A REVIEW OF THE REHAI (HOT SEA) GEOTHERMAL SYSTEM IN TENGCHONG COUNTY, YUNNAN PROVINCE, CHINA

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Abstract

Tengchong is the main volcanogeothermal region on the Chinese mainland where active thermal springs discharge fiercely around the margin of the Cenozoic volcanic cones. The Rehai (Hot Sea) geothermal field is the largest one. In this paper, a review of the results and a summary of the findings by the geological, geochemical and geophysical reconnaissance surveys, carried out in the Rehai field by the scientists from Pelting University and engineers from Yunnan Geology and Mineral Resources Bureau since 1973, is presented. The aim of this review is to attract scientists' attention and to promote the development of the Rehai.

Introduction

The Rehai (Hot Sea) geothermal system (24°57.5′N/98°26.5′E) is located in the westernmost part of Yunnan Province near the border between China and Burma. The arresting feature of the Rehai to the traveller visiting, or passing through, is the multitude of vapour plumes ascending from the thermal springs.

The earliest scientific record of thermal activity in the Rehai (Hot Sea) was in the travel dairy of Xu Xia-Ke in 1639. It was used for hot baths and had some small additional use for sulfurite mining since Ming Dynasty.

The scientists of Peking University and their cooperators described the geology and geochemistry in relation to the hydrothermal activity and made a preliminary assessment of the potential as a source of geothermal energy (USGECR, 1974; Tong, et al., 1989). During 1983-1987, the Second Hydrogeology and Engineering Geology Team of Yunnan Geology and Mineral Resource Bureau did geological, geochemical and geophysical reconnaissance, accompanied by the drilling of ten shallow (100-400m) holes (2nd HET of YGMRB, 1987).

From 1970s to 1980s, some drillholes for exploration of gold and/or uranium found the high geothermal gradient of about 100%/100m in the southern part of the thermal field.

Geology

Volcanism began at the present site of Tengchong in the Pliocene or Miocene and reached its peak roughly Lower Pleistocene (1Ma), but lasted for the whole Pleistocene period (Liao, 1989). The youngest volcanoes are Mt. Maanshan, Mt. Dayingshan and Mt. Heikongshan. The newest result of the K-Ar analyses were 24±7 Ka and 14±7 Ka for Mt. Maanshan, 48±7Ka and 62±7 Ka for Mt. Dayingshan and 7±7 Ka and 14±7 Ka for Mt. Heikongshan, respectively (Nakai, et al., 1993). The effect of this long period of volcanism is the geological setting of geothermal activities in Tengchong area (Fig. 1).

The regional trend of the range is tectonically from north to south, but is superimposed by many circular strctures. Their formation could be due to the intrusion from Jurassic to the Tertiary. The Rehai field is located inside a circular structure.

In the Rehai field, the oldest rock belongs to the Precamrian Gaoligongshan gneiss, which was discov4red in drillhole in the southern part of the thermal field and exposed in the Reshuitang area. The late Cretaceous granite is exposed in the Zaotanghe river valley. The gneiss and granite could be the reservoir and were covered by the Miocene sandstone and conglomerate. The stratigraphic sequence of the Rehai field is as follows:

Q_4 The alluvium distributed along the Zaotanghe river and the Menqianhe river;

$Q_{2\beta}$ The basalt located in the valley of the above-mentioned rivers, which came from the Mt. Dongdapotou volcano;

$Q_{1\alpha}$ The andesite at the top of the Mt. Bangeshan and Mt. Xidapotou;

N_1 The Miocene Molasse stratum, which is mostly altered;

K_2The granite in the valley of the Zaotanghe river;

PCm the gneiss of Gaoligongshan group, which is distributed at the border of the field.

Many faults, including the important Liuhuangtang-Huangguaqing fault, are probably good channels for the discharge of thermal fluids and are important locally in controlling hydrothermal activities including thermal springs and quartz veins.

Thermal Manifestations

The thermal activity at the Rehai field can be divided into two parts: the classical Rehai region at the eastern part and the Reshuitang (Hot Water Pool) region at western part. There is a simple road connecting the east part with the west part about 7 km over the mountains.

The surface manifestations of the Rehai field include boiling springs, fumaroles and steaming ground etc. The temperatures of the thermal springs range from 42% to 96℃, and the fumaroles are around 97℃. Sulfur is constantly crystallized out around the orifies of the fumalores by oxideation of H_2S.

The natural heat flow of about 180MW for the whole area was measured by Peking University.

Geochemistry

The chemistry of thermal water of the Rehai geothermal field has been discussed by many papers (Liao et al., 1981, 1991; Zhang et al., 1989; Liao, 1990, 1994) and will not be repeated here. Hot waters from boiling springs are mainly chloride-bicarbonate-sodium type with TDS of 2g/kg. It is found that the field is a hot-water system, whose subsurface boiling zone is close to the surface. Cation geothermometers indicate reservior temperature in the range of 230% to 275℃ (Liao, 1990).

Gas samples were taken at some sites in the Rehai field. Results of the gas analyses are listed in Table 1.

As indicated in the legend of Table 1, the analyses are characterized by anomalous methan and hydrogen and an average $^3He/^4He$ ratio of 4.6×10^{-6}. Obviously, the recently published gas analyses and anomalously high $^3He/^4He$ ratio of the Rehai field confirm the existence of degassing upper-mantle rocks at crustal levels. The result is lacking in perfection due to no H_2S data.

Table 1 Composition of gases and $^3He/^4He$ isotope ratio of samples in the Rehai field (taken from Wang et al., 1993)

Nos.	1	3	4	5	6	7
T(℃)	90	96	90	86	80	92
N_2%	56.33	47.67	61.35	41.83	38.08	54.75
CO_2%	32.41	42.38	25.08	46.69	55.20	35.26
CH_4%	0.34	0.04	0.93	1.03	0.33	0.33
Ar %	0.63	0.56	0.77	0.56	0.40	0.61
He ppm	31.5	5.2	99.6	129.4	39.0	41.0
H_2 ppm	75.5	220.0	663.0	802.0	23.0	140.0
$^3He/^4He$ (10^{-6})	4.59	4.0	6.02	5.01	5.46	5.4

Names of sampling sites: 1. Reshuitang; 3. Zaotanghe; 4. Huangguaqing; 5. Liuhuangtang; 6. Xiaogunguo; 7. Dagunguo.

Subsurface Temperature

Subsurface temperature were derived from 19 shallow holes drilled from 1976 to 1992. Thirteen holes range in depth from 100m to 400m. The highest bottom-hole temperature recorded at a depth of 380m in Zk1607 is 142%. The temperature gradient of the field is from 11.5 to 100℃/100m. The other six shallow holes with depth from 19 to 26m were drilled into the seasional variation zone.

The temperature data of shallow holes drilled are not sufficient to prepare a geothermal-gradient map. However, the geothermal gradinet is very irregularly with depth. This renders difficult the work of map compilation. The shallow drilling depth and the rugged topography also make the drawing of isotherms on one particular level impracticable, because many of these holes are either too high or too low in opsition to record the temperature. Contour maps of isothermal surface were not drawn because data were also insuffiecent. But three isothermal profiles were dwawn when possible as shown in Fig. 2. Obviously, profiles 1 and 3 are outside the north and south borders of the high-temperature region.

Geophysical Data

Four fundamentally different geophysical methods (magnetometry, DC sounding, microseismlology and magnetotelluic sounding) were employed in exploration of the Rehai field. It is very difficulty to carry out DC soundings due to the regged topograpy. Groundmagnetic measurement found the rock inside the, thermal field have been partly or completely de-magnetized by thermal alteration. Unfortunately, groundmagnetic measurement can not delineate the boundary of the field.

Two separate microearthquake surveys were made in December 1980 and March 1982 lasting 37 and 31 days respectively. A total of 334 events with a magnitude between 0 and 4. 4 were recorded at ten field stations. It was found that there is a thin crustal layer only about 7km thick beneath the surface of this field. Away from the center, the thickness of this layer gradually increases taking the shape of an umbrella, thus providing conditions for the formation of a geothermal reservoir or a magma chamber. It also shows that the seismic velocity of the upper crust in the Tengchong is anomlously low (Vp=4. 62km/s, Vs=2. 88km/s)(Liu, et al. , 1986, 1989).

Magnetotelluric (MT) sounding were made at 11 stations along a 13 km profile, which crosses the Rehai filed in an almost E-W direction perpendicular to the regional tectonic trend. An ID inversion algorithm produced the depth section shown in Fig. 3. The crustal resistivity anomaly between 5 and 25 km depth has been interpreted in terms of anomalous hot crustal rock, which probably enclose some magma (Bai, et al. , 1994; Liao, 1993).

Summary

Util now, all the investigations at the Rehai undertaken have been preliminary in scale. The basic aim during the reconnaissance of a geothermal field is to determine its energy potential. To do this it is necessary to assess: 1) the size of the field, 2) the shape of the field, 3) the structure of the field and 4) the capacity of the field to produce energy. Obviously, these problems at the Rehai field are not yet resolved satisfactorily. But the author affirms the following statement to be true: 1) the spectacular thermal springs and fumaroles at the Rehai are products of a history of intensive volcanism, mainly of the Pleistocene cone; 2) the Rehai field is a hot-water system with a magmatic heat source. Its reservoir temperature can exceed 230%. The reservoir rock body is granite or gneiss, of which the second permeability is still uncertain; 3) the geothermal resourece at the Rehai field should be one among the richest in China. Resource as sessment for purpose of electric generation remains to be solved due to lack of adequate drillholes.

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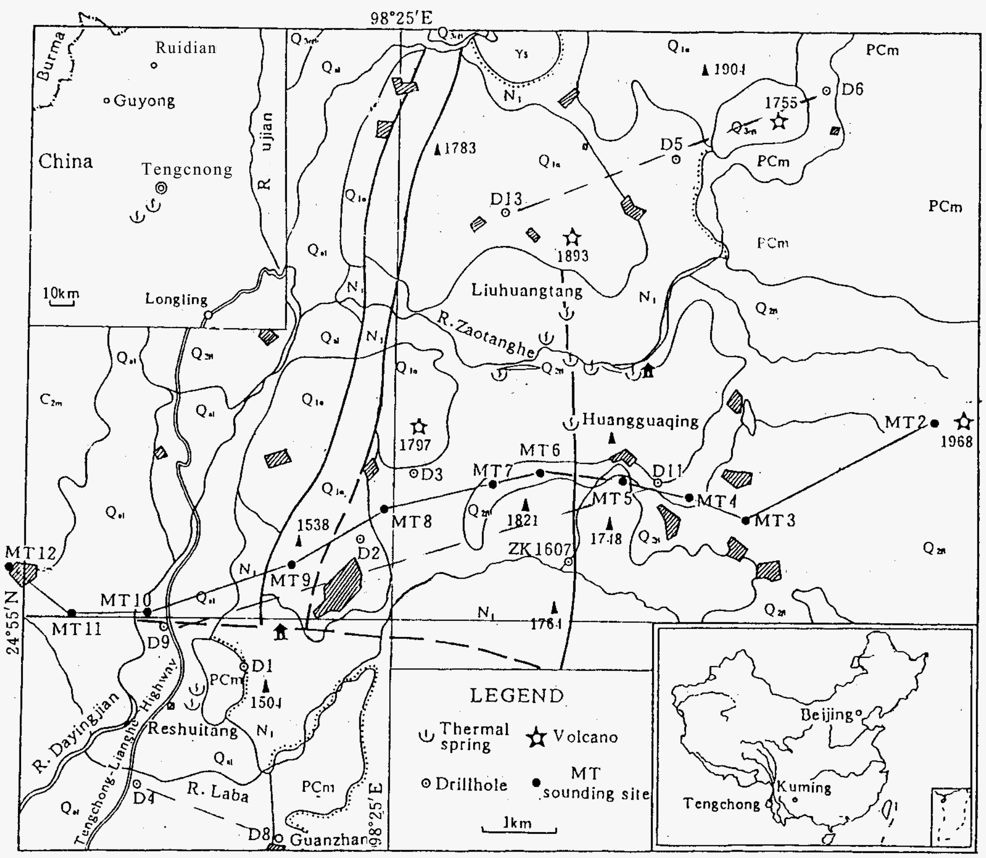

Fig. 1 Location of the Rehai field and sites of drillholes and MT sounding.

Q_{al} Quaternary alluvium

$Q_{3\alpha\beta}$ U. Pleistocene andesite-basalt

$Q_{2\beta}$ M. Pleistocene basalt

$Q_{1\alpha}$ L. Pleistocene andesite

N_1 Miocene

C_2 M. Carboniferous sandstone-bearing gravel

PC, Gaoligongshan group of Precambrian

γ_5 Cretaceous granite

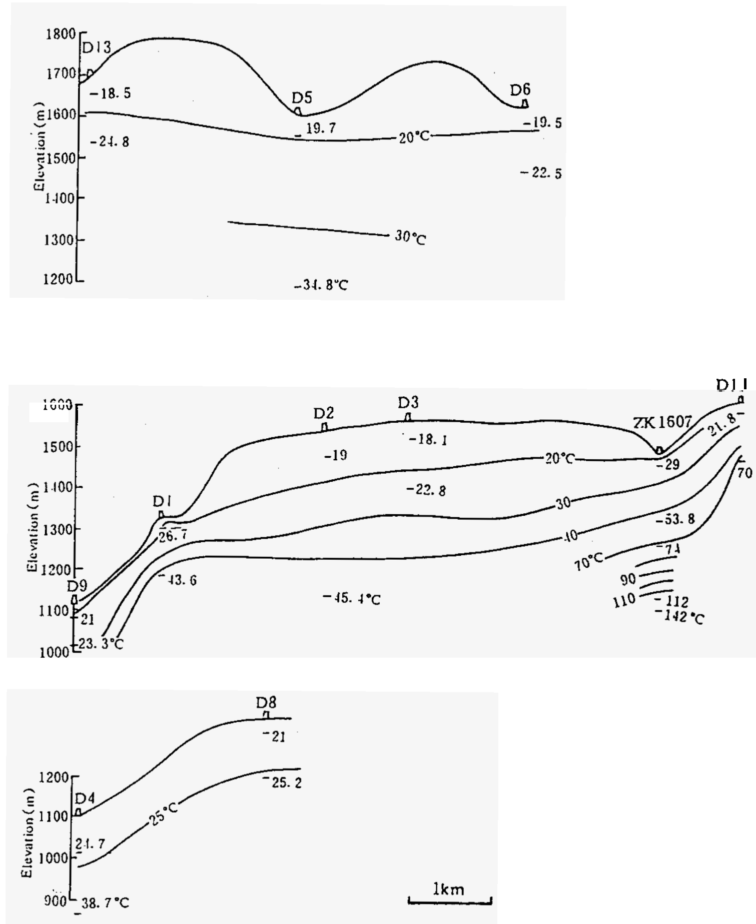

Fig. 2 Isothermal Profiles, Locations of drillhole on Fig.1 (Temperature data are taken from 2nd HEGT of Yunnan, 1987).

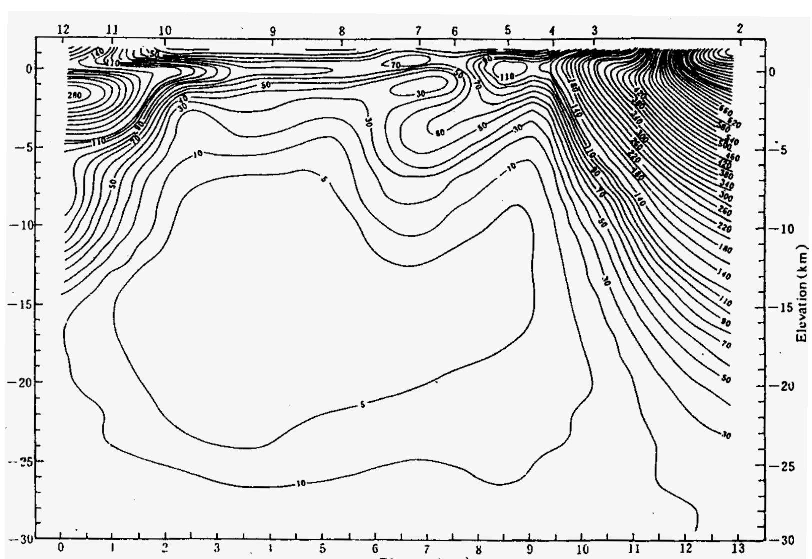

Fig. 3 Apparent resistivity pseudosection (in Ωm) (taken from Bai dt al. , 1994)