# Geothermics and Digital Earth

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**ABSTRACT** Geothermics is of significant importance for digital Earth. Based on 862 heat flow data and data base, a new version of heat flow map for continental area of China has been compiled. Furthermore, geothermics is closely correlated to resources and environmental problems worldwide and especially in China. Finally, the relationship between geothermics and the digital Earth is discussed in the paper.
**KEY WORDS** Geothermics; Digital Earth; Geothermal Resources; Environment; China.

Geothermics is of significant importance for digital Earth because:
1) As one of the basic geophysical fields, such as gravity, geomagnetic, geoelectric, seismic, geothermal field deals with energy balance of the Earth; 2) geothermics relates to both the resources and environmental problems of the World, of which the human beings is seriously concerned about; and 3) a great number of geothermal data exists nowadays all over the World. In China, geothermal studies started in early 1970's and numerous geothermal data were accumulated during the past two decades. It must be noted that geothermal studies in China have been carried out along two lines: 1) theoretically, it deals with geotemperature and heat flow pattern of a region; thermal regime and structure of the Earth's crust and lithosphere; thermal state and history of the Earth; 2) practically, it investigates the distribution and occurrence of geothermal resources; the temperature condition (both at present and in the past) for oil-gas generation and accumulation; temperature distribution at depth in mining areas and its prediction; geothermal systems in which water-rock interaction exists and ore deposits formed. Finally, geothermics may also serve as a useful tool in global change research because by using geotemperature data, the climate change history can be traced back to the past few centuries, which may extend the meteoric record for the mankind (Wang et al, 1996).

## 1. Terrestrial Heat Flow Data and Data Base

In modern concept of earth sciences, terrestrial heat flow (or simply, heat flow) data have been recognized as an important parameter for understanding the thermal state and regime of the Earth's interior at depth and the boundary condition at the Earth's surface. Furthermore, the net outward flow of heat across the Earth's surface is a fundamental term in energy balance of the processes within the Earth. Consequently, heat flow data contain a number of valuable informations about processes associated with the generation, transport and storage of the heat within it. It is why, therefore, more and more attention has been paid on this problem from different communities including digital Earth outside geosciences.

Worldwide, heat flow measurements started in 1939 and by the end of 1990, altogether 20201 heat flow data were reported (Pollack et al., 1993). The distribution of these heat flow data is stated in Fig.1. In China, systematical studies on heat flow begun much later. The first portion (25) of heat flow data were published by Geothermal Research Group, Institute of Geology, Chinese Academy of Sciences in 1979. At present, altogether 862 heat flow data have been accumulated in continental area of China. According to the data quality, all these data were grouped into 4 categories A, B, C and D. Data of category A&B are considered to be the "best" and "good" while data in category C&D, "fair" and/or with great uncertainties. Among 862 heat flow data, 46.2% and 34.1% have been assigned to category A and B respectively while 15.2% and 4.5%, C and D correspondingly (Wang and Hu etal., 1999).

To facilitate the data acquisition, storage and data processing, heat flow data base for continental area of China has been set up four years ago (Xiong et al., 1995) the file of which is composed of the following 12 items:
1)Borehole name in which heat flow measurements have been attempted;
2)Geographical location of the borehole;
3)Longitude & latitude of the borehole;
4)Elevation of the hole head;
5)Borehole depth;
6)Temperature logging interval;
7)Geothermal gradients of different interval;
8)Number of rock samples recovered in the borehole;
9)Thermal conductivity of the rock samples recovered;

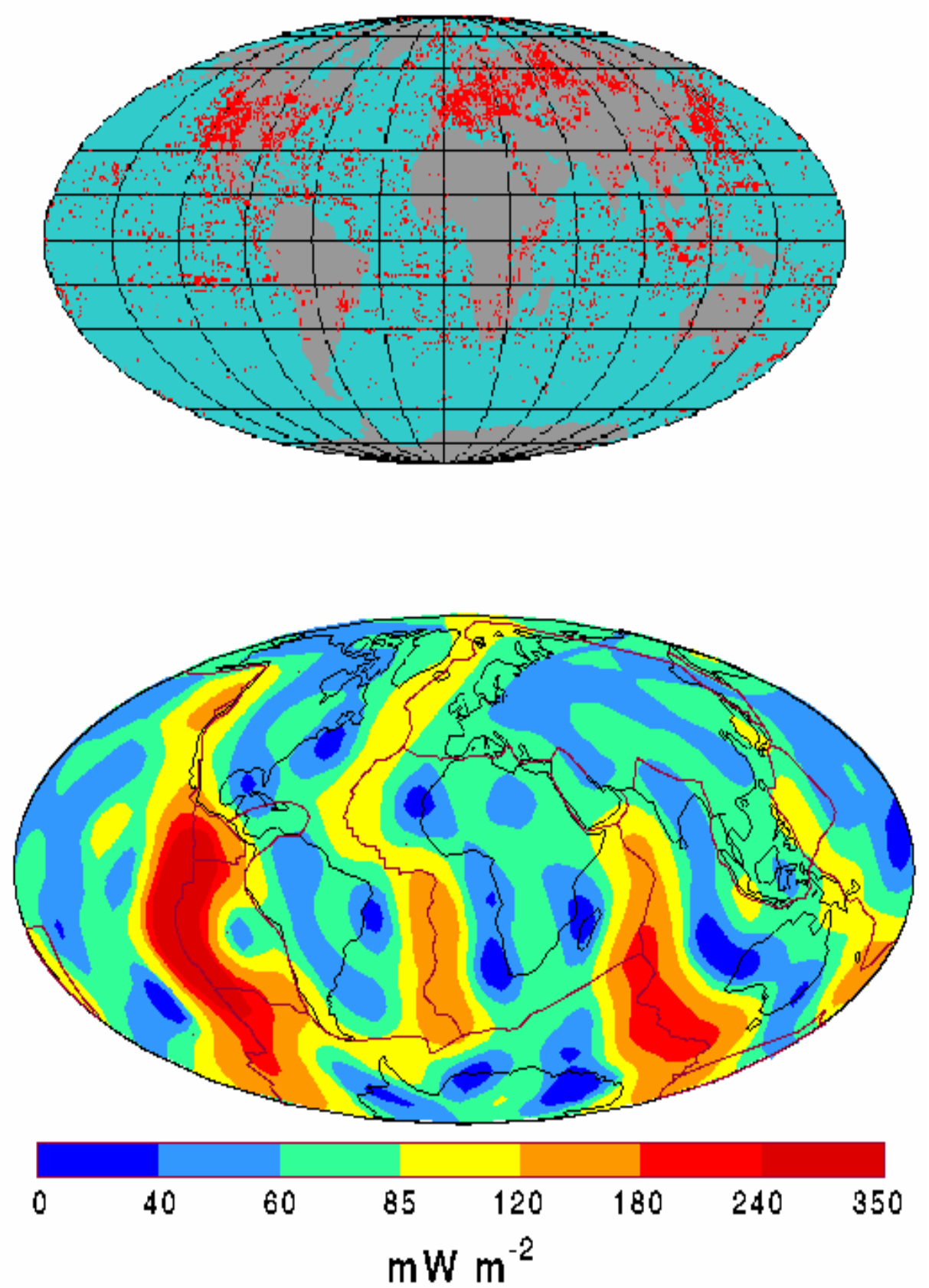


Fig. 1 Geographic distribution of measurement sites (up); Degree 12 spherical harmonic representation of global heat flow (down) (After Pollack et al., 1993)

10)Calculated heat flow value;
11)Corrections applied for the heat flow value;
12)Data quality assessment.

In addition, heat flow database contains numerous informations on geotemperature and physical properties of rocks, which are necessary for heat flow calculation and studies including:

1) Basic data of borehole: Coordination of the borehole; tectonic settings; elevation of water table in the borehole; starting and completion time of drilling etc.;
2) Data of rock nature and age: classification of rock type; detailed description of rock type; chemical and isotope composition of rocks etc.;
3) Data of thermo-physical properties and radio-element content of rocks: thermal diffusivity; specific heat; density; U, Th, K contents; heat productivity or heat generation of rocks;
4) Data of temperature measurements in boreholes: equipment for temperature measurements; measurement date and time; organization and staff of temperature measurements.

Based on these information, geothermal gradient, thermal conductivity, heat flow, heat productivity, statistic analysis of heat flow data as well as interpretation of geothermics of the lithosphere etc. can easily be conducted by data processing software in the data base.

## 2. Heat Flow Map of Continental Area of China

Heat flow map is regarded as the final step of data acquisition and/or data compilation, which displays the local, regional even global pattern of terrestrial heat flow. Heat flow map may be of different scale, area coverage, iso-line interval, projection, size etc., depending upon the different purpose of interests (Cermak and Haenel, 1988). For digital Earth, heat flow map should be compiled on global scale. However, global heat flow map must be based on regional even local heat flow maps. In 1970's, heat flow map of Europe was compiled by Cermak and Hurtig (1979) under the International Heat Flow Commission Project. In 1980's, heat flow map of SE Asia appeared (Matsubayashi and Nagao, 1991).

In China, first heat flow map was compiled and published in late 1980's and revised in 1990 (Wang and Huang, 1988, 1990). Two heat flow maps of scale 1: 12,000,000 with 441 and 485 measure-ments for the continental area of China have been attempted in 1992 and 1994 (Wang et al., 1996). On these maps, only the sites of individual heat flow measurements and/or the average heat flow value in $1^{o}x1^{o}$ grids were displayed. Owing to the insufficient data coverage density, contour lines (iso-heat flow lines) were not possible to be constructed at that time.Furthermore, all the sites as well as the grids were drawn by hand (by "eye"), i.e. by simple visual putting of individual heat flow measurement sites and average heat flow value in each grid. With increasing of heat flow data and to improve the data presentation, a new version of heat flow map with scale 1: 6,000,000 has been completed in 1995 (Xiong et al., 1995). Compare to the previous ones, the following advantages are obvious:

1) It contains more data (681 sites), which gives more information on heat flow pattern for continental area of China;
2) Based on heat flow database, ARC/INFO system has been applied for heat flow compilation. The close inter-correlation between database and the system allows the user to get necessary data from the map very easily, i. E. One can obtain all the heat flow information provided the longitude and latitude of heat flow measurement sites are given;
3) As the map compilation and drawing are totally processed by computer, the reliability and the quality of heat flow map are thus guaranteed. In addition, it is much more fast to compile and draw a map by computer than by hand;
4) It is very easy to update data, to check and revise the existed data as well as to modify even to re-compile map in terms of the advanced structure and function of the ARC/INFO system;
5) By means of ARC/INFO system, the map can be divided into several map-set of interests. For instance, the heat flow map of China can be divided into heat flow map of North China, SE China, Tibet, Tengchong volcanic area etc. Furthermore, heat flow map can also be superimposed on other maps, say, tectonic map to see the relationship between heat flow pattern and tectonics.

Currently, a newly updated heat flow data base and heat flow map is under the way. It contains 862 heat flow values and all the
data have been classified into 4 quality categories as mentioned before. For heat flow map compilation, in addition to the observed data, a synthetic supplement to the existing observations by predicting heat flow value in the un-sampled areas using empirical relationship between heat flow and tectonic age has been used and they gave good results (Wang and Hu etal., 1999).

## 3. Geothermics and the Digital Earth

From the afore-mentioned it is clear that geothermics is closely correlated to the digital Earth. Firstly, geothermics contains several important parameters of the Earth, that is: temperature at different depth of the Earth's interior; geothermal

gradient of the Earth's crust and upper mantle; thermal state and regime of the lithosphere; heat flux from the Earth etc.; Secondly, as one of the new and renewable energy source, geothermal energy plays important role in help solving energy-shortage problems worldwide and especially in certain areas. For instance, Tibet suffered energy-shortage problems very seriously because there's no conventional energy source such as coal and oil-gas at all but is rich in geothermal energy. Yangbajing geothermal power plant with capacity of 25.18 MW supplies 41% (60% in the winter time) of the electricity for the Lhasa city, the capital of Tibet. In 1995, the total installed capacity of geothermal power plants reached 6798 MW and the capacity of non-electric direct uses of geothermal energy amounts to 8228 MW equivalent all over the World. Statistics exhibits that new and renewable (including geothermal) energy already provides 15-20% of World primary energy and will have a growing part in the future energy budget; Thirdly, new and renewable (including geothermal) energy is generally environmentally friendly and widely available in many countries. Fourthly, many other important geothermal parameters such as paleo-temperature, paleo-geothermal gradient and paleo-heat flow are of significant importance in understanding oil-gas maturation and in assessment of oil-gas resources potential. In this context, it would be most desirable if we could construct a "Digital Geothermal Earth" which contains all the temperature- & heat-related data of the Earth. By using GIS, GPS, RS and other techniques, all these data can be used for different purpose and/or for understanding the Earth as a whole from the point of view of geothermics.

This is our goal in the near future.

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