THE TERRESTRIAL HEAT-FLOW DENSITY DATABASE IN THE FRAMEWORK OF GEOTHERMAL POTENTIAL STUDIES

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The terrestrial heat-flow density is the unique measurable evidence of the internal heat sources, which supply energy for fundamental processes, such as uplift, subduction, rifting and subsidence. It provides not only information of past geological events, but constitutes an important constraint for the assessment of geothermal resources of a region.

The first heat-flow density measurements in Italy were carried out in the late 1950s in the Alps tunnels. Systematic investigations, started in the mid-1980s, allowed significant geophysical and statistical interpretations at regional scale of the magnitude and distribution of the heat conducted to the surface of the earth from its interior. In principle, the determination of heat-flow density is straightforward, but in tectonic studies care is necessary in the choice of the measurement sites, which should be far from anomalous areas affected by volcanism, geothermal systems and lacking in terrain problems. The form of the so far used databases generally mixes text and tabular data in irregular fields and requires users to write specific computer programs to extract information in an useful format. This reduces the flexibility of the databases and impedes accessing to most of the scientific community. In order to store and to simplify the access to all the information on the terrestrial heat-flow density of a region, an appropriate data model has to be established, according to the requirements of the applications, as well as to the further analysis problems that might rise.

In relation to the interesting geothermal potential of the region shown in Fig. 1, in the last decade the Geophysical Group of Genoa (GGG) has implemented a database using about 600 heat-flow density values collected during the European Geotraverse project (Blundell et al., 1992). GGG is operating under the guidelines of the International Heat Flow Commission of International Association of Seismology and Physics of the Earth's Interior (IASPEI). The format adopted for the data base is similar to the general format of the global heat-flow density data set, available on the web site of the NOAA's National Geophysical Data Center (NGDC). In addition to the essential details of the heat-flow density determinations, this format includes codes indicating, for example, where the measurement was taken or the type of corrections made to the measurements (topography, sedimentation, etc.). Additional information about the measurements, lithologies encountered, or borehole code names, has in some instances also been included beyond column 80 (Table 1). If one excludes the few boreholes which were specifically drilled for geothermal studies, the onshore heat-flow density estimates are based on bottom hole temperature (BHT) and thermal conductivity data from petroleum exploration wells (Pasquale et al., 1986 and 1992). Processing these data is very complex, for example due to the corrections of the temperature and thermal gradient (Fig. 2 and 3) and the measurements of thermal conductivity (Fig. 4-6). Thus, the available database must be implemented taking into account these pieces of information.

In this paper we focus on the area of the Apennines buried structural arcs where the available 55 heat-flow data were implemented with new 78 heat-flow density values, based on a large number of temperature data collected in oil wells and on thermal conductivity measurements. Data were corrected for drilling disturbance, sedimentation and climate. They were sorted into various groups, each belonging to a different tectonic unit. We compiled the current data into a relational database and developed subsets of retrievable data and derivative maps (Fig. 7). The data subsets are accessible in a variety of forms, e.g., tables, colour contour maps, location maps, borehole sections etc., and include text descriptions that enable non-specialists to understand the strengths and limitations of the resource. This methodological approach will be extended to the other heat-flow determination in order to obtain a more homogenous database useful for geothermal potential studies.

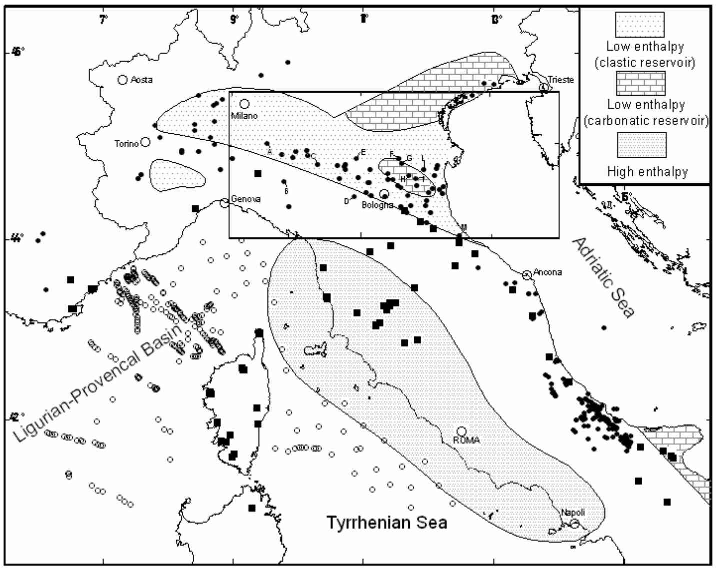

Fig. 1. Distribution of the available terrestrial heat-flow density data in central-northern Italy and surrounding seas. Heat-flow data from petroleum wells (full circle), from geothermal wells (full square) and from oceanographic techniques (empty circle). The main geothermal regions are also shown. In the inset, the area of the main buried structural arcs of the Apennines where new 78 heat-flow density values were determined.

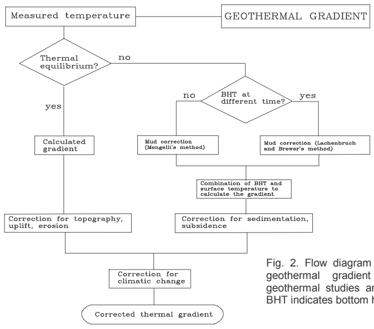

Fig. 2. Flow diagram for the determination of the geothermal gradient in boreholes drilled for geothermal studies and for petroleum exploration. BHT indicates bottom hole temperature.

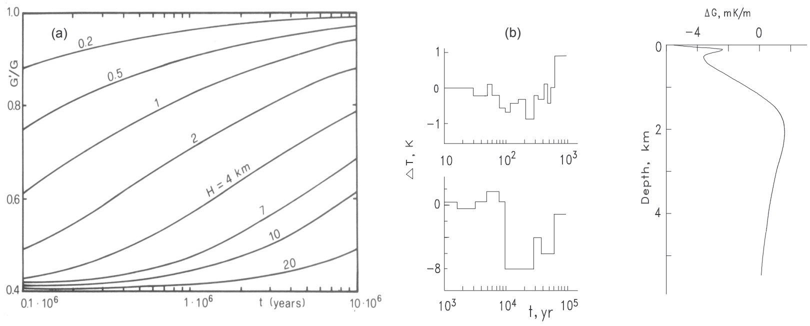

Fig. 3. Master curves for the correction of the thermal gradient. (a) Effect of sedimentation for different thickness *H* of the Plio-Quaternary layer as function of the deposition time *t*, at depth *z* = 0; G'/G is the ratio between disturbed and corrected temperature gradients. (b) Paleoclimatic correction as a function of depth (right) inferred from the reconstruction of the temperature variation for the Holocene and the last glacial epoch (left).

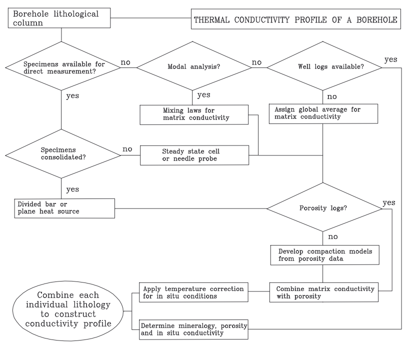

Fig. 4. Flow diagram for the determination of the thermal conductivity profile of a borehole.

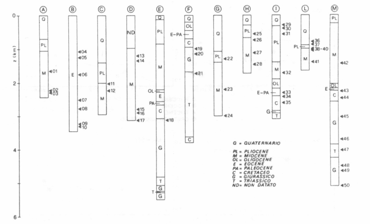

Fig. 5. Borehole stratigraphy and depth of the cores for laboratory measurements of thermal conductivity. Boreholes: A – Ponte Tidone 1bis; B – Prelerna 1, C – Parma 2, D – Levizzano 1, E – Cavone 1, F – Casaglia 1, G – Selva 3, H – Bova 1, I – Consandolo 1, L – Sabbioncello 1, M – Tavullia 1.

Description	Units	Columns	Description	Units	Columns
Data number		1-6	Temp. gradient	mK m^{-1}	52-54
Descriptive codes		7-13, 75	N. conductivities		55-57
Name of site		15-22	Conductivity	W m^{-1} K^{-1}	58-61
Latitude	Deg., min., tenths	23-28	N. heat production		62-64
Longitude	Deg., min., tenths	29-35	Heat production	10^{-6} W m^{-3}	65-68
Elevation	m	36-40	Heat flux	mW m^{-2}	69-72
Minimum depth	m	41-44	N. of sites		73-74
Maximum depth	m	45-48	References no.		76-78
N. temperatures		49-51	Year of publication		79-80

Table 1. Scheme of the format for documentation of terrestrial heat-flux data

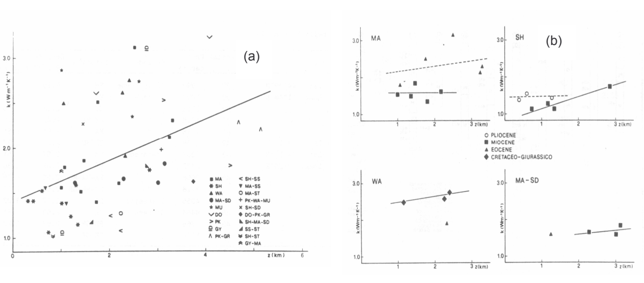

Fig. 6. Thermal conductivity against depth of the core samples from boreholes of Fig. 5, sorted by lithotypes (a) and age (b). DO – dolomite, GR – grainstone, GY – gypsum, MA – marl, MU – mudstone, PK – packstone, SD – sandstone, SH – shale, SS – sand, ST – silt, WA – wackestone.

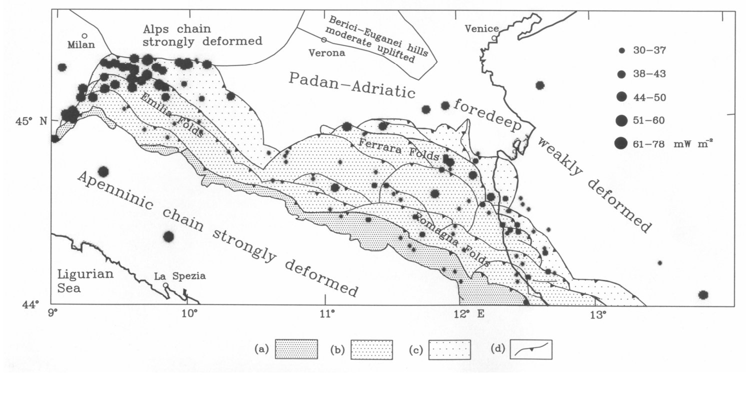

Fig. 7. Terrestrial heat-flow density in relation to the main buried structural arcs of the Apennines. Neotectonic zones: Pliocene and locally up to early Pleistocene foredeep evolving to Apenninic chain (a); Plio-Quaternary foredeep strongly deformed by faults, folds and thrusts (b) and mainly by folds and locally by thrusts (c). The main subsurface thrusts are indicated (d).