Proc. 10th New Zealand Geothermal Workshop 1988

DISCUSSION OF HIGH HEAT FLOW AND GEOTHERMAL ACTIVITIES IN SOUTHERN TIBET

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ABSTRACT

This paper covers three parts. The first one deals with the heat generation of granitoids in Southern Tibet which varies with petrological characteristics. The terrestrial heat flow in Southern Tibet is discussed in the second part referring to anomalously high heat flows of 146 ± 17 mW/m^2 and 91 ± 5 mW/m^2 which have been observed at the bottom of two lakes (Yamzhog Lake and Puma Lake respectively). The observed high heat flow can be produced by thick granites with high heat generation capacity. In the third part the high heat flow and the distribution of geothermal systems are compared; their spatial variation suggests the existence of shallow crustal heat anomalies which, together with the high heat flow is probably the source for the geothermal systems within the Himalayan Geothermal Belt.

Granitoids of Southern Tibet and their heat generation capacity

Granitoids are widespread in Southern Tibet covering an area of about 10^6 km^2; they occur in three parallel belts: the Gandise belt in the north, the Lhagoi-Kangri belt in the centre and the Himalayan belt in the south (Fig. 1). Plutons within these belts all occur on the upthrust side of great thrust zones.

The Gandise granitoids, located on the upthrust side of the Yarlung Zangbo suture, are characterised by clustering of large batholiths with composite plutons. The main rock types include diorite, granodiorite and tonalite with subordinate granites. The large granitoids of the Gandise belt have an isotopic age of 70 to 120 Ma, subordinate granitoids have ages between 10 and 50 Ma (Tu Gangzhi et al., 1983).

The Lhagoi Kangri and the Himalayan belt granites occur over the upthrust side of the Main Central and the Main Boundary Thrust belts. The granitoids in these two belts are only associated with smaller sized and widely separated plutons with simpler petrography. The main rock types are gneissic two-mica monzonitic granite in the Lhagoi-Kangri belt and tourmaline muscovite granite in the Himalayan Belt; their isotopic ages lie between 30 to 50 Ma and 10 to 20 Ma respectively (Tu Gujangzhi et al., 1983).

As part of a petrological study of these granitoids, U and Th values of 172 samples were analysed by the Analytical Group of the Geochemical Institute at the Academica Sinica (Beijing) under the supervision of Tu Guangzhi; potassium data were obtained from K_2O% values (Tu Guangzhi et al., 1983). All samples were collected during a scientific expedition to the Qinghai-Xizang (Tibet) Plateau. Using the U, Th and K values, the heat generation capacity of the various granitoids were computed using the method of Roy et al., (1968). The results are shown in Table 1.

High heat flow in Southern Tibet.

The terrestrial heat flow of Southern Tibet has been estimated in 1978 by using estimates of the heat generation capacity of crustal rocks for assumed crustal sections. The thickness of the crust was estimated from interpretations of gravity anomalies (Tong Wei et al., 1978; Liao Zhijie, 1979). The estimates are listed in Table 2.

Since then heat flow measurements have been made at the bottom of the two large freshwater lakes south of the Yarlung Zangbo River. The northern lake, Yamzhog Lake (29°N; 90° 40"E), lies at an elevation of about 4400m south of a prominent mountain range; the southern lake, Puma Lake (28° 35'N; 90° 30*E), lies at 5500m at the northern foot of the Himalayas. The observed heat flow is 146± 17 and 91± 5 mW/m^2 respectively.

Since both lakes are only about 25 km apart, the question arises as to what causes the significant changes in heat flow ? Assuming that near-surface effects can be neglected, Francheteau et al., (1984) considered three explanations: changes in crustal heat production, anomalous crustal heat sources (magma), and changes in anomalous mantle heat flow. They believed that the most likely explanation is the assumption of an anomalous crustal heat source beneath the northern lake which terminates between the two lakes. This heat source was thought to be an intrusive body within the depth range of 10 to 25 km.

We believe that an anomalously thick crust and a thick granitic layer is the best explanation for the anomalous high heat flow in Southern Tibet. Since 1978 seismic data defining the crustal thickness beneath Tibet have become available (Teng Jiwen, 1981). These data are from the 450 km long seismic profile between Damxung and Yadong measured in 1976, which runs about perpendicular to the strike of the tectonic structural features in Southern Tibet. According to Teng Yiwen, the crust beneath Tibet can be approximated by five layers: Layer 1 at the top are sedimentary rocks (average velocity of 4.99 km/s) which are about 3-4 km thick to the south of the suture. The second layer could be granitic rocks (velocity of 5.99 km/s) about 5 to 18 km thick; the third layer might also be granitic (velocity = 6.22 km/s) (the velocity increase being due to pressure effects), its thickness is about 6 to 10 km. A velocity inversion occurs in the fourth layer (5.64 km/s), which is about 11 to 13 km thick and could represent gneissic rocks which occur at depths between 29 and 45 km south of the suture. The fifth (bottom) layer could constitute a basaltic layer (7.24 km/s velocity). The total thickness of the crust is about 70 to 73 km north of the Yarlung Zangbo whereas it decreases in thickness to the south (Yadong) from 68 to 45 km; the Himalayas lie therefore on top of a crust with abrupt changes in crustal thickness.

Using the seismic structure and the observed heat generation capacities listed in Table 1, the likely heat flow of the crustal rocks can be re-assessed (see Table 3). For this it is assumed that the heat generation capacity of the thick sedimentary rocks and of the deeper inferred gneissic and basaltic layer is about 1.33, 1.24, and 0.48 fiW/m^3 respectively (Kappelmeyer et al., 1974), and that the heat generation of the two inferred granitic layers are the same and are given by the mean of the data listed in Table 1 (i.e. about 2.25 |iW/m^3). The approximate heat flow is then about 116 mW/m^2 for a 68 km thick crustal section (near Yamzhog Lake, for example) and about 79 mW/m^2 for a 45 km thick section beneath the high Himalayas. The difference of about 30mW/m^2 in the Yamzhog Lake region could be interpreted partly as upper mantle heat flow and partly as the effect of cooling bodies in the upper granitic layer.

The high heat flow in Southern Tibet and associated geothermal systems.

The belt with an anomalously thick granitic crustal layer north of the Himalayas belt and the associated anomalously thick crust correlates well with a belt of geothermal systems lying to both sides of the Yarlung Zangbo River. The various manifestations of this geothermal belt, the Himalayan geothermal belt, have been already described (Tong Wei et al., 1981), see Fig. 2. The geothermal belt extends for about 2000 km along the Yarlung Zangbo suture; it runs from the northern slopes of the Himalayas to the northern slopes of the Gandise and Nyainqentanglha Ranges. In this belt there are at least 11 geothermal fields exhibiting recent hydrothermal eruption features, three are associated with geyser activity, and many others with hot springs.

Although high crustal temperatures are indicated for the crust in Southern Tibet, which might be as high as 250"C at 5 km depth, the highly anomalous temperature caused by the anomalously high heat flow might not be the only source for the heat discharged by the numerous systems in the Himalayan geothermal field. Although there are no active volcanoes in Southern Tibet, and volcanic heat sources are therefore unlikely, it is possible that regional heat sources still occur within the second granitic layer.

Most high temperature prospects in Tibet are associated with graben structures and normal faults trending often approximately north-south caused by an east-west extension of Tibet at present. The Yangbajain field is probably associated with such structural features; it is the first geothermal prospect which has been exploited for electrical power production (13 MWe installed plant capacity). Maximum temperatures of about 200"C have been found recently in a deep well at Yangbajain and in the nearby Yangyingxian prospect.

The geothermal resources of Tibet have been assessed by Zhang Zhifei and Zhang Mingtao (1985) who identified a total of 345 geothermal prospects of which about 110 are intermediate to high temperature systems (inferred fluid temperature > 150"C in the upper reservoir) and at least 76 prospects are intermediate temperature systems (fluid temperatures between 90 and 150"C). The accessible energy resources are about 330 x 10^{18}J and 75 x 10^{18}J respectively.

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Table 1

ages	rock types	samples	U (ppm)	Th (ppm)	K (%)	M-W/m^3
K_2	granodiorite, diorite	34	2.6	15.9	1.18	1.92
K_2	macromesilic biotite granite	15	4.0	30.9	1.89	3.41
K_2	biotite granite	33	3.3	25.0	1.81	2.81
K_2	two-mica granite	37	2.8	12.0	1.74	1.54
E	two-mica granite	16	3.6	9.0	1.58	1.72
N	tourmaline muscovite granite	22	6.3	13.6	1.85	2.78

Table 2

Location	Layer of crust	Thickness (km)	Average rate of heat production (HW/m3)	Heat flow for every layer (mW/m2)	Heat Flow (mW/m^2)
Les Himalyas	Granite 1	16	2.91	46.57	
	Granite 2	10	1.24	12.4	64.7
	Basalt	12	0.48	5.75	
Mt Qomo Langa	Granite 1	20	2.91	58.2	
	Granite 2	12	1.24	14.9	80.8
	Basalt	16	0.48	7.68	
Yarlung Zangbo	Granite 1	32	2.91	93.1	
	Granite 2	15	1.24	18.6	122.3
	Basalt	22	0.48	10.6	
Gandise	Granite 1	24	2.91	69.84	
	Granite 2	16	1.24	19.84	101.2
	Basalt	24	0.48		

Table 3

Layer	Yamzhog Lake thickness (km)	Yamzhog Lake heat flow (mW/m^2)	High Himalayas thickness (km)	High Himalayas heat flow (mW/m2)
Sediment	4	5.3	3	4.0
Granite 1	18	92.5	5	57.4
Granite 2	23		20.5	
Gneiss	10	12.4	6	7.4
Basalt	13	6.2	11	5.3
Total	68	116.1	45.5	74.1

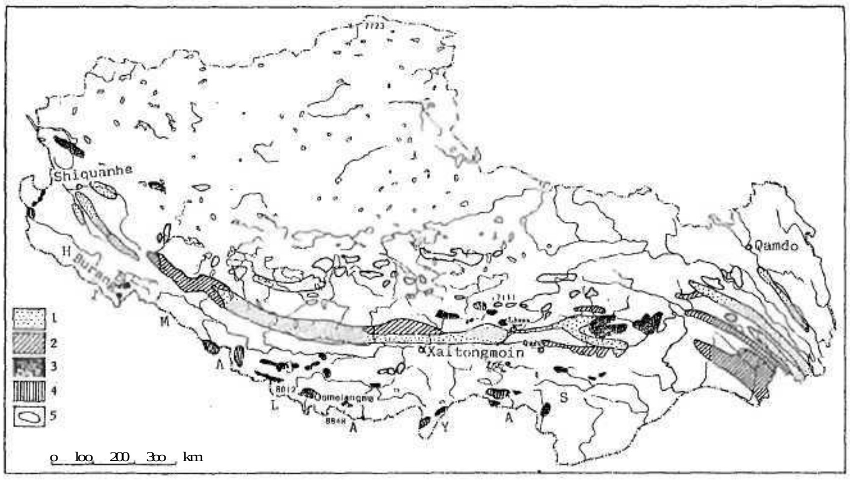
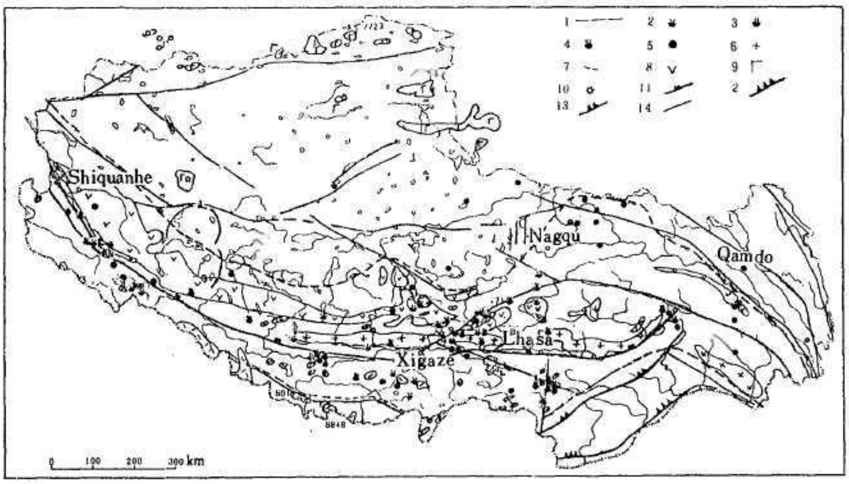


Fig. 1 The schematic map showing 1:hn distribution of intermedial >•-.icid magmatic rocks i.n l.hfi southern parl: o!' *Xi* znng

1.. Gandisws bell.: D.lori te granod ior i. l.n and porrjhjritic biotitA granite;
2. Gandla* bel tr. [iiot.ite rrun i- nr <l ino-ilni gnnitin;
3. Lhagoi. Krvngri. bolt: Gi." i -.••..,•- **Im-alw** gTUlltr:;
A. Himalayan bnlt: TounnaU nt-imisirovt. tc Rranite and two-mica granite;
b. Af;i=-iindi vi.dcMl grani.tr;.

(after Tu Guangzhi et al,1983)



Fijj. 2 The geothermal geology sketch map of Xizang.

.1.. Boundary of Himalayan geotlierrnal belt;
2. Hydrothernial explosion;
3. High teinperatm•<• geyser;
4. Boili ng spring;
5. Hot spring (>70 C);
6. \.***atm*** Yanshan and early Himalayan granite;
7. Himalayan granite;
8. Kaeane-Oligocene volcanic rocky;
9. Hi locene-Holocent! volcanos;
10. Volcanic cones;
11.. Stittire zone;
12. MBT (Main Boundary Thrust);
13. MCT (Main Central Thrust);
]A. KaulU.