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Geochemistry of hot springs in the Tengchong hydrothermal areas, Southwestern China

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ABSTRACT

As an important volcanic geothermal region in China, Tengchong belongs to the Mediterranean–Himalayas geothermal belt and is characterized by wide distribution of volcanic rocks. Fifty-eight hydrothermal areas have been identified in Tengchong, among which the Rehai hydrothermal system is the most geothermally active. The geothermal waters from Rehai are mainly Na-HCO_3-Cl and Na-HCO_3 types, whereas those from the other hydrothermal areas are mainly Na-HCO_3, Na-Ca-HCO_3, Ca-HCO_3, Ca-Mg-HCO_3, Mg-Na-Ca-HCO_3, and Mg-Ca-HCO_3 types. Both quartz geothermometer and K-Mg geothermometer indicate that the Rehai geothermal field has higher subsurface temperatures than the other hydrothermal areas. Except for three Rehai samples, most geothermal water samples collected from Tengchong are far from the full equilibrium line in Giggenbach's triangular diagram, suggesting that the complete chemical re-equilibrium has not been achieved as these geothermal waters flow upward from reservoirs towards spring vents and possibly mix with cooler waters. Statistical analysis shows that Cl, B, Li, Rb, and Cs are the characteristic constituents of the Tengchong geothermal waters, and the good linear relations among these elements in the Rehai geothermal waters reflect the existence of a deep parent geothermal liquid (PGL) below Rehai. An enthalpy-chloride diagram of the Rehai geothermal waters suggests that the parent geothermal liquid has Cl^- concentration of 291 mg/L and enthalpy of 1495 J/g. The PGL ascends to the surface through different channels and may cool by conduction of heat to reservoir host rocks, by boiling, or by mixing with cooler shallow groundwaters.

1. Introduction

In China, geothermal potential has been detected in every province. However, high-temperature hydrothermal systems are mainly distributed in Yunnan, Tibet and western Sichuan (Liao and Zhao, 1999). The Tengchong volcanic geothermal area, located in western Yunnan Province, is one of the most important high-temperature hydrothermal areas of China. Some hydrothermal systems in Tengchong, such as the Rehai hydrothermal system and the Ruidian hydrothermal system, have huge potential for electricity generation (Joint investigation group of geothermal resource in Tengchong, 1974). In this study, the geochemistry of geothermal waters from different hydrothermal areas of Tengchong was investigated, which is vitally important for policy making to improve hydrothermal resource management and utilization in Tengchong.

There are numerous geothermal springs distributed in the Tengchong area (Fig. 1). According to the investigations by Zhang et al. (1987) and Tong and Zhang (1989), Tengchong can be divided into fifty-eight hydrothermal areas, in each of which a group of hot springs are discharged to the surface. Among these hydrothermal areas, twenty-four are characterized by average spring water temperatures higher than 45 °C. In addition, three boiling spring groups have been found in Tengchong.

Rehai and Ruidian are the largest and second largest hydrothermal areas in Tengchong. So they were named the Rehai geothermal field and the Ruidian geothermal field, respectively, in view of their significant exploitation potential and economic value (Tong and Zhang, 1989). The Rehai geothermal field has a total area of about 10 km^2, and it is also the geothermal field with the highest inferred reservoir temperature in Yunnan (Liao and Zhao, 1999). The field is divided into two sub-areas: the west area (Reshuitang area) and the east area (Liuhuangtang area) where hydrothermal activities occur extensively. The strong hydrothermal manifestations include hydrothermal explosion, boiling spring, hot spring, warm spring, fumarole, steaming ground, hydrothermal alteration, and hot spring silica sinter (Liao et al., 1991). The water temperatures of hot springs range from 42 °C to more than 96 °C (local boiling point corresponding to an average altitude of 1260 m above sea level) (Liao and Zhao, 1999). It was estimated that the electricity generation potential at Rehai could reach 100 MW (Joint investigation group of geothermal

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resource in Tengchong, 1974). The Ruidian geothermal field lies in the north of Tengchong, with an area of 0.6 km^2, much smaller than the Rehai geothermal field. Six hot spring groups with water temperature ranging from 56 to 90 °C are distributed in the Ruidian field. The total spring discharge is up to 15.05 L/s. Besides geothermal springs, a great deal of spring sinter was found at Ruidian as well. Generally, the hydrothermal activities at Ruidian are not as strong as those at Rehai (Tong and Zhang, 1989).

2. Regional setting and geology

2.1. Tengchong

Tengchong belongs to the Yunnan–Tibet geothermal belt of China, a major part of the Mediterranean–Himalayas geothermal belt (Liao and Zhao, 1999). The topography of Tengchong is high in the north and low in the south, with altitudes varying from 930 m to 3780 m.

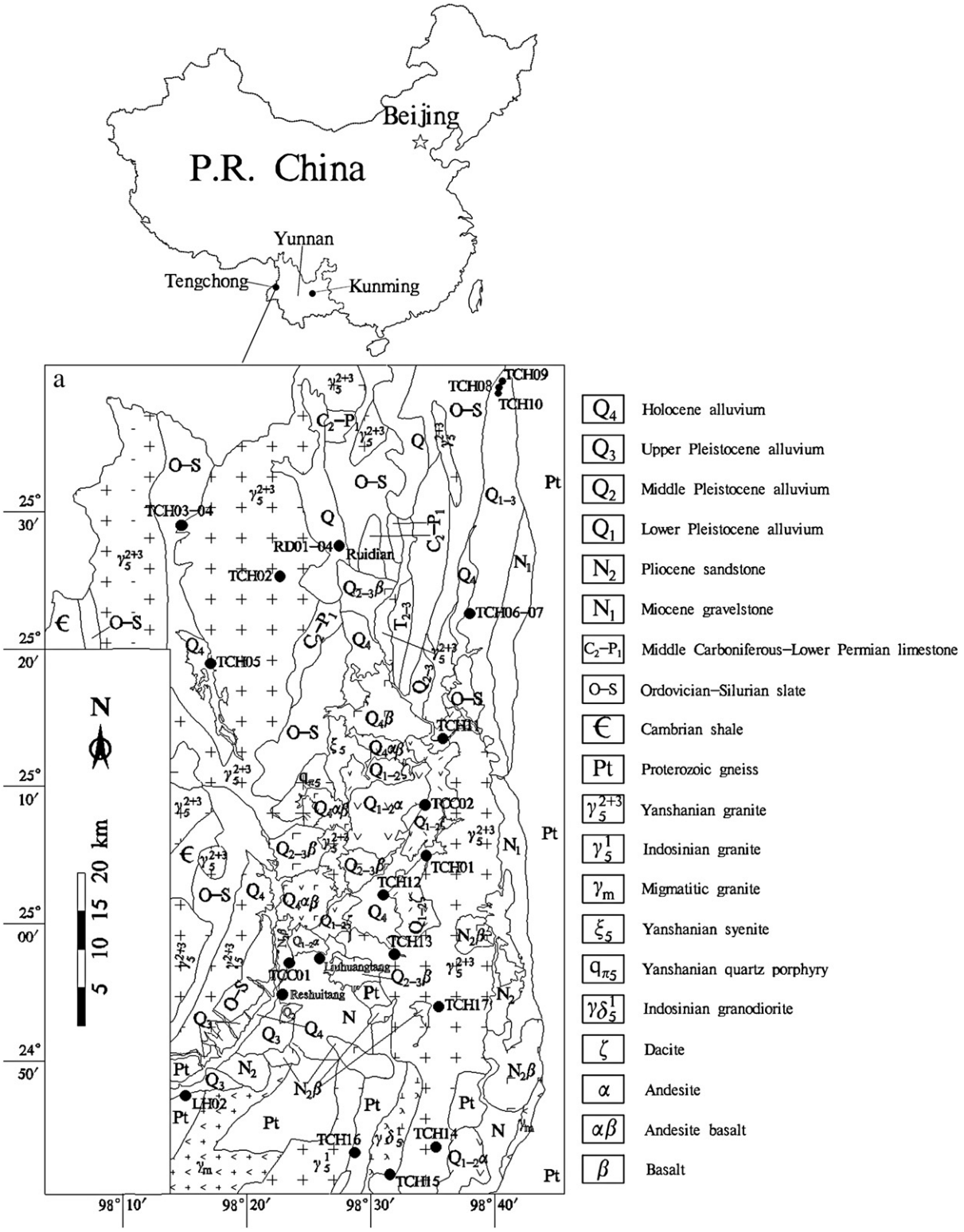

Fig. 1. Simplified geological maps and sampling locations of Tengchong (a) and Rehai (b).