Geothermics 53 (2015) 38–45

Contents lists available at ScienceDirect

Geothermics

journal homepage: www.elsevier.com/locate/geothermics

Hydrochemical characteristics and genesis analysis of the Jifei hot spring in Yunnan, southwestern China

Yaping Liu[a,b], Xun Zhou[a,c,*], Zijuan Deng[a,d], Bin Fang[a,c], Yamanaka Tsutomu[e], Jingbo Zhao[a], Xiaocui Wang[a]

[a] School of Water Resources and Environment, China University of Geosciences (Beijing), PR China
[b] Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan
[c] Key Laboratory of Groundwater Circulation and Evolution, China University of Geosciences (Beijing), Ministry of Education, PR China
[d] School of the Environment, Flinders University, Australia
[e] Terrestrial Environment Research Center, University of Tsukuba, Japan

ARTICLE INFO

Article history:
Received 25 August 2011
Accepted 2 April 2014
Available online 14 May 2014

Keywords:
Hot spring
Thermal groundwater
Hydrochemistry
Isotope
Travertine
Southwestern China

ABSTRACT

The Jifei hot spring is a typical travertine-depositing hot spring with many travertine cones. The spring water is meteoric in origin and is heated when it undergoes deep circulation of 1792 m through the well-developed faults. Based on the hydrochemical and isotopic analysis, the estimated residence time of the deep circulating meteoric water is 35–50 years and the estimated reservoir temperature of the thermal groundwater is approximate 110.9 °C. The mixing ratio of the cold groundwater is around 44% in the Jifei hot spring calculated by mass conservation method of enthalpy and silica dioxide concentration. Finally, a conceptual diagram of the genesis of the Jifei hot spring is given. In addition, it has been inferred that the travertine deposited from the beginning of the Holocene Epoch.

1. Introduction

The travertine formation is an important hydrothermal manifestation and may provide very useful information for the reconstitution of paleoclimate, paleoenvironment and paleohydrology (Liu et al., 2012). Clearly identifying the genesis of travertine-depositing hot springs is very important to understand the travertine formation and to provide useful information for rational use of hot water resources. Numerous studies have demonstrated the genesis of travertine and travertine-depositing hot springs using hydrochemical and isotopic tracers. For example, hydrochemical and isotopic studies of hot waters were conducted in the Pamukkale hydrothermal field and Kozakli geothermal area of Turkey (Dilsiz, 2006; Pasvanoğlu and Chandrasekharam, 2011). The hydrochemical and isotopic characteristics of Mammoth hot springs of Yellowstone Park in the U.S.A. were investigated by Friedman (1970), Sturchio (1990), Sorey and Colvard (1997) and Zhang et al. (2004). The hydrochemical and isotopic compositions were used to complement the travertine formation analysis in the Tyrrhenian region of Italy (Minissale et al., 2002). The hydrochemical analyses of spring waters were conducted to predict the potential for travertine formation in Fossil Creek, Arizona of the US. (Malusa et al., 2003). However, very few studies have previously documented the genesis of travertine-depositing hot springs as the Jifei hot spring (also named Zhushanxizaotang, Jifeizaotang, and Shiliu or Shipen hot spring; Y1 in Fig. 1), which is characterized by a huge travertine terrace with an area of about 4000 m^2 and 18 travertine cones among which the highest one reaches up to 7.1 m.

Previous studies conducted in the Jifei hot spring were as early as 1970s. However, they mainly focused on the geology, hydrogeology and hydrochemistry compositions of the hot spring (Chinese People's Liberation Army, 1980; Geological Bureau of Yunnan Province, 1980; Local Chronicles Codification Committee of Yunnan Province, 1999). The hydrochemical conditions of the travertine and travertine cone formation in the Jifei area were revealed by a companion paper (Liu et al., 2012). A detailed research on this geothermal system is still needed to address the genesis of the hot spring under a special geological setting. Furthermore, the knowledge which could be gained from this system can help to enhance our understanding of travertine and travertine cones formation.

The purposes of the present study are to characterize the recharge sources, circulation depth, residence time and hot-cold water mixing ratio of the Jifei hot spring by means of the

* Corresponding author at: School of Water Resources and Environment, China University of Geosciences (Beijing), Xueyuan Road 29, Beijing 100083, PR China. Tel.: +86 10 82323428; Fax: +86 10 82321081.
E-mail address: zhouxun@cugb.edu.cn (X. Zhou).

http://dx.doi.org/10.1016/j.geothermics.2014.04.002
0375-6505/

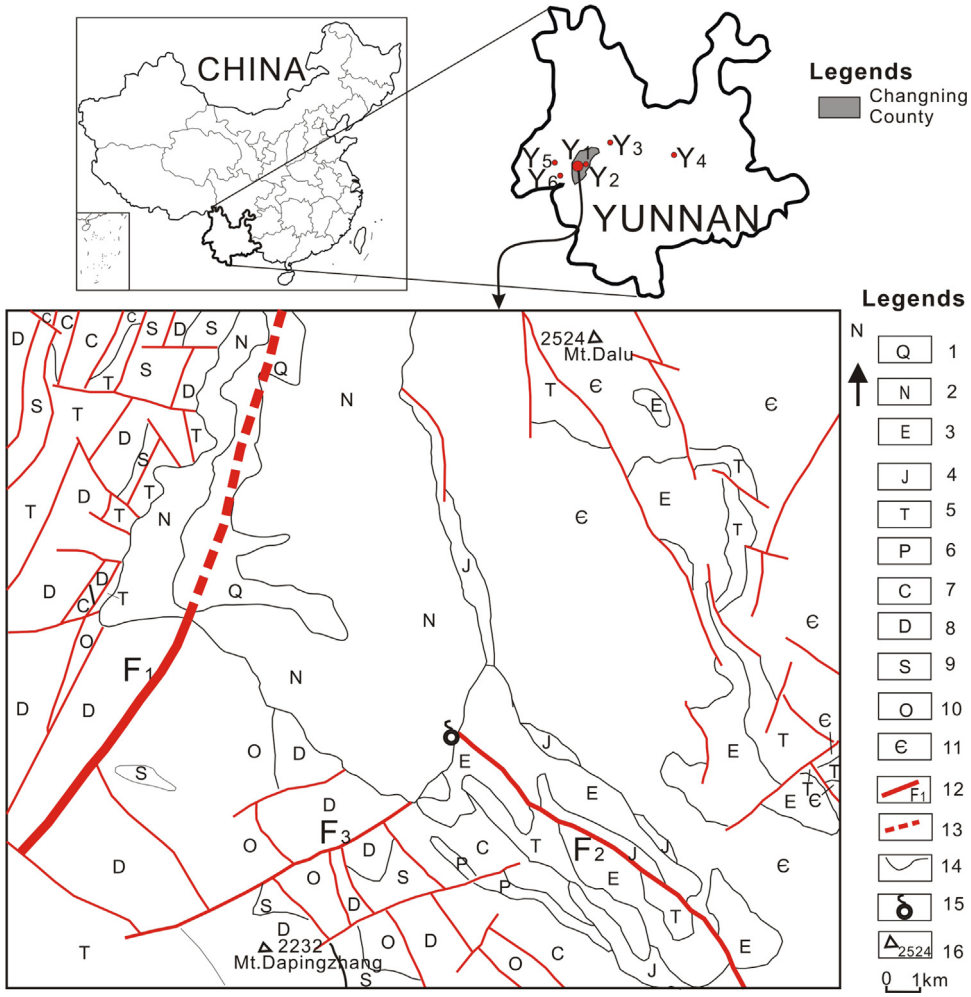

Fig. 1. Sampling locations and outline map of the hydrogeology outline of the Jifei hot spring. Y_1 – Jifei hot spring; Y_2 – Changning Wenquanxiang hot spring; Y_3 – Dali Xiaguan hot spring; Y_4 – Anning hot spring; Y_5 – Tengchong Rehai hot spring; Y_6 – Longling Banglazhang hot spring. 1 – Gravel, sand and clay (Quaternary); 2 – Claystone and glutenite (Neocene); 3 – Boulder conglomerate (Paleocene); 4 – Conglomerate and mudstone (Jurassic); 5 – Shale and dacite (Triassic); 6 – Limestone (Permian); 7 – Basalt and shale (Carboniferous); 8 – Sandstone, shale and siliceous rocks (Devonian); 9 – Limestone and shale (Silurian); 10 – Mudstone, limestone, shale and marlite (Ordovician); 11 – Limestone, sandstone and schist (Cambrian); 12 – Fault and its number; 13 – Inferred fault; 14 – Stratum line; 15 – The Jifei hot spring; 16 – Mountain peak and its elevation (m).

hydrochemistry and isotope methods. The formation time of the travertine sediment of the Jifei geothermal area would also be estimated based on the method of mass conservation.

2. Materials and methods

2.1. Geological and hydrogeological setting

The Jifei hot spring (Y1 in Fig. 1) emerges in the form of spring group on the right side of a small river in the Changning County (grey shadow in Fig. 1), southwest of Yunnan Province. The Yunnan–Tibet geothermal belt is a very important geothermal region of China (Chen et al., 1994; Kearey and Wei, 1993; Zhou et al., 2009). Yunnan Province has more than 1000 hot springs in total while the distribution of high temperature hot springs is concentrated in the west.

Faults are widely found in the study area. The main faults that control the structure are the following two sets. One is the set of NE-SW trending faults which is a part of the Sanjiang (Nujiang, Lancangjiang and Jinsajiang rivers) radial tectonic system. The other is the set of NW-NNW-NS-NNE trending arcuate faults crossing the areas of Changning, Yingpan and Yalian. Developed faults with multi-period divided the stratum into various shapes of geological tectonic units with different lithologies (Fig. 1). Exposed strata in the study area are mainly composed of sedimentary rock and metamorphic rock from the Quaternary system to the Cambrian system except the Cretaceous system. In addition, a few of magmatic rock (i.e., diabase) of the Yanshan-Indo-Chinese epoch exposes to the form of stocks and dikes in this region (Chinese People's Liberation Army, 1980; Geological Bureau of Yunnan Province, 1980).

The Kejiehe fault (F_1 in Fig. 1) is the main fault for the Jifie hot spring formation. The spring occurs at the intersection part of the Apianzhai fault (F_2 in Fig. 1) and the potential extension line of the Houshanbei fault (F_3 in Fig. 1). The aquifer in which the Jifei thermal groundwater occurs is the red sandstone of Neogene lacustrine deposition. Rocks underlying the Neocene lacustrine sediments include Mesozoic and Paleozoic shallow marine sediments and co-deposition of marine and continental clastic rocks and epimetamorphic clastic rocks, with the total thickness of about 2500–6000 m. More than 20 hot springs emerge in the Changning County and the temperature of the Jifei hot spring (up to 81 °C) is the highest among them (Local Chronicles Codification Committee of Yunnan Province, 1999). The hydrothermal activity of the study region is weaker than the nearby Tengchong region at which volcanic activity occurred recently (Fang and Ding, 1997; Zhou et al., 1995). The magma pocket is small or absent in this study area (Zhou