The Correlation Analysis and Continental Dynamics Significance of High-Temperature Geothermal Areas from the Eastern Margin to Central of the Qinghai-Tibet Plateau

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ABSTRACT

As one of the most developed high-temperature geothermal activity areas, the Tethys-Himalayan geothermal belt was strictly controlled by the structural system without the Neoid volcanic activities in the world. Accompanied with a large amount of hydrothermal activity and energy generation, the Qinghai-Tibet Plateau had the greatest potential and concentration of high-temperature geothermal resources in mainland China. From the eastern margin to central of the Qinghai-Tibet Plateau, there can be divided into three high-temperature geothermal areas: the western Sichuan geothermal area on eastern margin of the Qinghai-Tibet Plateau (WSQT), the eastern Tibet geothermal area in the eastern Himalayan syntaxis field (ETHF), and the southern Tibet geothermal area in the central of the Qinghai-Tibet Plateau (STQT). On the basis of the geothermal distribution and development characteristics of the Tibetan plateau, this paper systematically summarizes the heat source and heat-controlling structures of the high temperature geothermal fields, and discusses the deep dynamic mechanism of the high-temperature hydrothermal activities in the context of the land-land collisional uplift process in the Tibetan Plateau.

1. INTRODUCTION

In recent years, the global energy demand is increasing and the conventional energy reserves is reducing. In order to save energy, reduce emission and response to global climate change, the exploration and explotation of clean and renewable energy, such as geothermal energy, solar energy and wind energy have become an important strategy for energy development in all countries around the world (Cao et al., 2022). Due to the advantages of large

reserves, high energy efficiency, low operating costs, energy saving and emission reduction, the geothermal energy has become the spotlight in renewable energy field (Lund and Boyd., 2016).

The Qinghai-Tibet Plateau, located in the world-famous Mediterranean-Tethys Himalayan tropics, is the most intensely tectonically active region of the Cenozoic in mainland China (Xu et al., 2006). Accompanied with a large amount of hydrothermal activity and energy generation, this region had the greatest potential and concentration of high-temperature geothermal resources in mainland China. In recent years, with the use of centralized geothermal heating, hot spring therapy, recreation and tourism industries, the geothermal energy industry is in the orderly and rapid development stage. Furthermore, the comparative analysis of high-temperature geothermal genetic mechanisms of the Tethys-Himalayan geothermal belt have a great scientific significance for enrich and improvement the continental dynamics theory of the Qinghai-Tibet Plateau.

2. THE DISTRIBUTION AND CHARACTERISTICS OF THE HYDROTHERMAL ACTIVITY NEAR THE QINGHAI-TIBET PLATEAU

From the eastern margin to central of the Qinghai-Tibet Plateau, there can be divided into three high-temperature geothermal areas (Fig.1; Dor et al., 2000; Zhao et al., 2002; Zhao et al.,1998): the western Sichuan geothermal area on eastern margin of the Qinghai-Tibet Plateau (WSQT), the eastern Tibet geothermal area in the eastern Himalayan syntaxis field (ETHF), and the southern Tibet geothermal area in the central of the Qinghai-Tibet Plateau (STQT).

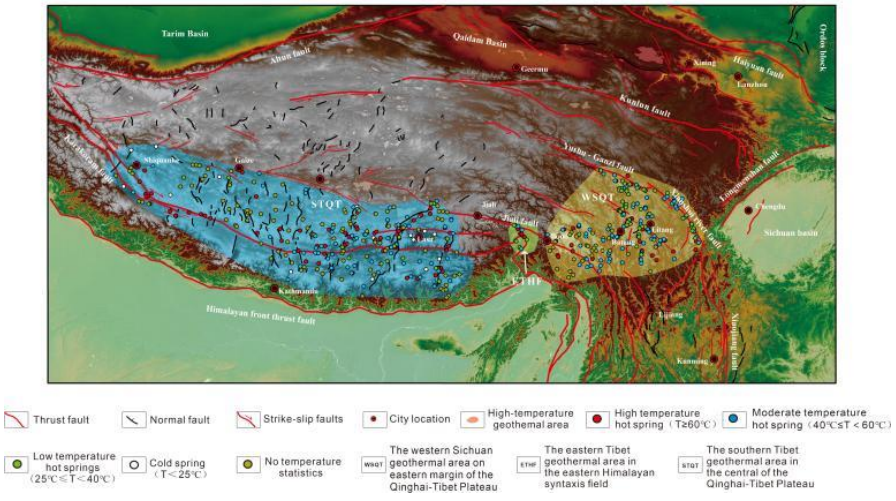
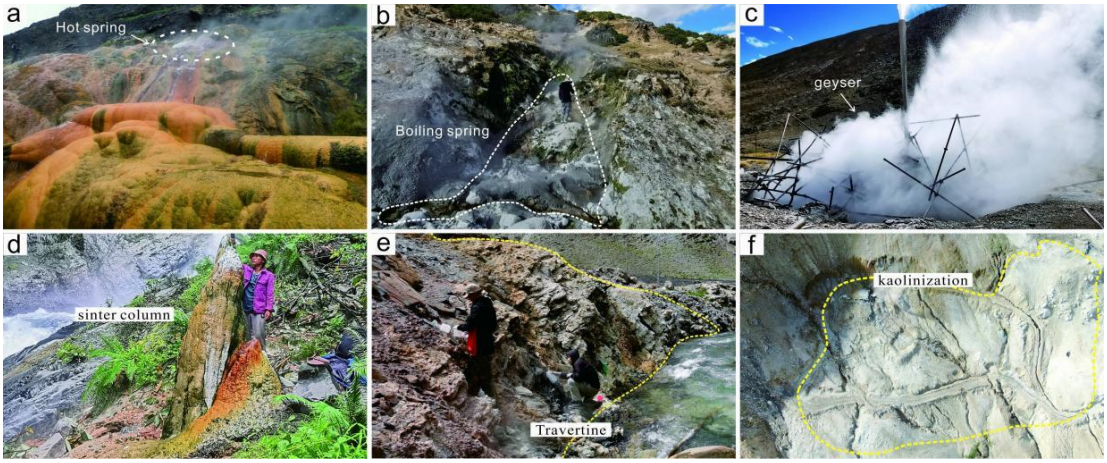


Fig. 1. Fault and spring locations of the western Sichuan geothermal area, the eastern Tibet geothermal area, and the southern Tibet geothermal area in the central of Qinghai-Tibet Plateau

With a variety of different geothermal manifestations include boiling spring, geyser, fumarole, steaming ground, boiling mud, hydrothermal explosion, sinter, travertine and hydrothermal alteration, the hydrothermal activities in Tibet have strong surface expressions (Fig.2). Yangbajing geothermal power station is the first high temperature geothermal power station in Tibet, with an installed capacity of 25.18 MW. In the early 1990s, as the pearl on the Qinghai-Tibet Plateau, the Yangbajing geothermal power station's power generation accounted for 40% (in summer) to 60 % (in winter) of Lhasa 's power grid. By the end of 2018, Yangbajing geothermal power station had



accumulated 34 kWh of power generation and saved 1.5 million tons of standard coal with reduction reduced about 3.5 million tons of CO_2 emissions and 25,000 tons of SO_2 emissions.

Fig.2 Typical hydrothermal manifestations in south Tibet. (a)Quzhuomu hot spring; (b)The boiling spring of Yangyi high-temperature geothermal fields; (c)The geyser of Gudui geothermal fields; (d) A sinter column exposed in Duoka village, Motuo; (e)The travertine exposed along the river of Kawu hot spring; (f)Large area kalinization of Gudui geothermal field

3. THE HEAT SOURCE OF HIGH-TEMPERATURE GEOTHERMAL ACTIVITY AREAS

Four seismic bright-spots between Nimu-Yangbajing-Dangxiong were found by Zhao et al., (2002), and were considered to be partial melting layers, which belongs to granitic magma chambers, with a depth of 15-20km and a thickness of about 20km. The Yangbajing and Dangxiong seismic bright-spots correspond to the Yangbajing geothermal field and the Gulu geothermal field, respectively. The geological, hydrological, geochemical and geophysical data of Himalaya geothermal belt indicate that the low-resistivity anomaly reflects partial melting body exists in the crust below 7 km of the geothermal field, which can be provides geophysical evidence for the heat source of the high-temperature geothermal field.

4. THE MAIN PATHWAY AND HEAT-CONTROLLING STRUCTURE OF THE HYDROTHERMAL

ACTIVITY

High-temperature geotherms are densely distributed in groups or zones, particularly in the composite area of regional active fault in different directions(Dewey et al., 1986). In addition, the cutting depth of active fault has certain effect on the temperature and chemical composition of geothermal water, with the increases of the circulation depth of atmospheric precipitation and the temperature of geothermal water, the mineral composition leached form the surrounding rock also increase(Zhao et al., 2003). The northern and center of Yangbajing is the metamorphic rock mass of Nyainqentanglha uplift mountain and the hanging wall in the southern of Nyainqentanglha detachment fault, respectively (Fig.3a Dor et al.,1998). The distribution pattern and characteristics of geothermal of Yangbajing were controlled by the NW-SW extended active fault and detachment fault system in the southern of the Nyainqentanglha, and this complex faulting system connect the deep-seated heat source with the shallow groundwater system. The Yangbajing faulted basin and its hydrothermal activities could be produced by the tectonic setting of fault effect (detachment fault) in the southern margin of Nyenchen Tanglha anticline (Fig.3b). It is reveal that the high-temperature geothermal system controlled by deformation and distribution feature of fault as the heat-controlling structure (Dor and Zhao., 2000 ; Dor et al., 2003).

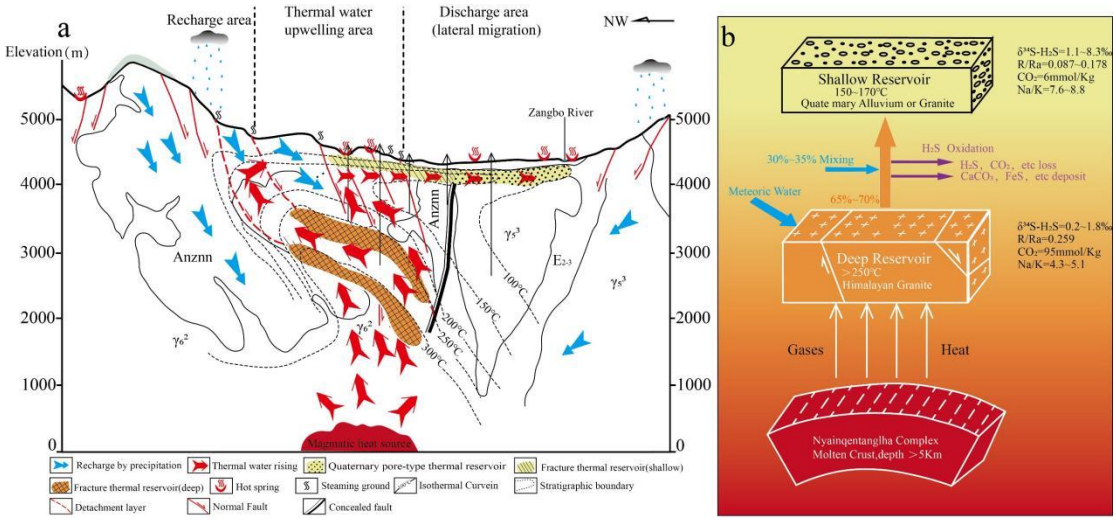


Fig.3 (a) Conceptual model of the Yangbajing geothermal field and (b) Thermal fluid evolution model of Yangbajing geothermal field (Modified from Dor et al., 2003 and Zhao et al., 2001)

5. SEVERAL IMPORTANT ISSUES ABOUT FUTURE RESEARCH OF THE HYDROTHERMAL ACTIVITY

The thermal structure of lithosphere and the Moho depth of Tibetan Plateau are heterogeneous: with the anomalous thermal structure of "hot crust-cold mantle " and "hot crust-hot mantle", the southern Tibetan Block has strong tectonic activity and high heat flow value (up to 300-400W/m^2) in Cenozoic. Due to the uplifting of

Qinghai-Tibet Plateau during the continent-continent collision, the hydrothermal activity, active tectonic and seismic activity present a coupling relationship with the deep tectonic-thermal events. The research on the genetic mechanism of high-temperature geothermal, enrichment of rare elements in fluids, and the significance of continental dynamics should focus on the following aspects: First, a variety of rare mineral resources are associated with geothermal fluids in China, but some issues exist in the development of the associated mineral resources in high-temperature geothermal fluids, such as unclear trace element distribution and development potential, resulting in a low level of resource development. Consequently, based on the potential evaluation of the associated mineral resources, comprehensive utilization of the associated mineral resources in deep geothermal fluids should be strengthened. High-temperature heat harm has become a significant problem as engineering construction in the high-temperature geothermal area has advanced, and the mining depth of mineral resources has gradually increased. The high-temperature heat harm not only has a serious impact on the health of workers but also impedes the construction process and raises costs. However, the resource attribute of high-temperature heat harm, on the other hand, has received little attention. Hence, there is relatively little research on the "resource utilization of heat energy" in deep mines and engineering construction, resulting in the waste of geothermal resources. Based on the potential evaluation of "heat harm resources," more attention should be paid to the utilization of "heat harm resources" in engineering construction and "ore-thermal co-mining" in deep mines, as well as actively developing high-temperature heat harm resource utilization technology.

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