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Geochemical and isotopic characteristics of geothermal springs hosted by deep-seated faults in Dongguan Basin, Southern China

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ABSTRACT

Chemical and isotopic compositions of thermal springs and non-thermal springs and well from Dongguan Basian of Southern China were measured and used to assess the mechanism of hydrothermal system hosted by deep-seated faults. Thermal springs had relatively higher temperatures and dissolved ion contents than non-thermal springs and wells, and were classified as water chemistry type of HCO_3-Na + K. The reservoir temperatures were determined with their chemical compositions, and 131.0 to 138.9 °C estimated by a quartz geothermometer after steam loss were regarded as the most suitable assessment. Inadequate equilibrium between water and rock interaction is mostly speculated and the mixing with shallow non-thermal groundwater probably has minor contribution to the thermal springs. Stable isotope compositions of thermal springs ranged from −45.1‰ to −40.8‰ for δD and from −7.2‰ to −6.9‰ for $\delta^{18}O$, respectively. These isotopic results were almost identical to those of non-thermal springs. All the thermal and non-thermal groundwater samples scattered around the meteoric water lines, thus indicating meteoric water origin without further influences of evaporation and groundwater–rock interaction. The similarity of thermal and non-thermal groundwater in chemical and isotopic compositions suggested that groundwater migrating and being heated very quickly in a relatively fast conductive fracture system hosted by deep-seated faults mostly represented the mechanism of thermal springs.

1. Introduction

Thermal springs are associated with various heat sources, such as active volcano (Fischer et al., 1997; Guido and Campbell, 2012; Ishikawa et al., 2007; Tassi et al., 2003; Werner et al., 2008), magma intrusion (Minissale et al., 2007), tectogenesis and radioactivity (Guo and Wang, 2012; Larson et al., 2009; Mottl et al., 2011; Zaher et al., 2012). The distribution of thermal springs depends on different tectonic backgrounds, such as extrusion, collision, subduction, faults and the edge of sedimentary basin (De Filippis and Billi, 2012; Han and Huh, 2009; Lau et al., 2008; Thiebaud et al., 2010; Ueda et al., 2006; Yokoyama et al., 1999). With respect to the form of thermal springs hosted by faults, it is generally considered to be the mixing of deep thermal water and shallow non-thermal groundwater (Capaccioni et al., 2011; Duchi et al., 1992; Majumdar et al., 2005; Minissale et al., 1997; Parry and Bowman, 1990; Ruffa et al., 1999). In southern China, a large number of thermal springs focus on the fault zones and are exposed into a linear distribution (Huang and Goff, 1986; Lin et al., 2010; Sun et al., 2006). Most of thermal springs had been used to warm water aquaculture and health bath, and recently raised much interest for potential development of geothermal exploitation for green energy. Despite this increasing interest, few works had been published on the chemistry and isotopes of these thermal springs in southern China because their recharge temperatures are generally less than 90 °C.

In the recent four years, we found that the subsurface temperatures of some thermal springs or boreholes (artesian and the depth no more than 600 m) are around 120 °C near Dongguan Basin, Southern China. These temperatures considered as hopeful power generation using thermal groundwater raised the concentrations of the economic use and the origin of water for thermal springs. Then heat sources and water circulation need further investigation as they are hosted by deep-seated faults in the non-magmatic activity area that is untypical for thermal springs with high temperature. Recently, the mechanisms of nearby submarine thermal springs had been outlined as well as the evolutions of local geology and geochemistry in Southern China (Guo et al., 2012; Liang et al., 2007; Lin et al., 2010; Ye et al., 2014). Although the thermal springs around Dongguan Basin are known and used since dozens of years, the origin and the structure of these hydrothermal systems are still not well understood. The main objective of this paper is therefore to characterize the thermal springs hosted by deep-seated faults in Dongguan Basin with the first set of geochemical data and water stable isotopes. Comparison with non-thermal groundwater (from non-thermal springs or wells) helps to understand the recharge sources and to outline the potential hydrothermal mechanisms.

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2. Hydrogeologic setting

Dongguan Basin is located in the east part of Pearl River Delta Regions, Guangdong province of Southern China (Fig. 1). The terrain is tilted from northeast to southwest. The southwest part, estuarine sedimentary plain with relatively flat topography, is about 10 m above mean sea level (m.s.l.). The northeast part, low mountains and hills, is about 100 m above m.s.l. It is a sub-tropical monsoon climate with an average annual temperature of 23.3 °C. The local annual precipitation is 1336 mm, while the annual evaporation is up to 1100 mm.

Three broad stages of regional geological activity (known as Sinian–Silurian, Devonian–Mid-Triassic, and Later Triassic–Present) had a great influence on the local strata and geology structure. As magma intrusion from Paleozoic to Mesozoic and the subduction of Pacific plate and Eurasian plate (Guo et al., 2012; Zhu et al., 2010), granite is the most widely outcropping bedrock, accounting for more than 40% of bedrocks at Guangdong province (Song et al., 2011). A series of complicated tectonic activities form the main deep-seated faults with the direction of northeast, accompanying with continuous stratigraphic deposition, which have undergone frequent metamorphism and intense magmatism (GBGMI, 1988). Two deep-seated faults existing in the studied area, F1 and F2 in Fig. 1, are known as Heyuan Fault and Zijin–Boluo Fault, respectively.

Four hydrostratigraphic groups can be recognized according to different types of lithology and pore structures in the studied area. The coarse-medium sands and gravel of Quaternary strata are rich in pore water as the first hydrostratigraphic group distributed in the delta plain, mountain basins and coastal plains. Local main hydrostratigraphic group (the second group), are red sandstones and siltstones of Jurassic to Tertiary strata with abundant fissure water, which are widely distributed in the studied area and up to 1500 m of sedimentary thickness in Dongguan Basin. The limestone fissure water mainly exists in Carboniferous to Permian strata as the third hydrostratigraphic group

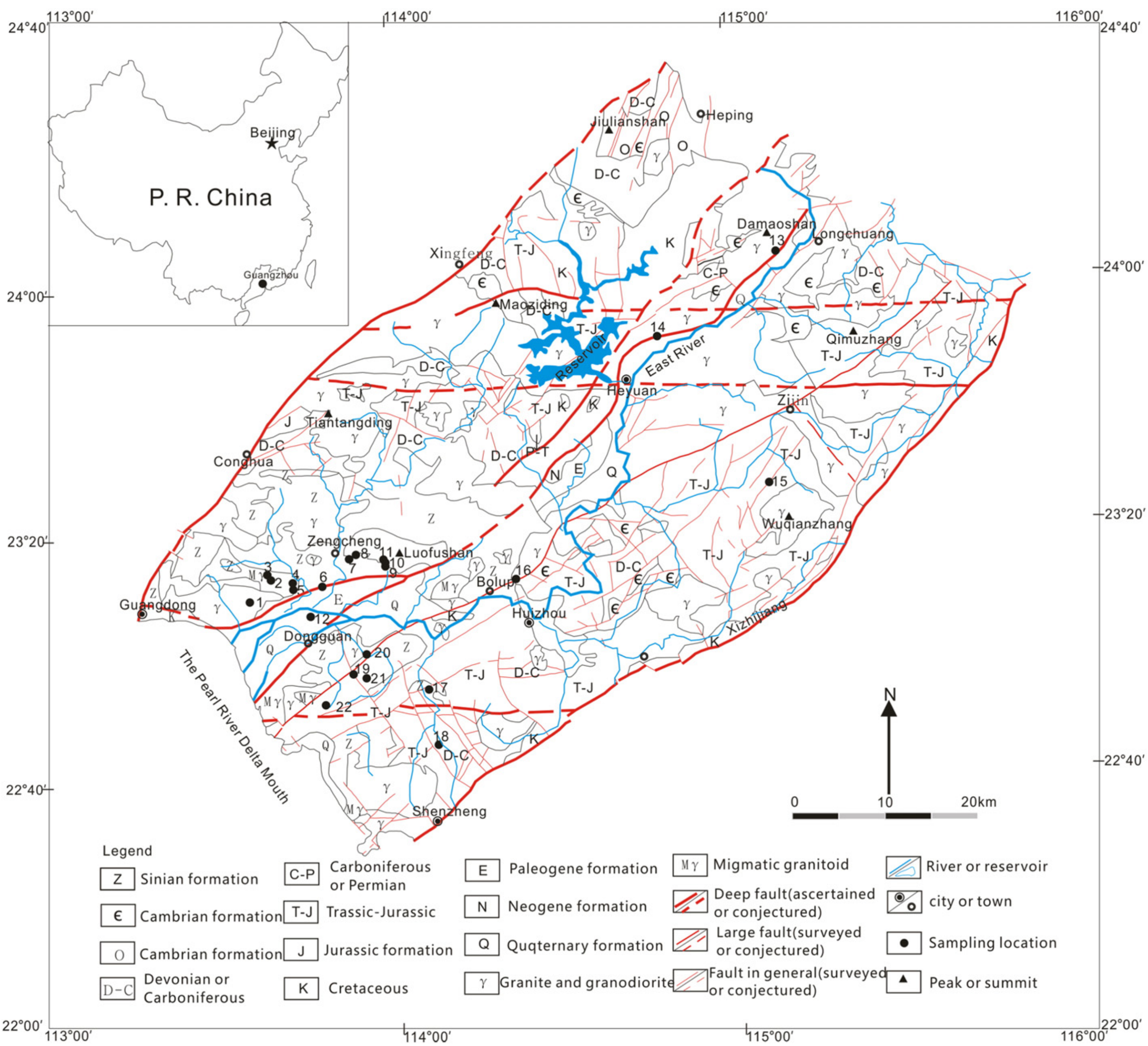

Fig. 1. Simplified map of geology and tectonic structure of Dongguan Basin and its surrounding areas in Guangdong province of Southern China. F1 and F2 represent Heyuan Fault and Zijin–Boluo Fault, respectively.