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Hydrochemical and isotopic features of the Khaung Daing hot spring (Inle lake, Southern Shan State, Myanmar)

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Abstract

The Inle lake watershed develops along a right-lateral strike-slip fault running parallel to the Sangaing fault, a major continental transform fault between the India and Sunda Plates. Located on the northwestern border of the Inle lake basin, the Khaung Daing hot spring outflows at a temperature of about 70°C. This contribution represents a reconnaissance study of the spring and describes its main hydrochemical and isotopic features, compared to surface and ground waters in the watershed. The water pH is slightly acidic, and, compared to the other water samples from the watershed, shows an EC in the high range (57-1284 μS/cm), the lowest pH and Eh values, and is Na-HCO_3, whereas surface and ground waters are Ca(Mg)-HCO_3 type. The hot spring isotopic composition falls close to the Yangon Meteoric Water Line, indicating that, despite its temperature, it is not strongly modified by water-rock interaction processes. Preliminary results suggest that this hydrothermal water is likely related to deep meteoric and ground water circulation within a fault zone, in a region characterized by an elevated geothermal gradient.

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Keywords: groundwater; stable isotopes; hydrothermal waters; mineralogy

1. Introduction

Located on the northwestern border of the Inle lake watershed (Southern Shan State, Myanmar), the Khaung Daing hot spring is well known to the local population for cultural and recreational purposes, with two bathing pools of free access. In recent years, due to the touristic development of the Inle lake area, the hot water emerging

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naturally from one of the outflows has also been conveyed to a private spa resort[1]. Nevertheless, no data are available in the international literature about this peculiar water. In the frame of an ongoing hydrogeological investigation of the Inle lake watershed, two sampling campaigns were conducted in different seasons, also including the Khaung Daing hot spring. The aim of this contribution is to provide hydrochemical and isotopic data of this water as a first reconnaissance of its characteristics.

1.1. Study area

The Inle lake basin is located in the Shan Plateau, belonging to the Sibumasu block[2], and mainly constituted by Permo-Triassic carbonates. In Southern Shan State, the stratigraphic sequence is constituted by the Thitsipin Limestone Formation (TLF), and the overlying Nwabandgyi Dolomite Formation (NDF)[3]. The TLF comprises five main lithofacies including conglomerates, laminated calcareous shales, fined grained calcareous sediments, calcareous sandstones and massive cherty wackestones, with some domains of the formation partially dolomitised. The TLF passes transitionally upwards into the NDF, subdivided in four main lithofacies which comprise calcareous conglomerates and sandstones, dolomitic and bioclastic wackestone and turbiditic dolomitic mudstone. Triassic limestones tend to be more crystalline and less sandy than the underlying Devonian strata, and contain a greater proportion of calcium carbonate, up to 98%. The sequence of carbonate rocks is thought to be of considerable thickness, with estimates in the range of approximately 1650 m in the Northern Shan State and up to 1000 m in the Southern Shan State.

The area is strongly conditioned by the recent tectonic activity, and particularly the movement of the eastern Himalayan syntaxis[4]. The watershed is located about 50 km eastwards of the tectonically active Sagaing fault, a major continental transform fault between the India and Sunda Plates that connects spreading centers in the Andaman Sea and the continental convergence zone along the Himalayan front. The Sagaing fault runs from north to south and sets the boundary between the Central Myanmar Basin and the Mogok Metamorphic Belt; its total offset is debated but ranges from 330 km to as much as 1000 km, and most of this has occurred since the Miocene[4]. Recent neotectonic studies[5] indicate that the Inle lake watershed develops along a right-lateral strike-slip fault running parallel to the Sangaing fault; the lake itself is bordered on the east side by the so-called Taunggyi normal fault, showing a complex geometry and determining the asymmetrical shape of the basin.

1.2. Description

The hot spring area is located to the NW of the Inle lake, at the foothills of the Western Range. Three main outflows are present. The most accessible is actually constituted by two small pools (UTM long. 47Q 0279107; lat. 2282607): thermal waters are merged together and flow to feed the main public pools (Fig. 1). A second, larger outflow (long. 47Q 0279103; lat. 2282517), bordered by a white fence, is a holy site, as indicated by a panel forbidding the entrance to women; nevertheless, the spring feeds the water to a recently constructed spa[1]. A third small pool is located more uphill and is not presently used (long. 47Q 0279103; lat. 2282517).

Fig. 1. The Khaung Daing hot springs: (a) the two main spring outflows feeding the public pools, located to the right (Photo by V. Re); (b) the outflow feeding the spa (Photo by M. Setti).

2. Materials and methods

Rock samples were collected in the area, and especially from the recently excavated side of the Inle lake West Corridor Rd. Samples were ground to fine powder in an agate mortar and the mineralogical composition was measured by X-Ray Powder Diffraction.

Two water sampling campaigns were conducted. The first, in March 2014, focused on waters from the Inle lake[6], while the second, in December 2015, included also samples of river and ground waters from the lake watershed. During this second campaign, Temperature, Electrical Conductivity (EC), pH and Eh were measured in the field with a multiparameter probe. In the laboratory, samples were analyzed for alkalinity by titration, whereas the ionic contents were determined by ion chromatography at the University of Pavia. The analytical error was estimated from electro-neutrality balances to be less than ±5%. Stable isotopes of the water molecule were determined by Wavelength-Scanned Cavity Ring-Down Spectroscopy (WS-CRDS) at ISO4 in Italy. Results are reported in the usual delta (δ) notation vs V-SMOW, with an uncertainty (2σ) of ±0.2‰ for $\delta^{18}O$ and ±1‰ for $\delta^{2}H$.

3. Results and discussion

Rock samples from the springs area contain variable proportions of calcite (48-92%), quartz (3-20%), muscovite (5-15%), kaolinite (0-12%) and rutile (3-5%). Their mineralogical content is comparable to that of rocks outcropping to the East of Inle lake, and could belong to the TLF. Also, one sample without carbonates but containing quartz (18%), a high proportion of Fe-rich phases (goethite 22%, hematite 12%) and kaolinite (20%) was found. The kaolinite content is likely related to a circulation of hydrothermal fluids interacting with feldspar-rich rocks at depth. Dolomite was not detected in any of the analyzed specimen.

Concerning hot waters, field measurements of temperature and EC were performed at the three main outflows, ranging within 69.1-71.1°C and 1099-1150 μS/cm respectively. The full hydrochemical and isotopic characterization was conducted on the spring displaying the highest EC, with results reported in Table 1. The water pH is slightly acidic, likely due to the presence of H_2S, as also indicated by the typical smell and low ORP value. Compared to the other water samples, the hot spring shows an EC in the high range (57-1284 μS/cm), the lowest pH and Eh values, and is Na-HCO_3, whereas surface and ground waters are Ca(Mg)-HCO_3 type.

Table 1. Hydrochemistry and isotopic composition of the Khaung Daing hot spring.

Parameter	Unit	30/03/2014	16/12/2015
Temperature	°C	n.m.	69.1
Electrical conductivity	μS/cm	n.m.	1150
pH		n.m.	6.20
Eh	mV	n.m.	-108
Ca^{2+}	mg/l	4.7	4.7
Mg^{2+}	mg/l	5.9	5.9
Na^{+}	mg/l	260	267.9
K^{+}	mg/l	27.1	27.2
Li^{+}	mg/l	0.8	0.5
HCO_3^{-}	mg/l	617.3	654
SO_4^{2-}	mg/l	47.3	56.5
Cl^{-}	mg/l	15.6	16.6
F^{-}	mg/l	5.3	5.5
NO_3^{-}	mg/l	0	0
$\delta^{18}O$	‰ vs SMOW	-7.28	-7.12
$\delta^{2}H$	‰ vs SMOW	-50.7	-50.5

The isotopic composition of the hot spring is reported in the δ^2H *vs* $\delta^{18}O$ diagram (Fig. 2), together with the Global Meteoric Water Line[7] and the regression line for Yangon precipitation data[8]. The hot spring falls very close to the latter indicating that, despite its temperature, it is not strongly modified by water-rock interaction processes. Also, compared to the other surface and ground water samples from the watershed, it is not affected by evaporation, as many lake waters, and can be considered representative of the isotopic composition of groundwater. According to previous studies[6], the hot spring isotopic composition agrees with the mean composition of lake water during the rainy season, therefore suggesting that the hydrothermal circuit could be recharged by local precipitation.

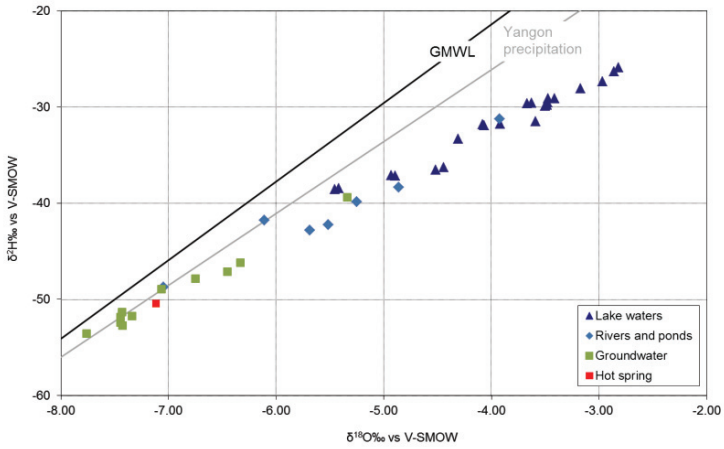

Fig. 2. Isotopic composition of the Khaung Daing hot spring compared to that of other surface and ground waters from the Inle lake watershed.

4. Conclusion

As a preliminary reconnaissance study, this investigation shows the occurrence of a series of hot water outflows in an area where little information is available on geology and tectonic settings. From these preliminary results, and the given complex structural setting of the area, the presence of this geothermal fluid is likely related to deep meteoric water and groundwater circulation within a fault zone in a region characterized by an elevated geothermal gradient, rather than to the existence of active or recent magmatism. More information should be retrieved to enable the application of chemical geothermometers and fully characterize this resource.

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