Proc. 6th NZ Geothermal Workshop 1984

PREDEVELOPMENT INVESTIGATION OF DAKONGBENG HYDROTHERMAL AREA, YUNXIAN COUNTY, YUNNAN PROVINCE, CHINA

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ABSTRACT

Dakongbeng Hydrothermal Area is one of powerful hydrothermal areas in Himalayan Geothermal Belt and is located at 14 km west of town of Yunxian county, western part of Yunnan Province. This paper described its geological settings, surface manifestations, and discussed the results of chemical analyses of hot waters and soil mercury survey. Finaly, the heat content beneath the area has been estimated to be about $1.4 \cdot 10^{18}$ J and its electrical potential is about 11 MW.cent.

INTRODUCTION

In the last decade, Comperehensive Scientifical Expedition to the Qinghai–Xizang (Tibet) Plateau made an extensive survey of geothermal resources in the Xizang and western parts of Yunnan and Sichuan Provinces and it showed that the Himalayan Geothermal Belt runs through the south–western part of China as an essential part of the global geothermal belt(1). The total of known hydrothermal areas within the Himalayan Geothermal Belt is, at least, over 1500, among which more than 60 areas are powerful, the temperatures at orifice are over boiling point respected to local altitude. Those areas might be of resource potential and are carrying on predevelopment investigation one by one according to priority of feasibility of development. One of them is Dakongbeng Hydrothermal Area.

GEMOLOGICAL SETTINGS

Dakongbeng Hydrothermal Area is located at 14 km west of town of Yunxian county, western part of Yunnan Province. Its altitude is 1280 m to which corresponding boiling point temperature is aoout 95.5°C. The annual air temperature in average is 19.4°C, and the annual precipitation in average is 909 mm. Wanqiaohe river with a drainage area of more than 1500 km2 flows through the area from southwest to northeast. The Dakongbeng Hydrothermal Area is locted tectonically within Sanjiang Folded Strata Belt formed in Indo-China stage and reformed by more strong tectonism during Yenshan and Himalayan stage later. The rocks occured in this area include biotite grano-gneiss which may be the metamophosed migmatizationally products from Manghuei group of Middle Triassic or may be deep metamorphic strata of Lancang qun of Lower Palaeoeic Era not to come to conclusion yet, and some Middle Jurassic red bed overlaped the gneiss, and granite of Yenshan stage as an offshoot intrusive contact with those rocks mentioned above. Nandinhe Fault is a sinistral fault across the area from southwest to northeast and dips to southeast with a high dip angle. Two groups of quartz vein with strick of 330° and 0-15° respectively are common within the area. Those may related to proximate grade fault derived from the cardinal, and which could control directly the distribution of htdrothermal manifestations.

From the facts, the reservoir is composed of gneiss and granite and is of veinlike and crevassenesa.

SURFACE MANIFESTATIONS

Dakongbeng Hydrothermal Area may be divided into following five subareas.

Dakangzhixi Hot Spring subarea, as shown in Fig.1 labelled by number 1, is located in a valley with a direction of 330° where the calley intersected the Nandinhe foult. Three hot springs issued from the bottom of the valley near left cliff and their temperatures at orifice are 60°C, 89°C, 86°C respectively, and hot water shows PH value of 7.7-7.9, with total discharge of 2.4 l/sec.

Xuetang Hot Spring subarea, as shown in Fig.1 labelled by number 2, located in another valley in western bank of the Nanqiaohe river, issued from the right bottom of the valley where granite night be intrusive contact with gneiss or a proximate grade fault night run through along the valley. The subarea with 40m long have more than 20 springs, the highest one is about 7-8 m above river level. A spring with maximum temperature of 67°C, and pH value of 7.5 isseced at middle part of the subarea, and other'a temperatures were decreased gradually upstreamward and down streamward. Because of numerous springs and immedately mixture with stream water after dischrging, total amount of discharge were too difficult to mearsure directly, but could be estimated from temperature difference of stream water between downstream and upstream (21.5°C-16°C=5.5°C) and flow rate of stream to be 200 l/sec by perusal. Assumed the mean temperature of hot water to be 60°C, the discharge of the subarea was about 18.3 l/sec.

Dakongbeng boiling spring subarea, as shown in Fig 1 labelled by number 3, is of typical for whole area and located within a deep valley stretching nearly west-eastwards over 500 m in length. There manifest 3 boilings spouters, large-scale steaming and altered ground and numerous hot and boiling aprings with maximum temperature 97.6°C at orifice. The roaring noise from these spouters reaches as distant as half of kilometer.

Adjoining rocks were alterated strongly and kaolinization was dominant. On groundsurface near orifices of springs, a lot of salt efflorescence and a few natural sulfur were deposited, but large-scale fossil sinter and travertine remained on the ridges both sides of this valley. The fossil travertine's visiable thickness is about 6-7 m, and bottom of the travertine bodies are higher by 10-30 than orifices of the springs which are discharging from bottom of the valley. Total discharge of the subarea was 21.37 l/s by previous report.

On east valley flat of Nanqiaohe river there were two subareas: situated south of the mouth of Dakongbeng valley and had several small springs contributing thermal water to a pond 40 m long and 10 m wide and another located in north of former 200 m away. The maximum temperatures for the two subareas are 73°C, 68°C, respectively. Their discharge could not measure.

GEOCHEMISTRY OF HOT FLUID

Resalts of Chemical analysis for 9 hot water samples collected from this area were listed in table 1. All of these samples are of HCO_3-Na type except NO 5. which was of $HCO_3CO_3^-$Na type. Their B/Cl ratios are very close each other, 1.69 in average with a standart deriation of 0.23. In the light of these facts it is reasonable that all springs in the five subareas could be come from same deep reservoir.

In spite of the ratios of sone ions for the 9 samples being very close, from view point of concentrations of some major compositions the hydrochemical of 1,3,4,5 subarea are more uniform but considerable difference from that of 2 sabarea, Xuetang hot spring subarea , its most indicators are low abviously. Thus we would like to infer that hot water issued in Xuetang sabarea was affected by mixing evidently with cold dilute.

Reservoir temperatures have been calculated by various geothermonetars and shown in table 1 also. We used quartz-no steam loss equation (2) to calculate the SiO_2 geothermometer temperature for most samples but equation-mimum steam loss(2) for samples No5 and No 6, collected from boiling spring.

Results calculated show that temperature of subsurface beneath subsurface beneath subaera 2 are considerable low, so that temperatures were left out of consideration for calculating the mean values of geothermometer temperatures. The mean values for SiO_2, Na/K, Na-K-Ca, Na-K-Ca-Mg geothermometer temperatures are of 173.2°C, 228.4°C, 213°C, 196.5°C, with standart deviations of 6.6°C, 15.5°C, 18.6°C, and 27°C respectively. The SiO_2 geothermometer temperatures are commonly lower than that of Na/K by 52.3°C and of Na-K-Ca by 40°C. This would be resulted from dilution and/or precipitation of silica underground. The authors tented to consider SiO_2 temperature as a minimum probable mean temperature of the reservoir and Na/K temperature as a maximum one. The standart deviation of mean temperature of Na-K-Ca-Mg geothermometer is distinctly large. It is possible that concentrations of some cations in hot water could be somewhat changed with different degrees during hot water rising from reservoir to surface by different conduits, thus we would leave Na-K-Ca-Mg temperature out of consideration to estimate a reasonable mesn temperature for the reservoir.

According to conception of probablity

density triangular'[3)], the mean temperature of SiO_2 geothermometer would be considered as a minimum, that of Na/K geothermometer as amaximum, and that of Na-K-Ca geothezmometer as a most likely temperature of the reservoir, then the mean temperature of the reservoir could be given to be 204.9°C. By Fournier's esperience[(4)]: If the silica, Na/K, and Na-K-Ca geothermometers all give temperatures in excess of 150°C and Mg^{++} concentrations are relatively low, chance are good that a deep reservoir temperature will be as great or greater than that indicated by the geothermometers, the mean temperature of the reservoir would be over 250°C, from a conservative point of view, however, we would prefer former to later.

SOIL MERCURY SURVEY

In order to delineate range of the reservoir, soil mercury survey as an effictive technique as well as inference from surface manifestations can be used. At the end of 1981, soil samples for the survey were collected by irregular net because of thick vegetation, incised landform and bad accessibility, and the sample locations are shown in Fig.2. The method followed in this survey was to collect samples of soil from depths of approximately 20 cm and seal them in plastic *bags;* after air drying in the laboratory, the samples were ground gently with china mortar and were sieved to less than 80 mesh, and Hg concentration was determined in the Environmental Monitoring Centre of Beijing using a Rigaku mercury detector. Sensitivity of the determination reached 10^{-10} gram and the precision of analysis was within ±0.5ppb, when the sample for each feeding was 100 mg. The results of determination expressed in ppb were labelled by the sampling points in Fig.2.

There are 64 Hg concentrations in Fig.2, among which 4 samples have not been affected by the geothermal activity evidently, and their Hg concentrations are 10ppb, 11ppb, 11ppb, 12ppb respectively, and llppb in average with a root mean square of 0.7ppb. The average plusing twic root mean square were considered as back ground which is 12.5ppb.

Using a computer program of weighted means complementary data, we obtained a refular net data, from which we delineate anomalous area contoured at diffenent value intervals shown in Fig.3.

In order to estimating the effects of bed rocks to the Hg concentration is soil, Hg concentration in rocks with different alteration was determined that they were considerable low and their range was very narrow (2.3 ppb-7.5ppb), while the Hg concentrations in soil ranged from 10ppb-262ppb, and maximum was higher than minimum up to 26 times. It is too difficult to imagine that such difference is resulted from the nature of the bed rock, rather than hydrothermal activity underground. Fig.3 shows that four anomalous areas with a contrast of greater than 4 times, and the larggest area AD_1, about *0.5* km2, encloses 1, 3,4,5 four subareas and covers majar part of Dakongbeng Hydrothermal Area, Anomalous area AD_2 is about 0.1 km2, Its longer axis runs approximately parallel to the Nandinhe Fault. This could suggest that a proximate grade falt paralleled to the cardinal was hidden beneath AD_2. From previous section, we infered that springs in five subares were fed by a the same reservoir, the soil marcury surrey, however, shows that anomalous areas are separated into two parts, west and east, that, perhaps, might be short of permanent soil on the river bed for sampling and could offer little conduits for escaping of geothermal fluids.

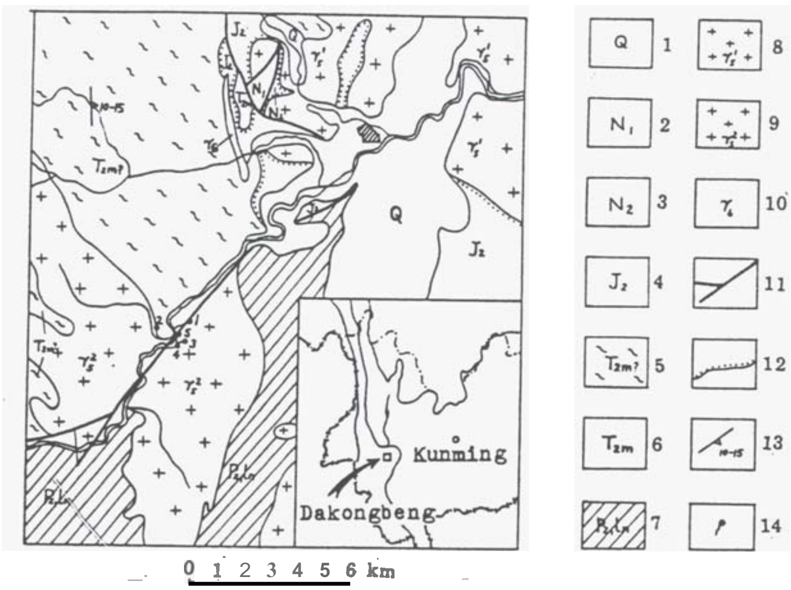
ROUGH ASSESSMENT OF HEAT CONTENT

According to avaidable data, we would like to assess the heat content *of* Dakongbeng Hydrothermal Areas using "volum method", (5)

The mean reservoir temperature is know as 205°C, base temperature is taken-from the mean annual surface temperature, about 20°C. The depth *of* reservoir is arbitrarily assumed to extent commonly to 3 km, and the top of the reservoir is generally assumed to have a average depth of 1 km. The area of the reservoir at least is *0.8* km2 from Hg anomalous area with a contrast of 4 times or 1.5 km2 assumed the AD_2 and AD_1 could be link, then volume of the reservoir is 1.6 km^3 or 3 km3. If the volumetric specific heat is assumed to be of 0.6 cal·cm^{-3}. The heat content of Dakongbeng Hydrothermal Area will be approximately 1.4x1018 J, and its total amount of electrical power is 11 MW. cent.

AEKNONLEDGMENTS

We thank gratofully Zhao Fengsan of Dspt. of Geology for analysing of hot water chemically, and Xu qian of the Environmental Monitoring Centre of Beijing for determination of soil mercury concentrations.



1. Quaternary
2. New Tertiary
3. Old Tertiary
4. Middle Jurassic red bed
5. Middle Triassic Manghuai Group? gneiss
6. Middle Triassic
7. Lower Palaeozoic Lancang qun, schist.
8. granite of Indo-China stage
9. granite of Yenshan stage
10. granite of Himalayan stage
11. fault
12. overlap
13. occurence of gneissositg
14. hydrothermal manifestation

Fig.1. Geological map of Dakongbeng Hydrothermal Area and its adjacept.

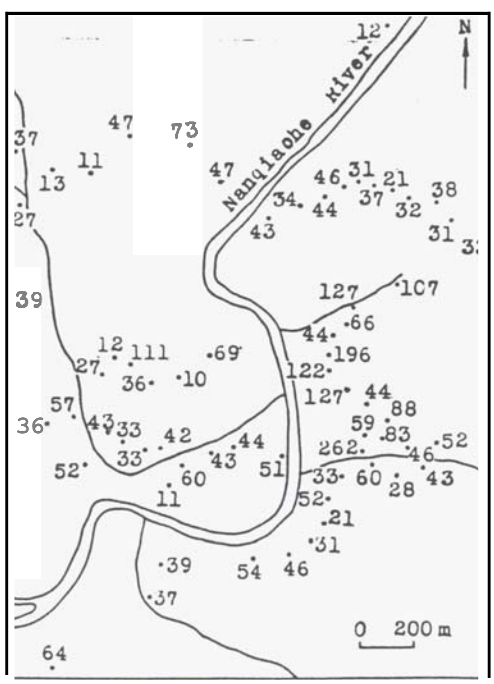


Fig.2. Distribution of soil samples and their Hg concentrations expressed in ppb.

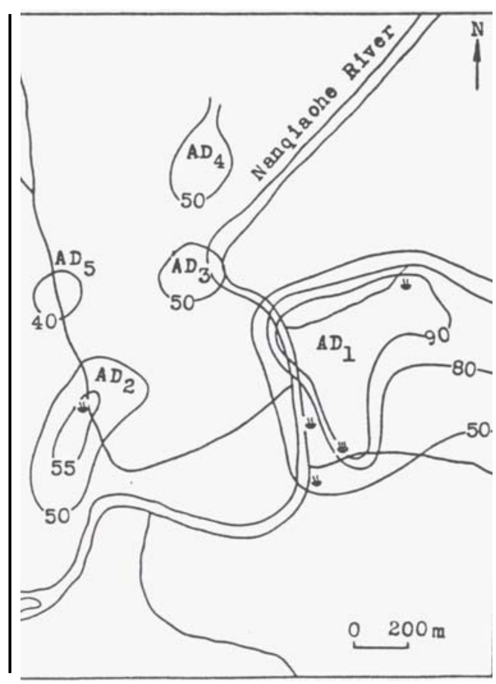


Fig.3. Anomalous areas of Hg concentration in soil on Dakongbeng Hydrothermal Area, contoured at different intervals.
hot spring
boiling spring

Table 1. Chemical analyses of hot waters, Dakongbeng Hydrothermal Area (in ppm)

	No 1 Dabang-Xhixi	No 2 Xuetang	No 3 Dakong-beng	No 4 Dakong-beng	No 5 Dakong-beng	No 6 Dakong-beng	No 7 Dakong-beng	No 8	No 9
	LC-4-1	LC-4-2	LC-4-3-1	LC-4-3-8	LC-4-3-13	LC-4-3-16	LC-4-3-20	LC-4-4	LC-4-5
temp. °C	89	67	73	91	96	85	88.5	68	67
pH(field)	7.9	7.5	7.5	8.0	8.5	8.0	8.0	7.2	7.5
pH(Lab.)	8.10	8.40	8.15	8.00	9.00	8.15	8.15	7.9	8.10
Na	169	118	175	170	177	178	175	199	205
K	20.4	4.68	23.6	20.7	23.4	21.0	21.7	17.0	17.1
Ca	2.50	0.65	1.05	2.21	0.12	6.05	3.61	3.51	2.20
Mg	0.81	0.10	0.25	0.92	0.11	0.25	0.51	0.00	0.00
Li	0.97	0.26	1.15	0.94	1.20	1.05	1.04	1.02	1.01
NH_4	2.70	0.58	0.701	2.18	0.38	1.03	1.03	1.61	0.38
CO_3	0.00	0.00	0.00	0.00	37.5	0.00	0.00	0.00	0.00
HCO_3	377	247	420	374	329	419	412	406	403
CO_2	8.55	0.00	6.41	11.7	0.00	6.41	8.12	19.2	10.7
SO_4	44.0	25.4	26.2	50.6	31.0	30.2	20.5	51.6	40.4
Cl	31.0	24.8	42.0	30.0	33.0	31.2	31.2	31.5	34.9
F	12.1	10.4	17.1	13.2	16.1	13.2	13.7	15.3	17.1
HBO_2	13.2	6.88	15.2	12.7	15.2	13.8	14.0	14.8	15.2
As	0.02	0.01	0.02	'-0.04	0.04	0.03	0.03	0.01	0.01
SiO_2	201	75.0	204	187	201	174	184	171	191
TDS*	0.695	0.390	0.727	0.689	0.701	0.685	0.681	0.727	0.745
SO_4/Cl	1.42	1.02	0.62	1.69	0.94	0.97	0.66	1.64	1.39
B/Cl	1.83	1.13	1.47	1.72	1.87	1.80	1.82	1.91	1.77
HCO_3/Cl	12.44	9.96	10.34	12.85	10.61	13.63	13.47	13.50	11.85
T_{SiO_2}	180.3	121.7	197.3	175	168	160.	174.3	169.5	176.8
$T_{Na/K}$	233.7	148.7	244.0	234.5	242.1	231.6	236.1	203	201.9
$T_{Na-K-Ca}$	211.5	156.1	228.6	213.5	252.5	203.2	209.9	190.9	194.5'
$T_{Na-K-Ca-Mg}$	186.5	152.1	215.6	148	250	200.2	186	190.9	194.5
Chemical type	HCO_3-Na	HCO_3-Na	HCO_3-Na	HCO_3-Na	HCO_3-CO_3-Na	HCO_3-Na	HCO_3-Na	HCO_3-Na	HCO_3-Na

*TDS express in g/l

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