research results of project, the hot springs developed along the XSF are systematically analyzed and regionalized. 58 hot springs were discovered in the XSF, of which 18 hot springs were high-temperature spring (>60℃), 28 hot springs were medium-temperature spring (40-60℃), and 12 hot springs were low-temperature spring (25-40℃). These hot springs were basically distributed in beads-shaped along the XSF, and most of them

are concentrated distributed in group. Based on the zonality of the XSF and the characteristics of occurrence and distribution of hot springs, along the XSF can be divided into six hydrothermal areas: Luhuo, Daofu, Qingning-Bamei, Yalahe-Zhonggu, Kangding and Moxi hydrothermal area. The XSF is relatively active and has a certain degree of zonality, according to the seismic data and slip rate. Therefore, there is a good coupling relationship among the hydrothermal activity, earthquake, and fault near the XSF. It presents a coupling relationship between the the earthquake and hydrothermal activity. adjacent rocks and fault zones experienced intense compression and cutting, caused by the intense compression-slip of the XSF and resulting in the favorable environment of the deep circulation and reserve of the underground water and play a significant role in conduction and reservoir heat.

1. Geological setting and the feature of Xianshui River fault

The XSF extends from Donggu, and passes through Zhuwo, Luhuo, Daofu, Bamei, Kengding Moxi, and extends south to Shimian. It combines with the Longmenshan, Anninghe faults to become a significant tectonic framework with Y-shaped. The terrace, ridge, and alluvial fan were dislocated due to continuously movement of the XSF during Epipleistocene to Holocene, especially the gully(water systems) with different grades traversed by fault zones has taken place left-lateral movement in horizontal . The XSF can be divided into NW and SE segment along the Huiyuan Temple approximately, based on the features of geometry, seismic activity and deep structure (Wen et al., 1989; Tang et al., 1993). The integral slip rate of the NW segment of the XSF is approximately 10.5-17.1mm·a^{-1}, consist of Luhuo, Daofu and Qianning shear faults arranged in left-step en-echelon (Li et al., 1997; An, 2010). The SE segment of the XSF with complicated geometry, as such, it can be divided into Yalahe, Selahe and Zheduotang faults with fusiform and sinistral shear from the Huiyuan Temple to east.

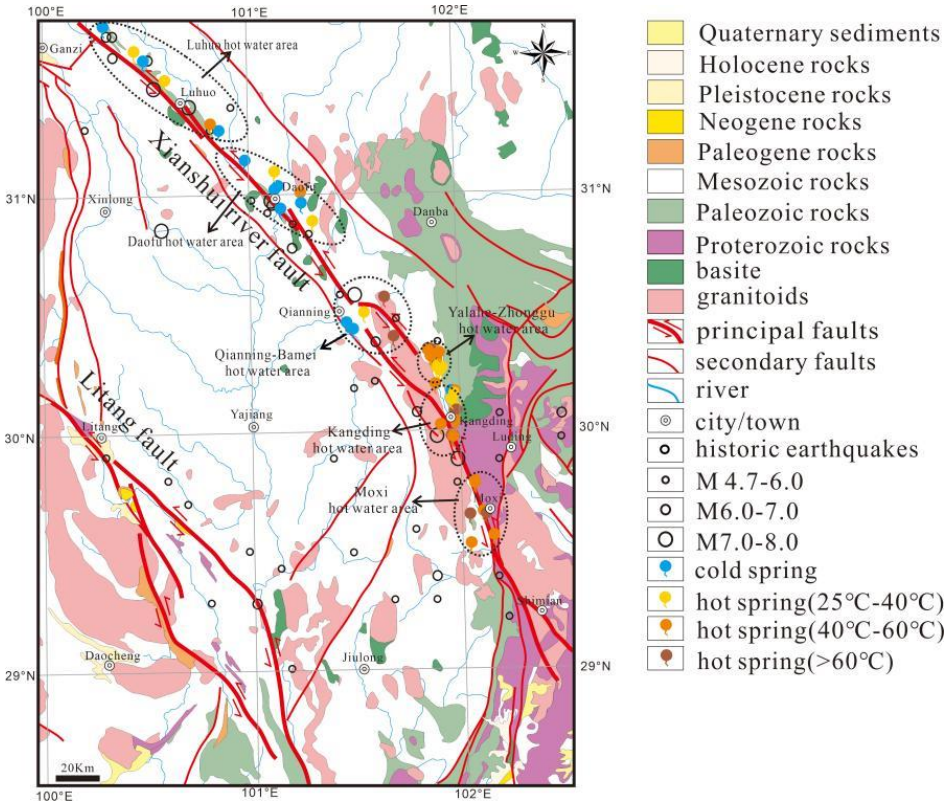

Fig. 1. Distribution of hot spring and hydrothermal activity area near Xianshui River fault

2. Characterizations and zonation of hydrothermal activity areas

Along the XSF can be divided into six hydrothermal activity area: Luhuo, Daofu, Qingning-Bamei, Yalahe-Zhonggu, Kangding and MOxi hydrothermal activity area, according to the zonality of the XSF and Characterizations of occurred and distributed of spring.

The spring in Luhuo hydrothermal activity area has a relatively low temperature, except for the temperature of the spring in Kangba is 84.5℃, all the other spring temperatures are 15~44℃, and have an average temperature for 42.2℃. The Daofu hydrothermal activity area, located in the Daofu secondary fault of the XSF, its hot springs are developed in the NE secondary tense-shear fault of middle section of the XSF. The Daofu hydrothermal activity area has controlled 4 medium-low temperature hot spring groups and about 10 springs, most of them are distributed in the Northwest-most end of the Daofu: Kongse, Mazi, Xianshui, Geka, Wari. The Qianning-Bamei hydrothermal activity area, is located in Xiede, Bamei of the Southeast-most end of Daofu and Tagong of the Northeast of Kangding. The

Qianning-Bamei hydrothermal activity area has controlled Reshuitang and Yala mountain high-temperature spring groups and about 20 springs, which have a relatively strong H_2S smell and a relatively small range of sinter, and temperatures with a range of 48-68.6℃.

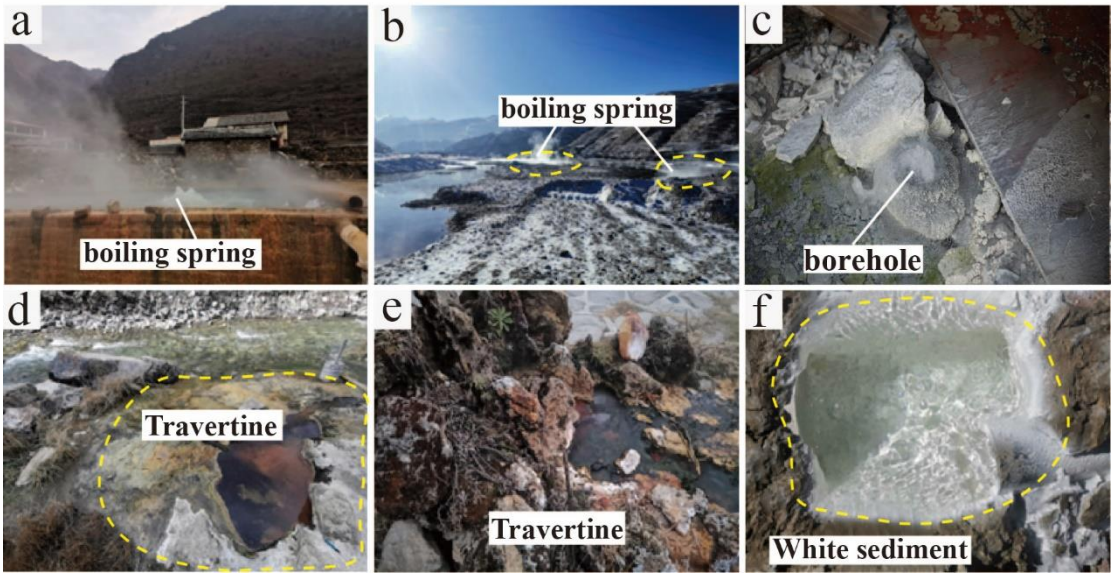

Fig.2 Typical hydrothermal manifestations in south Tibet. (a) The boiling spring exposed on the left of the river in Zhonggu Village; (b) Tuoba boiling spring ; (c)The borehole of Erdaoqiao hot spring; (d)The travertine exposed along the river of Longba hot spring; (e)The travertine of Reshuitang hot spring; (f) The White sediment of Yulingong geothermal field

The Yalahe-Zhonggu hydrothermal activity area, extends 20km from Reshuitang, Zhonggu, to the southern entrance of Yala mountain scenic spot. A large amount of hot springs were concentrated in this area, and are to formed several hot spring groups such as Zhonggu, Dagai and Reshuitang. 15 hot spring spots are occurred in this area along the Yala valley, which have an average temperature for 49.24℃ and a smell relatively strong hydrogen sulfide. The maximum and minimum temperatures of springs are 71.1℃ and 40℃, and are in Dagai No. 1 hot spring in Yulin village and Qingquan Village Hot Spring in Erdaoqiao, respectively.

The Kangking hydrothermal activity area occur mainly from Yulingong and Erxianqiao to Guanding, is the region with intense hydrothermal activity, and controlled several hot spring groups such as Yulingong, Simaqiao, Longdonggou, Maojinchuang and Jinjiaheba. The thermal water temperature in the north section of

Kangding hydrothermal area is relatively low and occurred in Permian crystalline limestone, such as Erdaoqiao hot spring. The Kangking hydrothermal activity area is located in the pull apart basin between NE Selaha fault, NS principal fault and NW Zhedotang fault. It is traversed by Several secondary faults such as Yalahe, Selaha and Zhedotang fault.

The Moxi hydrothermal activity area, distributed mainly in Detuo Town, Moxi town and Xinxiang Town, is the region with intense hydrothermal activity, and controlled several hot spring groups such as Hailuogou, Caoke. Moxi hydrothermal activity area, including several hot spring points such as Wandong, Mingxiang, Shiyue River, Shiyue River Valley, Wajiao, Caoko and Dagangshan. the spring in the Caoke hot spring group has a relatively high temperature, generally above 50 ℃, especially the temperature of hot spring in Hailuo hot water ditch can up to 70°C.

3. Coupling relation between the earthquake and hydrothermal activity

The XSF fault has controlled Eight earthquakes with M≥ 7 and more than twenty earthquakes with M≥ 6 since the earthquakes was recorded in 1725, accounting for about 50% of earthquakes at the same magnitude in Western Sichuan (Gu et al., 1983). strong earthquakes were continuous occurred in this area since the twentieth century, three earthquakes with M≥ 7.5 were occurred in 1923, 1955 and 1973, respectively, and are indicative of the high-activity of the XSF (Zhang et al., 2012). small earthquakes are distributed in narrow belt-like along the XSF in past 30 years, which are indicative of the XSF with continuity in time, repetitiveness in space and differential of segmented activity intensity (Zhu, et al., 2005). A large amount of heat was likely produced by the concentration and release of stress linked to faulting activity (Ouyang et al., 2002). Simultaneously, adjacent rocks and fault zones experienced intense compression and cutting, caused by the intense compression-slip of the XSF and resulting in the favorable environment of the deep circulation and reserve of the underground water and play a significant role in conduction and reservoir heat.

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