MAPS OF TERRESTRIAL HEAT FLOW DENSITY DISTRIBUTION IN SOUTH AMERICA

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INTRODUCTION

Considerable amount of geothermal work has been carried out in South America over the last few decades, but lack of efforts for evaluating the significance of such observations on a continental scale has been an obstacle in understanding the nature of tectonic processes affecting the continent. Attempts to prepare a heat flow map were initiated as early as 1982; during the period 1985-1987 further improvements in the data base for Brazil led to the preparation of a set of geothermal maps for the Brazilian territory (Hamza et al., 1987). The preliminary heat flow map of South America presented here is based on improvements made on these earlier maps. In the present work the available geothermal data have been put together in a form suitable for the evaluation of regional geothermal characteristics. We also report the progress obtained in preparing mosaics of regional heat flow variations in the South American continent.

DATA BASE AND QUALITY LEVELS

The data compiled in this work are based on both published as well as unpublished reports of geothermal investigations in South America. Because of the large amount of related bibliographical material the sources of geothermal data will not be referenced here. The compilation includes 655 heat flow determinations; thus the overall data density is $37/10^6$ km^2, a value comparable to data densities in several regions of eastern Europe at the time of preparation of the preliminary heat flow map of Europe (Cermak and Hurtig, 1979). Different methods have been used for determining heat flow in the South American continent. In order to make use of such data, having a wide spectrum of quality levels, a priority scheme was adopted that takes into account not only the reliability of the technique used but also the nature of primary geothermal data. The distribution of available data within such a priority scheme is shown in Table 1.

TABLE 1. Priority of the Geothermal Data

Priority Level	Geothermal Methods	Percentage of Data
High	Conventional Logging (CVL) Bottom-Hole Temperature (BHT) Underground Mine Measurements (MGT)	60
Intermediate	Conventional Bottom Temperature (CBT) Aquifer Temperature (AQT) Oceanic-type Probing (OHF)	6
Low	Geochemical Estimates (GCL) Thermal Fluid Discharge (TFD)	34

The spatial distribution of data is non-uniform and relatively reasonable data densities are available only for certain specific regions in Chile, Brazil, Venezuela, Bolivia, Argentina and Perú. In spite of such difficulties the available data set has allowed not only the determination of reliable mean heat flow values for a large number of major geological structures but also the preparation of mosaics of regional heat flow variations.

AUTOMATIC AND MANUAL CONTOURING

In map preparation efforts a variety of contouring schemes were tested using commercially available software packages such as the GMT (Wessel and Smith, 1992) and the SURFER (Golden Software Inc., 1994). The data interpolation methods employed in automatic contour map generation include adjustable tension continuous curvature gridding algorithm as well as kriging. The area selected for automatic contouring lies between latitudes 0°S and 40°S where the data quality is relatively better and its distribution rather uniform. Due to space limitations the automatic contouring maps are not shown in this abstract.

For manual contouring the procedure employed uses information on tectonic setting to control the interpolation scheme, a procedure which has been employed with success by Cermak and Hurtig (1979). The main advantage of this technique is the ease with which geologically meaningful restrictions can be imposed on the aereal extent of anomalies that are of questionable character. The map prepared by manual contouring is presented in Fig.1 (see the last page of this abstract) where an upper limit of 100 mW/m^2 has been imposed for the contouring range and 20 mW/m^2 was selected for the contouring interval. Contouring has been extended to regions above the Equator using inferred values of heat flow based on the heat flow-age relationship (Polyak and Smirnov, 1968; Hamza and Verma, 1969), employing essentially the same procedure as that adopted by Chapman and Pollack (1975). In the southeastern part of the Patagonian Platform contouring has been based on the geothermal gradient maps of Robles (1987; 1988).

The prominent features in the maps generated by automatic contouring are also encountered in the map produced by manual contouring. There are however some differences in the shapes and sizes of the thermal anomalies, arising mainly as a result of taking into consideration the tectonic background in the interpolation scheme.

DISCUSSION AND CONCLUSIONS

The preparation of the heat flow maps has led to the identification of some geothermal features that may be related to tectonic processes affecting the South American continent. Prominent among these are east-west trending belts of low heat flow in northern Perú and in central Chile (extending into Sierra Pampeanas in Argentina) as well as the belts of high heat flow in northern Chile (extending into the Altiplano and Bolivia) and southern Chile (extending into western Argentina). The low heat flow belts are found to coincide approximately with the flattening of the Wadati-Benioff zone. Some of these features are found to correlate well with results of studies on anelastic attenuation (e.g., Whitman et al., 1992), electrical resistivity distribution (Muñoz et al., 1992; Schwarz et al., 1994) and some patterns of global seismic tomography (e.g., Zhang and Tanimoto, 1991). These features are not seen in the recent spherical harmonic analysis of heat flow (Pollack et al., 1993), which suggests that use of empirical predictors based on the heat flow-age relationship in divising global heat flow maps should be restricted to tectonically stable areas. Low heat flow values in Panamá and northwestern Colombia could arise as a result of underthrusting of cold oceanic crust eastward of the trench line (Sass et al., 1974).

In the eastern part of the continent heat flow is low to normal (mean values <75 mW/m^2) but there are indications that heat flow in the Patagonian Platform is high compared to that in the Brazilian Platform. High heat flow anomalies are observed in the northeastern region and in the Mato Grosso (south-central region) of Brazil. It is worth noting that the anomaly in the northeastern region is contiguous with the westward extension, onto the continent, of the Fernando de Noronha oceanic lineament, known for its recent volcanic and magmatic activities (Almeida, 1958). Recent results of surface wave propagation indicate higher than normal slowness factor for this region (Souza, 1994). In the region of Mato Grosso heat flow is high along a narrow belt extending from the eastern part of Bolivia to the western border of the Sao Francisco craton. This is also an area characterized by the occurrence of a large number of thermal springs. Recent subcrustal magma emplacement could explain the high heat flow anomaly in this region but evidence for associated uplift is lacking.

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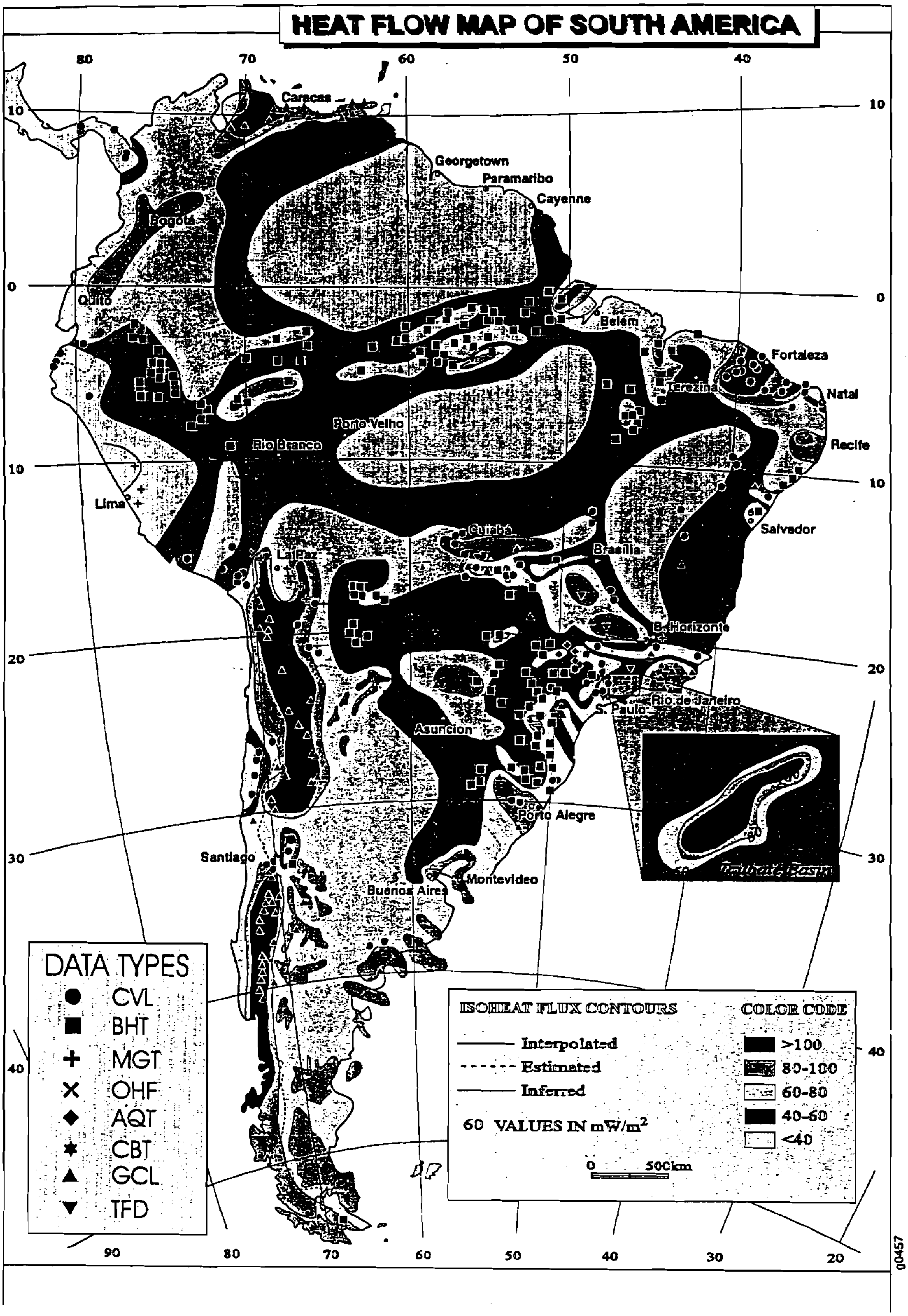
Fig.1. Heat flow map of South America produced by manual contouring (see next page).
Data types are given in Table 1.


HEAT FLOW MAP OF SOUTH AMERICA
80
70
60
50
40
10
0
10
20
30
40
Caracas
Georgetown
Paramaribo
Cayenne
Bogotá
Quito
Belém
Fortaleza
Terezina
Natal
Recife
Porto Velho
Rio Branco
Lima
Salvador
Cuiabá
Brasilia
La Paz
B. Horizonte
Rio de Janeiro
S. Paulo
Asuncion
Porto Alegre
Santiago
Buenos Aires
Montevideo
Taubaté Basin
DATA TYPES
CVL
BHT
MGT
OHF
AQT
CBT
GCL
TFD
ISOHEAT FLUX CONTOURS
Interpolated
Estimated
Inferred
60 VALUES IN mW/m²
0 500km
COLOR CODE
>100
80-100
60-80
40-60
<40
90
80
70
60
50
40
30
20
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