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THE ANALYSIS OF GEOTHERMAL FIELD CHARACTERISTICS IN SICHUAN BASIN OF CHINA

ZHOU Xixiang, WANG Xuben, YANG Shaoguo, YU Huijin, and ZENG Yi
Chengdu University of Technology, Sichuan, Chengdu, 610059, People's Republic of China

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ABSTRACT

Basic on the selecting thermal logs of 128 wells from 368 measuring temperature wells of oil field, we have established the geothermal distribution in Sichuan Basin of China. For those unsteady-state temperature log data, we have given a statistical analysis correcting method. With the corrected temperature data we have established the geothermal distribution at depth from 1000 m to 6000 m. Viewing these geothermal distribution, we find the following geothermal field characteristics in this Basin. The geo-temperature distributions in the shallow crust and the average geothermal gradient of sedimentary cover in Sichuan Basin show that the geo-temperature distribution in sediments are essentially controlled by the form and undulation of the upper Triassic and the pre-Sinian crystalline basement surface. Higher geotemperatures are located in the areas of elevated basement, such as the middle uplift and the southwestern uplift, whereas lower temperatures are located in the areas of depressed basement, such as the northwestern sag or the eastern high folded belt. Using calculating and estimating method according to data, we have obtained the terrestrial heat-flow in the Basin. The values range from 35 to 80 mW/m^2, with a mean value of 62.44mW/m^2.

1. INTRODUCTION

Sichuan basin is located at the southwestern of China. For the needs of oil and gas exploration there are about 400 systematically temperature logging wells and more than 1500 point temperature logging data including bottom hole temperature (BHT) and oil layer steady-state temperature (OLST) and oil layer unsteady-state temperature (OLUT) distributing in the Basin. Among them, the deepest well is well Guanjijing (7020 m), while there are 9 wells for their depth at about 5000 – 7000 m and 20 wells at about 4000 – 5000 m. The continuous temperature logs were normally measured at depth regional of 1000 m – 4000 m. Basic on the selecting thermal logs of 128 wells from 368 measuring temperature wells of oil field, we have established the geothermal distribution in Sichuan Basin of China. There 72 wells are high quality for a long period of well shut down, including temperature gradient measurement of 24 wells and 48 measured at early stage of oil production. The other 56 wells are temperature data of comprehensive logs. The terrestrial heat-flow values ranges from 35 to 80 mW/m^2, with a mean value of 62.44mW/m^2.

2. CORRECTION OF TEMPERATURE LOG DATA

For that unknown well shutdown time, we have referred a new method to correct the temperature data as following.

2.1 Correction Factor

By using bottom hole temperature (BHT) and oil layer steady-state temperature (OLST), and oil layer unsteady-state temperature (OLUT), we can get one correcting factor.

$$G_c = BHT_{OLST} - BHT_{OLUT} \; . \qquad (1)$$

Suppose that G_c satisfy $G_c = A_0 + A_1 d + A_2 d^2 + A_3 d^3$, where *d* is the corresponding depth, we can obtain A_0, A_1, A_2, A_3 from the statistical analysis at study area.

2.2 Calculating the Correcting Value of BHT (BHT_c)

We use the following formula to calculate the BHT_c

$$BHT_c = BHT + G_c d \qquad (2)$$

d is the corresponding bottom depth of the well.

2.3 Calculating Thermal Gradient

For

$$BHT_c = T_0 + \sum_{j=1}^{N} H_j G_j \qquad (3)$$

H_j is the stratum thickness, G_j is temperature gradient, T_0 is temperature of the isothermal belt, suggesting that there are temperature logs M and strata N, we have the system of equation:

$$\sum_{i=1}^{M} (BHT_i - T_0) = \sum_{i=1}^{M} \sum_{j=1}^{N} H_{ij} G_{ij} \qquad (4)$$

$$\vec{B} = \vec{H}_{ij} \vec{G} \qquad (5)$$

H**ij =H(i,j)* represent the depth of well *i* and stratum *j*; $\boldsymbol{G}=(G_1,G_2,...G_N)^T$; $B = [BHT_i - T_0]^T$. We can obtain the gradient values ***G from the resolution of the system equation and then could calculate the temperatures at any depth.

2.4 Geothermal Distribution

With the corrected temperature data and steady-state systematically temperature logging data we have established the average geothermal gradient of the cover layer and then the geothermal distribution at depth from 1000 m to 6000 m. Viewing these geothermal distribution, we find the following geothermal field characteristics in this Basin. The geo-temperature distributions in the shallow crust and the average geothermal gradient of sedimentary cover in Sichuan Basin show that the geo-temperature distribution in sediments are essentially controlled by the form and undulation of the upper Triassic and the pre-Sinian crystalline basement surface. Higher geotemperatures are located in the areas of elevated basement, such as the middle uplift and the southwestern uplift, whereas lower temperatures are located in the areas of depressed basement, such as the northwestern sag or the eastern high folded belt.

3. TERRESTRIAL HEAT FLOW

3.1 Stratum Rock Conductivity k

$$k = D(\frac{d_1}{k_1} + \frac{d_2}{k_2} + ... + \frac{d_n}{k_n}) \qquad (6)$$
$$D = d_1 + d_2 + ... + d_n$$

$k_1, k_2 ... k_n; d_1, d_2, ... d_n$ are the mean thermal conductivity and the accumulated thickness for each lithologic respectively. There are two high *K* strata in the Basin. One is the Th - Tc and the other is the Z.

3.2 Calculating and Estimating Heat Flow

- Calculating heat flow

One dimension steady state:

$$q = kG \qquad (7)$$

- Estimating local area heat flow by using the least square procedure.

$$T(z) = T_0 + q\int_{z_0}^{z} \frac{dz}{k(z)} \qquad (8)$$

If k is constant in each strata so

$$T(z) = T_0 + q(\frac{H_1}{k_1} + \frac{H_2}{k_2} + ... + \frac{H_n}{k_n}) \qquad (9)$$

and if the number of measured data is m so there are

$$T_i(z) = T_0 + q\sum_{j=1}^{n} \frac{H(i,j)}{k_j} \qquad (10)$$

For i=1,2.... m; j=1,2,...n.

- We can obtain the heat flow *q* according to the least square procedure:

$$\min S = \min \sum_{i=1}^{m} [T_i - (T_0 + q\sum_{j=1}^{n} \frac{H(i,j)}{kj})]^2 \qquad (11)$$

3.3 The Characteristics of Heat Flow in Sichuan Basin

The terrestrial heat-flow values ranges from 35 to 80 mW/m^2, with a mean value of $62.44 mW/m^2$. Relationship between heat flow and the structure has the same characteristics as the geo-temperature at spatial distribution.

CONCLUSION

The geothermal distributions in the shallow crust and the average geothermal gradient of sedimentary cover in Sichuan Basin show that the geothermal distribution in sediments are essentially controlled by the form and undulation of the upper Triassic and the pre-Sinian crystalline basement surface. Higher geothermal point are located in the areas of elevated basement, such as the middle uplift and the southwestern uplift, whereas lower temperatures are located in the areas of depressed basement, such as the northwestern sag or the eastern high folded belt. This distribution indicates that the terrestrial heat flow is redistributed during flow from deep to shallow part of the earth.

By means of calculating or estimating about 100 terrestrial heat flow values distributing in the Basin we know that the Basin is a stable sub-tectonic unit. The terrestrial heat-flow values ranges from 35 to 80 mW/m^2, with a mean value of $62.44 mW/m^2$, which has the same characteristics as the geo-temperature at spatial distribution.

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Table 1 Stratigraphic heat conductivity, k, in Sichuan Basin

Stratigraphic unit	Major lithologicss	k (W/m°K)	Num. of samples
Cretaceous (K)	Sandstone, mudstone	2.03	26
Group Shaximiao of Jurassic (Jc)	Sandstone, mudstone	2.38	55
Group Zhiliujing of Jurassic (Jt)	Sandstone, sandy mudstone	2.09	54
Group Xujiahe of Triassic (Th)	Sandstone, limestone, mudstone, dolomite	2.60	42
Group Recoubuo of Triassic (Tr)	Limestone, dolomite	3.53	26
Group Jialingjing of Triassic (Tc)	Limestone, dolomite	3.22	33
Group Feixianguan of Triassic (Tf)	Limestone, dolomite, mudstone	2.74	42
Permian (P)	Limestone, dolomite, mudstone	2.76	43
Carboniferous (C)	Limestone, shale	2.67	11
Silurian (S)	Limestone, mudstone	2.22	6
Ordovician (O)	Limestone, shale, dolomite	2.10	6
Cambrian(∈)	Limestone, dolomite	3.07	5
Sinian (Z)	Dolomite	3.34	2
M.Proterozoic (Pt)	Gneiss, migmatite, schist	4.0	6
Upper-crust		2.9	26*
Lower-crust		2.8	107*

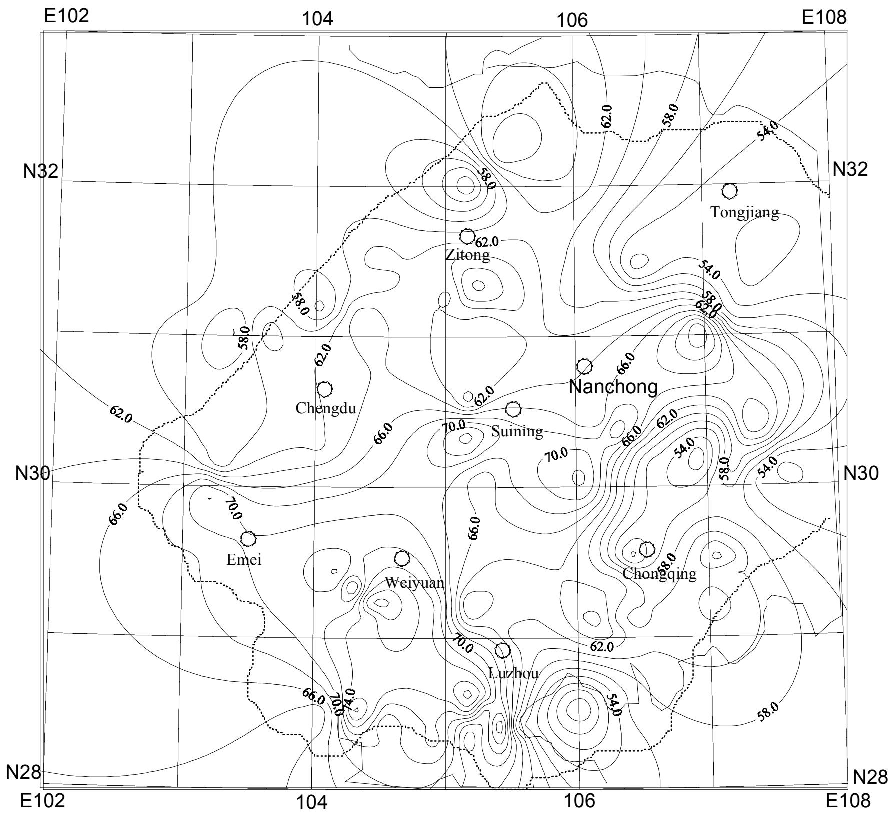

Fig 1 Isothermal map at depth 2000m in Sichuan Basin of China

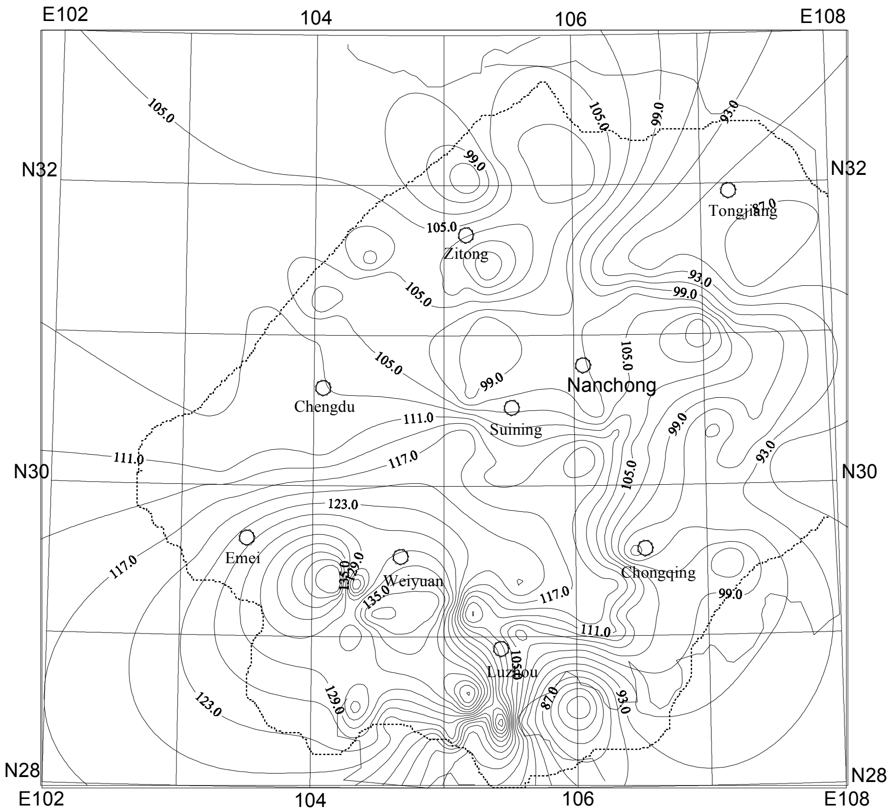

Fig 2 Isothermal map at 4000m in Sichuan Basin of China

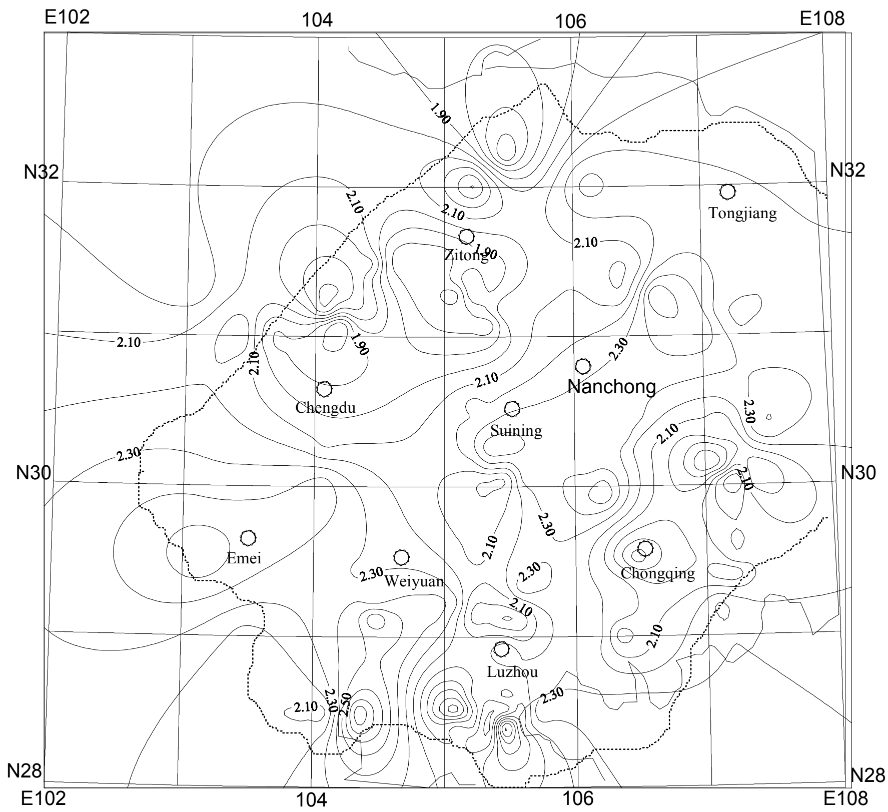

Fig 3 Geothermal gradient of sedimental layer of Sichuan Basin

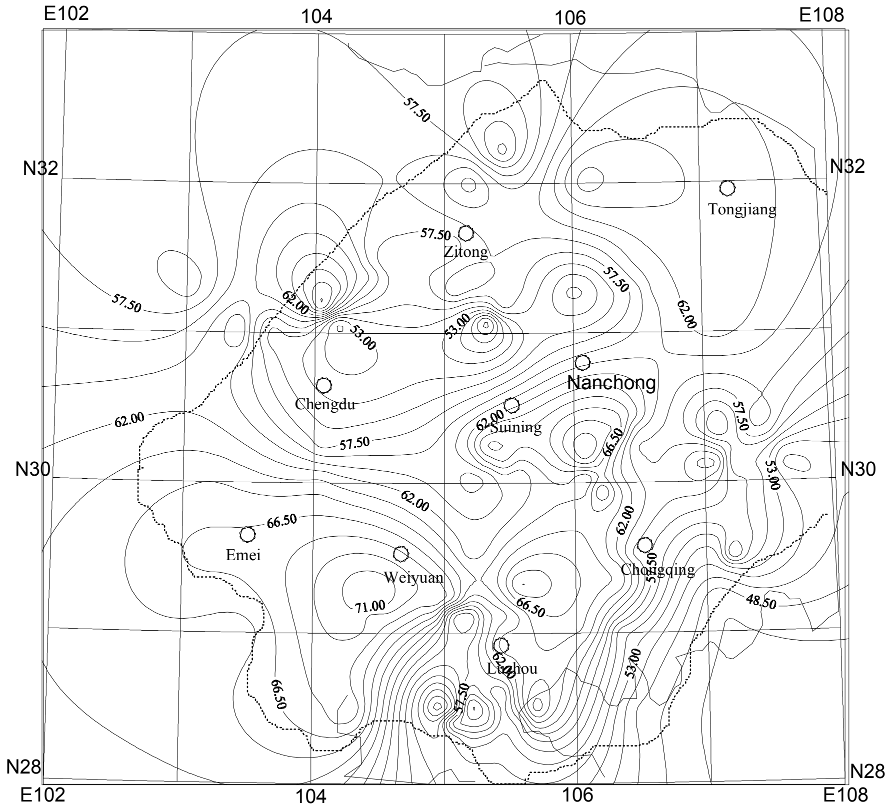

Fig. 4 Heat flow distribution in Sichuan Basin