GEOTHERMAL FIELD AND THERMAL STATE OF THE EARTHS CRUST IN YUNNAN, CHINA

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ABSTRACT Based on the heat flow, thermal conductivity and heat production data obtained in Yunnan Province in the southwest of China, a heat flow map, and a geotemperature map at 500 m depth under the earth's surface are presented. The thermal state pattern of the earth's crust in Yunnan is outlined.

Key words. Yunnan, temperature logs. crustal temperature, heat flow, thermal conductivity, heat production

1. INTRODUCTION

Yunnan Province is located in the southwest part of China. It possesses a complex geological history and is a part of famous Tethys-Himalayan orogeny belt(Chen et al., 1987)(fig.1). Based on a number of borehole geotemperature logs combined with thermal conductivity and radiogenic heat production determination on rock-samples, the basic geothermal characteristics in Yunnan Province are discussed.

Figure 1 A simplified tectonic map of Central-South Asia

Explanation: I-The Precambrian continental massif of Pal-Asia, 2-The Pal-Asian Block in the geosynclinal fold belt, 3-The Precambrian continental massif of Gondwana land; 4-The Gondwana land Block in the geosynclinal fold belt; 5-Foreland molasses of the Himalaya stage. 6-Geosynclinal fold belt: 7-Tectonic boundary of the first order, 8-Tectonic boundary of the suborder; 9-Major shear I-Central Asia-Mongolia Tectonic Region: I_1-Kyzylkum Block; I_2-Karakum Block II-Cathaysia Tectonic Region: II_1-Sino-Korean Paraplatform; II_2-Tarim Platform; II_3-Yangtze Paraplatform; II_4-Songpan-Garze fold System; II_5-Qinling-Qilian-Kunlun Fold System; II_6-Qaidam Block; 11,-South China Fold System. III-Tanggula-Saiijiang Tectonic Belt: III_1-Changtang Block; III_2-Indo-China Block. IV-Turkey-Central Iran-Gangdise Tectonic Belt: IV_1-Baoshan Block, IV_2-Kerman Block V-Zagros-Himalaya Tectonic Belt: V_1-Zagros Fold Belt; V_2-Sulaiman Fold Belt; V_3-Himalaya Fold Belt; V_4-Arakan Fold Belt. VI-India-Arabia Tectonic Region: VI,-India-Arabia Platform; VI,-India Platform. (This figure is revised from Chen et al., 1987, figure 1 which is quoted from Tectonic Map of Asia of Li et al., 1982)

2. HEATFLOW

2.1 Temperature Logging and Thermal Conductivity

In **Yunnan,** temperature logging of 29 boreholes has been conducted. Temperature logging interval varies with the change of rock type and demand, generally logging is conducted from top to bottom at an interval of 10 m using semiconductor thermistor instrument manufactured by Institute of Geology, Academia Sinica.

The thermal conductivities of 99 rock samples from 25 boreholes were measured(fig.2). The thermal conductivity determinations were carried out under laboratory conditions. The measuring precision is from ± 10% to ±5%(Shen and Lu, 1979, Yang and Zhang, 1982)

Figure 2 Thermal conductivity of rock samples in Yunnan

Rock samples are cut from wellcores, polished surface is perpendicular to well core. On the polished surface, five measured points, one point is placed on the centre of the surface, the other four points on the four angles of square. The values of five measured points of the sample are statistically analyzed by the thermal conductivity meter as the representative value

2.2 Heat Flow and Basic Geotemperature Pattern

In this paper. heat flow **is** calculated by using the interval method, and **is** the product of measured thermal conductivity(K) and temperature gradient(G) by the following formula, $q=-KG$ To illustrate the method of heat flow calculation, the temperature log of borehole ZK7(fig *3)* is taken as an example The temperature log of borehole ZK7 is closely related with lithologic variation **A** total of 16 rock samples were collected from ZK7 In terms of lithologic columnar section, the heat flow values of 4 main lithologic depth ranges are calculated The first range, from 70 m depth down to 220 m, is mainly sandstone, by linear regression, $T=17\ 88+23\ 37Z$ $T_0=17\ 88$ ^0C, $G_1=23\ 37$ $^0C/km$, regression coefficient $r=0\ 9967$ The weighted average K of 3 rock samples is 3 9 W/(m ^0C), which **is** calculated in terms of 1/5 radio between mudstone/sandstone Therefore, calculated heat flow value $q_1=91 mW/m^2$ By the same method, the heat flow values of the second, the third, and the fourth ranges are $116 mW/m^2$, $109 mW/m^2$ and $93.1 mW/m^2$, respectively. The average value of heat flow values of 4 ranges is taken as the representative one of the borehole.

Figure **3** Temperature log of Borehole ZK7 at Kunming

In this way, 29 heat flow values are calculated as shown in table 1 To get the detail geothermal picture, heat flow data from other researchers(Wu et al., 1988; Wang et al., 1990) are also taken into consideration. These data are recalculated by using the thermal conductivity of this paper to make an identical evaluation, based on rock types, among different researchers.

The heat flow pattern is shown in figure 4 Geotemperature(figs *5)* of Yunnan at 500 m depth beneath earth's surface are outlined based on temperature logging and heat flow data (Table 1).

Figure **4** Heat flow map in Yunnan Legend 1- >$85mW/m^2$; 2- $75-85mW/m^2$; **3-** $65-75mW/m^2$; 4- $55-65mW/m^2$; 5- <$55mW/m^2$

Figure 5 Geotemperature diagram of Yunnan at 500 m depth beneath Earths surface(^0C)

3 ROCK RADIOGENIC HEAT PRODUCTION

In Yunnan, the contents of radioactive elements(U, Th, **K**) of 56 rock-samples were analyzed using FH451 type 1024 Multichannel spectroscopy in the Geothermal Lab. of Institute of Geology, Academia Sinica. Rock radiogenic heat production was calculated by the formula from Birch(1954)

$$A=0.317\rho(0.73U+0.2Th+0.27K) \quad (1)$$

where, A is rock radiogenic heat production, $10^{-13} cal/(cm^3 s)$, i.e. HGU(1 HGU=0.41868 $\mu W/m^3$); ρ density of rock, g/cm^3; The units

of U and Th are ppm; K is expressed by content per cent.
Since core is limited, the data of rock radiogenic heat production is incorporated in terms of the strata sequence as the basis for calculating temperatures in deep earths crust(table 2). The average thermal conductivities corresponding to each layer are also listed in table 2.

4. THERMAL REGIME OF THE EARTH'S CRUST

Temperatures in deep earth's crust are calculated by one-dimensional conduction formula as follows

$$T_z = T_0 + \frac{qH}{K} - \frac{AH^2}{2K} \qquad (2)$$

where, T_z is the temperature at depth Z; T_0 and q are the temperature and heat flow values at the surface of each calculated interval(at earth's surface, T_0 is supposed to be equal to the temperature at the constant temperature zone), H is the thickness of each interval. K=rock thermal conductivity. A=rock radiogenic production. According to the data in table 2 and geological models(Xu et al., 1993), the thermal structure of deep crust and partition of surface heat flow are shown in figure 6.
Fig. 6 Geotemperatures(^{0}C) at given depth in different subareas
The variation of Moho surface temperature is large. Some of this is probably the artifact of extending shallow crustal heat flow anomalies to predict Moho temperatures using a one-D conduction model(Jim Combs' reviewed comments). The temperatures of Moho surface at Tengchong, Lijiang and Kunming reach to 939 to 1050 ^{0}C, and can be compared to the temperature (860-1 115 "C) of Moho surface in Cenozoic tectonic active area of Basin and Range province of western United States. The Moho temperature in southeastern Yunnan is 630 ^{0}C, which shows that southeastern Yunnan is a stable area just like the stable area of eastern United States with 660 ^{0}C Moho surface temperature. The Moho temperatures at other areas in Yunnan are 700 "C or so, which shows that these parts lie between active tectonic and stable regimes, such as, Yongping Huaping regimes with Moho temperature reaching to 800 ^{0}C can be compared with that of downfaulted basin of Huabei platform which is active during Cenozoic Era, and generally speaking, can be compared with the "activation of stable crustal block, which. in studied area, is reflected by the activation of the blocks between overthrust sheer zones due to the influence of these active overthrusts.

5. RESULTS

1. Tengchong Cenozoic volcanic area with 94 mW/m^2 average heat flow is the southern extension of Tethys-Himalayan tectonic-geothermal belt of continent-continent collision type and characterized by high heat flow, high ratio of mantle to surface heat flow and high Moho-temperature as well as strong seismic and hydrothermal activity. 2. In southeastern part of Yunnan, the heat flow values range from 37 to 70 mW/m^2, half of them are under 50 mW/m^2, which indicates that this area is geologically stable and that folding, faulting and magmatic activities are not well-developed. 3. Moderate geotemperature between the two types as mentioned above is met in Three-Rivers(also known as Sanjiang) part among Nujiang, Jinshajiang and Honghe. The average heat flow value of 16 measurements is 59 mW/m^2. The heat flow values in Mesozoic red-basins east of Lancangjiang are slightly higher than those in Palaeozoic terrains west of it. 4. Temperature in S-N tectonic zone of the southern extension of Panxi paleo-rift zone of Hercynian-Indosinian age. also shows S-N distributive geotemperature pattern. The average heat flow value in the rift around Lijiang-Eryuan is 79 mW/m^2, and in Kunming 85 mW/m^2 Between the two areas is red basins with undeveloped faulting in which heat flow values are relatively lower

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