GEOLOGY OF THE TENGCHONG GEOTHERMAL FIELD AND SURROUNDING AREA, WEST YUNNAN, CHINA

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(Received October 1985; accepted for publication March 1986)

Abstract—This paper describes the regional tectonics, active structures and thermal springs of the Tengchong geothermal field and surrounding area. Regional tectonic evidence shows that Tengchong and the surrounding area was a microcontinent between the Gondwanaland and Eurasian plates. The distribution of the thermal springs is controlled by active faults in the “arched” and circular structures. The majority of the thermal areas have a deep circulation within the fault system. Only a few high-temperature hydrothermal systems issuing sodium chloride may be heated by a local magmatic source.

INTRODUCTION

The study area includes the Tengchong county, the Dehong Tai Autonomous Prefecture of Yunnan Province and the Kachin State of Burma. This study was based on data on the regional tectonics, structures and relationship between the volcanoes and their thermal source. Their interpretation is based on the plate tectonics theory which, in the authors' opinion, is the only hypothesis compatible with these data.

REGIONAL TECTONICS

All high-temperature hydrothermal systems, including the Hot Sea geothermal field of Tengchong County, are located along the margins of active plates.

The geology of the study area indicates that since the late Paleozoic the Tengchong area has been a microcontinent between the Gondwanaland and Eurasian Plate (Fig. 1). The lithostratigraphic data of the gravel-bearing rocks of the U. Carboniferous and especially the fauna (without fusulinids) from the north Yarlung Zangbo river to the Tengchong area indicate that Tengchong belongs to the Gondwanaland plate.

The separation of the Tengchong area from the southern Continent, beginning in the Triassic, created the Tethys ocean, which contained turbid sediment deposits. After the Triassic the Tengchong area formed a peninsula in the Tethys and then adhered to the Eurasian plate. During the Cretaceous the Gondwanaland plate broke away altogether and the Indian plate drifted northwards. Many Jurassic and Cretaceous granites intruded into the Tengchong area, as the Tethys oceanic crust subducted under the peninsula. At the end of this phase of spreading, lasting about 50 Ma, the Indian plate collided with the Eurasian plate (Fig. 2). This continent-to-continent collision, along with the subduction of the oceanic lithosphere of the Indian Ocean beneath the Burmese Central basin and Shan Massif, formed the Indo – Burma ranges.

The predominantly andesitic volcanoes, Pliocene to Pleistocene in age, extend from Tengchong in Yunnan Province through Burma to Sumatra, and range from high potassic calc-alkaline lava to weak alkaline basalts. There is a direct correlation between the K of the volcanic rocks and the depth of the Benioff zone. An Sr isotope ratio of 0.71 indicates a contamination of the original magma by crustal material. The widespread hot spring activity between Tengchong and Shan Scarp could indicate concealed intrusions.
Recent volcanoes, faults and circular structures are the most conspicuous tectonic features on the Landsat satellite images of Tengchong. Lava flows and volcanic cones are well preserved, the youngest three dated from 0.12 to 0.05 Ma (Mu et al., 1986).

Although deformation throughout West Asia seems to be mainly the result of a north–south compression and shortening, the recent tectonics of Tengchong appears to be characterized by dextral slips in a N–S direction along the Hengduan ranges. The most prominent fault systems extend in four directions: N–S, ENE, NE, NNW (Fig. 3). The NE and NNW fault systems form an “arched” structure. The arc’s top faces in an ESE direction. Along the NE branches many younger grabens have formed, covered with Miocene–Pleistocene deposits. The most peculiar circular shape in this area may be the result of some intrusions during the Mesozoic.

Hydrothermal activity on this microcontinent has been particularly intense. There are 58 thermal areas of different extension in Tengchong County, 72 in the Dehong Tai Autonomous Prefecture and 42 in LongLing County. The distribution of these thermal areas is related to the above-mentioned “arched” faults. Some high-temperature thermal areas are located at the
HEAT SOURCES

Using geochemistry and geothermometers, the 172 geothermal areas scattered in and around Tengchong County can be divided into different hydrothermal systems. Nine of these geothermal areas with reservoir temperatures above 150°C belong to the high-temperature hydrothermal system. Based on the chemical composition, these thermal waters can be classified into two main types: alkali–chloride waters and bicarbonate–sodium waters (Zhang et al., 1986).

The thermal water from the Hot Sea geothermal field and the Langpu Hot Pool area is diluted alkali–chloride water, in which the dissolved salts are mainly sodium and potassium chlorides. The water also contains high concentrations of silica, fluoride, arsenic and lithium, as well as high TDS (> 1 g/l).

The surface activity of the Hot Sea geothermal field is spread over 7.5 km². This field is located in a circular structure between two arcuate faults. The basement of the geothermal field is late Cretaceous granite with a K–Ar age of 68.8 Ma. At the surface, this granite is covered
Fig. 3. Simplified map showing active tectonics and thermal springs distribution in Tengchong and the surrounding area. Heavy lines are major active faults recognized on Landsat images.
Geology of Tengchong Geothermal Field

by Miocene sandstones and conglomerates which have been altered into kaolinite and a mixture of illite and montmorillonite. An anticline with a N–S strike developed in the Miocene. On its crest are many longitudinal faults with dextral rotations, joints, fissures and other features. As passages for thermal fluids these faults are important locally in controlling the hydrothermal activity of the thermal springs and the quartz veins (Fig. 4) (Liao et al., 1981).

![Geological map of Hot Sea geothermal field in Tengchong (after Liao et al., 1981).]

The Langpu Hot pool area is situated on the western border of the circular structure near the westernmost arcuate fault.

Although there are many microearthquakes around this circle, there is a seismic-free zone (Fig. 5) within it. This field is related to volcanoes, because molten andesitic magma intruded at a shallow depth to create the circle and act as a heat source of the intense geothermal activity. The Hot Sea field and the Langpu Hot Pool areas probably have a common heat source, but a different convective system.

The other seven high-temperature hydrothermal systems have boiling water which produce sodium bicarbonate water on the surface. The water is rich in silica, high in sulfate, low in chloride and contains relatively high fluoride and low TDS (< 1 g/l). Outside Tengchong County, the chloride concentration in the water decreases. The chemical composition indicates a common origin for the hot waters. All these high-temperature systems are distributed along the major active faults. They belong to cyclic systems in the Cenozoic tectonic activity zone (Fig. 6).

The bulk of the warm and thermal springs in Tengchong and surrounding area has a deep circulation of water with temperatures in the reservoir usually below 150°C. The faulting and fracturing of igneous and metamorphic rocks allow the water to circulate to greater depth. The warm waters frequently contain calcium or sodium bicarbonate with TDS < 1 g/l. The discharges of the springs are usually small and the water stored within the systems is probably not very large.

Estimates have been made of the heat content of some geothermal systems in Tengchong County. The methodology used to evaluate these hydrothermal convective systems is similar to
Fig. 5. Sketch map showing the distribution of earthquakes in Tengchong and the surrounding area from 1965 to 1975. The data are taken from Yunnan Seismic Bureau.

Fig. 6. Sketch map showing the fault systems of the Ruidian geothermal field.
that used by Muffler and Cataldi (1978) in their assessment of the energy content of hydrothermal systems.

Figure 7 shows the thermal energy of six hydrothermal systems in Tengchong County. The reservoir thermal energy in the Hot Sea field (DTC-22) and Langpu Hot Pool system (DTC-21) discharging Cl−HCO₃−Na waters, is about 9.21 and 4.03 × 10¹⁸ J, respectively.

By contrast, the other four systems issuing sodium bicarbonate water have lower reservoir thermal energy, because of their smaller reservoir volume. The largest is Panzhihua Boiling spring (DTC-34) with a mean heat content and standard deviation of about (2.25 ± 0.94) × 10¹⁸ J. Similarly, the total reservoir thermal energy in 45 intermediate temperature systems is about 54.6 × 10¹⁸ J, with an average heat content of about 1.20 × 10¹⁸ J each.

![Fig. 7. Monte Carlo distribution of the thermal energy in six hydrothermal convection systems with high reservoir temperatures. Vertical axis shows the probability that the reservoir thermal energy is greater than or equal to a value indicated on the horizontal axis. Mean and standard deviations are shown for each curve in units of 10¹⁸ J.](image)

REFERENCES


