THE ITALIAN GEOTHERMAL INVENTORY: A VALID TOOL FOR ENERGY STRATEGY

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Abstract

In the early 1980s, with the development of geothermal research and the new National Energy Plan. the Italian authorities and the private sector became aware of the need of a national geothermal reference standard. In 1986 Parliament decreed that a "National Geothermal Inventory" be set up to assess the national geothermal resources. The four main organizations involved in geothennal R&D in Italy, CNR, ENEL.. ENEA and AGIP, collaborated in compiling the inventory. The results were made available to regional authorities and to the public. The inventory. updated to March 1994. will be a useful tool for planning further geothermal activity. particularly the exploration of new areas and development of low temperature resources. All the available and potentially useful geological, hydrogeological. geophysical. thermal and drilling data have been collected. Maps of temperature distribution at various depth have been compiled using these data, and a geothermal ranking of all the Italian territory has been carried out.

Keywords:

Geothermal inventory, geothermal database. Italy

1. INTRODUCTION

On 9 December 1986, with the objective of providing incentives fir geothermal energy development. the Italian Parliament ratified Rill no. 896, "Regulation of Research and Development of Geothermal Resources". which was to regulate the geothermal sector in a similar way to the legislation enacted some years previously for hydrocarbon research and development.

The National Energy Plan launched in that same period gave priority to the exploitation of renewable energy sourccs. in view of the strong dependence of Italy on energy imports. and emphasired the panicular importance of utilizing Italian geothermal resources in non-electric applications.

Bill no. R96 provided economic incentives in the research sector, to offset the mining risk involved in geothermal exploration. It also decreed that the Ministry of Industry should compile an inventory of Italy's geothermal resources that was to be updated periodically.

The incentives fur promoting non-electric applications of geothermal resources consisted of granting loans to the holders of research leases for drilling exploratory wells. These loans, granted by the Ministry of Industry. corresponded to 75%of the cost of unproductive wells. and 25% of productive wells. These percentages increased to 80 and 30% respectively for increased drilling costs resulting from environmental requirements.
The objective of the inventory was tu rank all of Italian territory. integrate all data of geothermal interest, and organize them in a standard. readily accessible and readable format for the private and public user.

Development of the inventory was assigned to the four main organizations involved in the geothermal sector in Italy:
- the National Research Council (CNR), which. through its International Institute fur Geothermal Research in Pisa, conducts geothermal research:

- the National Electric Power Company (ENEL). which. apart from research and exploratory drilling. is also involved in the industrial utilization of geothermal energy;

- the National Oil Company (AGIP), which has conducted geothermal research from 1975 to 1989 in joint - ventures with ENEL. and is proprietor of a large number of data on the underground deriving from its hydrocarbon research activity;

- the Nuclear and Renewable Energy Board (ENEA), which is responsible for promoting the development of renewable energy sources.

The inventory includes stratigraphic. hydrogeological. thermal and production data from geothennal and other wells, thermal springs and gas manifestations. A repon was compiled for rach of the twenty Italian administrative regions, with accompanying maps of identified or presumed aquifers, and of the temperatures at various drptha. All the data gathered were stored in a database set up specifically for this purpose by CNR in collaboration with ENEL (ENEL *et al.* 1988; CNR. 1994).
The reports prepared for the inventory. and the data stored m the geothermal database are available through the Ministry of Industry and regional authorities. as well as CNR. ENEL and ENEA.

2. THE DATABASE FOR THE INVENTORY

A computerized database was created to store and organize thin information for subsequent retrieval and processing. The database was set up for the Italian Ministry of Industry (SARACCO and BARBIER. 1988) and is referred to as the National Geothermal Database (NGD).

The NGD contains specific data an thermal springs. gar manifestations, and wells of geothermal interest spread all over Italian territory.
The data in the SGD are organised in a tlexible. readily accessible form. so that the user can either simply retrieve the data or process them to wit his requirements.

The model chosen for NGD is a relational database, which displays data in tabular form and allows the user to retrieve and work with the same information in many different ways.
The database has been implemented on an IBM mainframe and can he accessed from remote workstations. Copies of the database are being installed in computers of local administrative offices.

Description and acquisition of stared data.

The objective of the NGD is to store information related to the location and characteristics of geothermal fluids in Italy.
In the NGD the objects are wells that produce a geothermal fluid (hot water. steam, or gas) or wells such as geothermal exploratory wells or hydrocarbon wells (AGIP. 1977), water wells (above 30°C). unproductive wells, which can also provide useful geothermal information on, e.g., temperatures at depth in the area.
Thermal springs and other geothermal manifestations are also classified as objects. The manifestations are classified according to the type of fluid produced: gas manifestations, gas and liquid water manifestations. or gas and steam manifestations (fumaroles).

Each of the above objects is described through attributes. The attributes describe the essential features of the object. In the case of a well, for instance. the attributes include its name, geographic coordinates, altitude and depth. the temperature of the fluid if the well is productive. or of the rocks at various depths. Attributes can be both numerical and textual. The most common units of measurements are accepted, but the database automatically converts all units into equivalents of the International System.
A thermal spring or a gas manifestation can be defined, in the current organization of the database, by 131 different attributes, including location parameters and the attributes related to the hydrogeological, chemical, and isotopical characteristics of the spring. There are 360

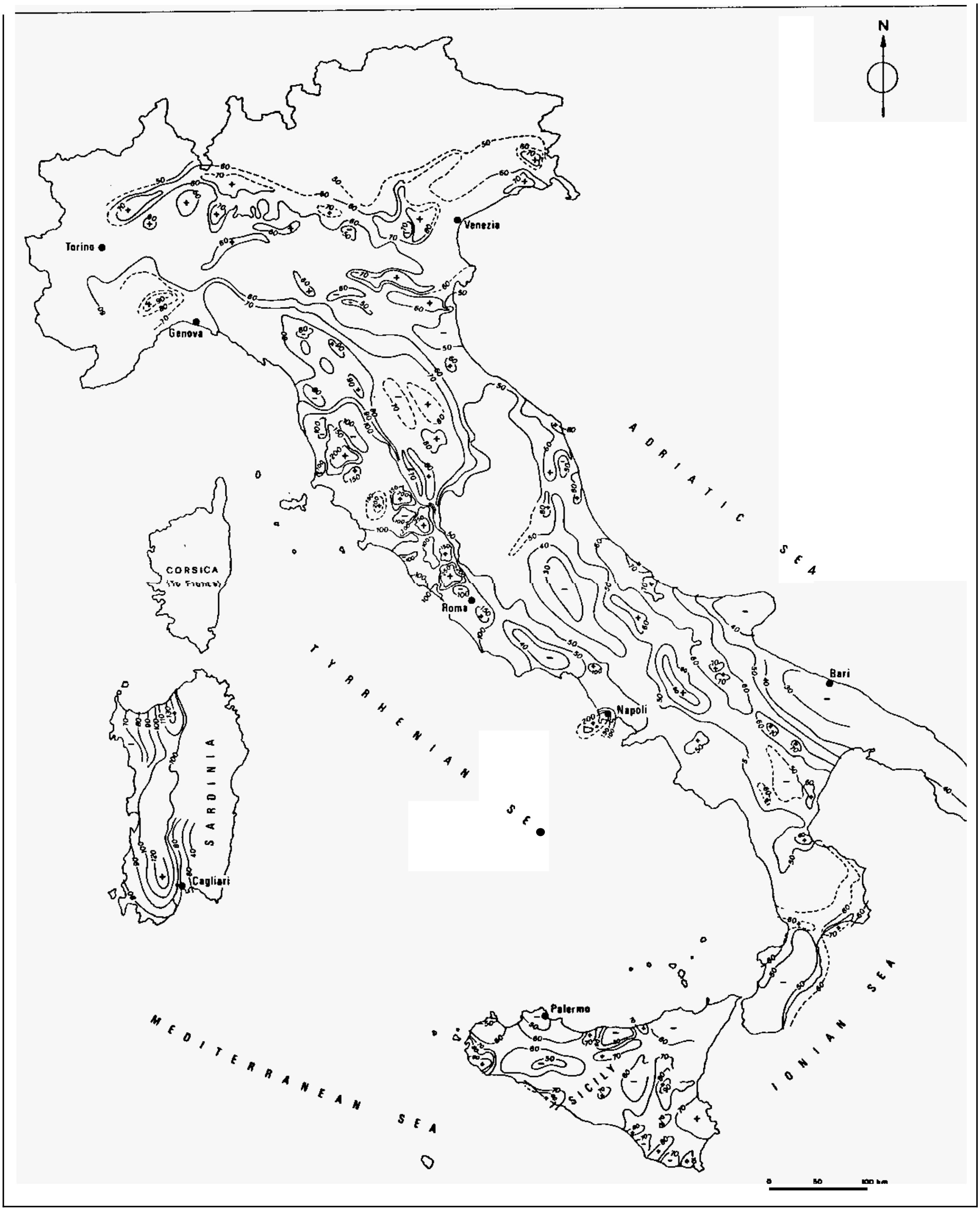

Figure 1 - Isotherm map (°C) at 2000 m depth. below ground level

possible attributes for wells. apan from these mentioned above. these include the lithological sequence met hy drilling. temperatures measured at different depths. geothermal gradient. heat ilow at the surface. hydraulic charactenstics of the reservoir, production data, and the technical parameters of the well (diameter, casing. etc.). For a directional well. the NCD also provides the data for the vertical depth. Although this describes the potential of the NGD, obviously very few wells offer such a wide range of information, hydrocarbon wells for example, are generally not drilled with the objective of collecting data of geothermal interest.

In order tu assign a standardized format to the data available. 15 paper forms where developed. The following data are logged on these forms and then loaded in the NGD:

1) Identification. location. use, and history ofthe well.
2) Identification. location. use, and history of the spring or manifestation.
3) Lithostratigraphic sequence of the well.
4) Temperature data in the well.
5) Temperature gradients in the well and surface heat flow.
6) Trend of the reservoir/aquifer ofthe well.
7) Reservoir/aquifer ofthe well.
8) Permeable interval/fracture in the reservoir of the well.
9) Production data of the well.
10) Technical profile of the well.
11) Chemical. physical. and isotopic charactericstics of water.
12) Chemical. physical, and isotopic charactericstics of gas.
13) Reservoir temperatures calculated by means of geothermometers.
14) Relationship between depths in directional wells.
15) Bibliographic references.

To date (1994) the National Geothermal Database includes 468 thermal springs and gas manifestations and 2139 wells of geothermal merest. including hydrocarbon and water wells (above 30°C).
The present volume of data. is at the moment. 5 megabites.
Record lengths vary from about *750* alphanumeric characters (bytes) for springs or manifestations to about 2200 characters for wells.

3. THE RANKING OF ITALIAN GEOTHERMAL AREAS

All the data collected, together with available geological. geophysical and geochemical information. were used to reconstruct the depth ofthe geothermal aquifers and their temperature distribution. The subsequent regional repons formed the basis for a nation-wide assessment of geothermal resources. and a geothermal ranking of Italian territory. This paper repons the main results of the national assessment. and describes three ofthe more significant maps.

Italy is located in the middle ofthe Mediterranean Sea on a tectonically active belt where the African and Euro-Asian plates. have collided.

Crustal thinning, (thinnest in the Tyrrhenian area). and the consequent rise of the earth's mantle, marked by recent magmatic and volcanic activity. are factors responsible for the conspicuous heal flow anomaly present along the Tyrrhenian pre-Apennine belt. Heat flow in some zones is as much as ten times the average terrestrial value. This belt is often characterized by permeable structures overlain by impermeable cap rocks. creating conditions ideal for the development of geothermal systems.

The information available on temperature distribution underground are mainly from wells drilled for hydrocarbons by AGIP (1977). Some information is from geothcnnal research reports provided by ENEL. The "classical" geothermal zones of Tuscany, Latium and Campania provide the most precise and detailed data, although these zones are generally limited to the areas of intense geothermal exploitation.

Two parameters of the potential geothermal reservoir were utilized to identify the most interesting zones on a national scale: *temperature* and *depth* The gmding rule in this case was that the depths should be economically accessible with current technology, and that the temperatures should he within the rangc required in the different applications of geothermal fluids.

The geothermal ranking ofthe areas was based on two main criteria:

- the existence (or absence) of large aquifers (on a regional scale) within a depth limit of2000 m:

- the maximum temperature expected in these aquifers within 2000 m depth.

The first sub-division was therefore conducted on areas with major aquifers within 2000 m, and on areas with prevalently impermeable formations within the same depth limit. The areas with aquifers were then sub-divided according to their presumed maximum temperature value.

The temperature trend at 2000 m below ground-level (Fig.1) reflects the geological. structural and hydrogeological characteristics of Italy : the highest temperature values (up to 250 °C) occur in the Tyrrhenian area, where the crust is thin, as manifest by a number of magmatic and recent volcanic features. The lowest temperatures (less than *60°C)* occur in rough correspondence to the central belt of Italy. and are tied to infiltration and circulation of meteoric waters within deep Mesozoic carbonate structures of the Apennine chain. Zones of a low-to-medium temperature (60-100 'C) are present in the marginal subsidence basins of the Alpine and Apennine chams. Some buried structures with high permeability may contain major convective zones of hot water at shallow depths (for example, the Po-Venetian plain, southern Apemines. Sicily and Sardinia).

The prevalently carbonate Mesozoic units, which crop out in the Apennine cham and are buried on its margins. comprise a stratigraphic section of major interest since these units are permeable and regionally continuous.

Locally interesting aquifers are also found in the volcanites within active or recent volcanic systems (Napoli region, the Eolian Islands. and the island of Pantelkria. Fig. 2b).

The assessment identified several areas with interesting temperatures in aquifers within 2000 m from ground-level (Fig.2a, 2b). The ranking continued with a definition of the "high-temperature" areas of potential interest for generating electricity (Tyrrhenian belt and volcanic islands), and the areas in which geothermal resources could be recovered within economically accessible depths for direct heat uses. The best areas for generating geothermal electricity are the Larderello-Travale and Mt.Amiata zones in Tuscany (80 km SW of Florence), and the Latera zone (50 km NW of Roma) in Latium; other zones of Tuscany are also under exploration.
Research carried out in volcanic areas of Latium. Phlegraean Fields (Napoli), and the Aeolian islands. found high temperatures (>250°C) hut very low permeability, and thus these areas are not suitable far producing electric energy. A comprehensive description of geothennal power plants existing in Italy in 1995 is given in Allegrini *et al.* (1995).

The geothermal map showing the ranking of Italy. and the regional reports. represent imponant references for planning future research and for optimizing the utilization of Italy's geothermal resources. especially far direct use. Although the study identified the areas of major Interest. eventual utilization projects in a specific area requires detailed local investigations to better define the thermal and structural charactenstics, as well as the potential users.
Rased an the available data, a preliminary selection has been made (Fig. 3 and Table 1) of the areas most likely to contain geothermal fluids that could k used in direct heat applications. In the same Figure. the Italian climatic zones are also shown. Utilization plants already exist in same ofthese areas (BURGASSI *et al.* 1995).

The identified resources have been classified as proven, *probable*, or *possible*. on the basis of the reliability of the assessments made from the available data. *Proven* resources are mainly located in areas surrounding geothermal fields under exploitation far electricity generation, or where recent research has identified fluids that are not suitable for electric energy production [Latium (Roma) and Campania (Napoli) regional. *Probable* resources are those for which the thennal and structural data are still incomplete. *Possible* resources are those still not sufficiently defined. and are hased only on surface geological and geothcnnal data.
Table 1 shows temperature and depth. for rach area. and the geological nature of the reservoir. There arras. which need more detailed investigation, represent a valuable energy source far Italy, and could make a significant contribution to reducing Italy's consumption of fossil fuels, as well as promoting new activities in the industrial and agricultural sectors. Funhermore, if the economic analysis includes the cost of pollution abatement measures far fossil fuels, then geothennal energy would prove cheaper than the other energy sources. Policy-makers at a governmental level should therefore propose incentives for the direct uses of geothennal energy, as already exist in Italy for other energy sources and for co-generation schemes. A further benefit would come from the ravings in imports of fossil fuels. sincc the geothermal resource. and the technology and labour force adopted to exploit it. are all local.

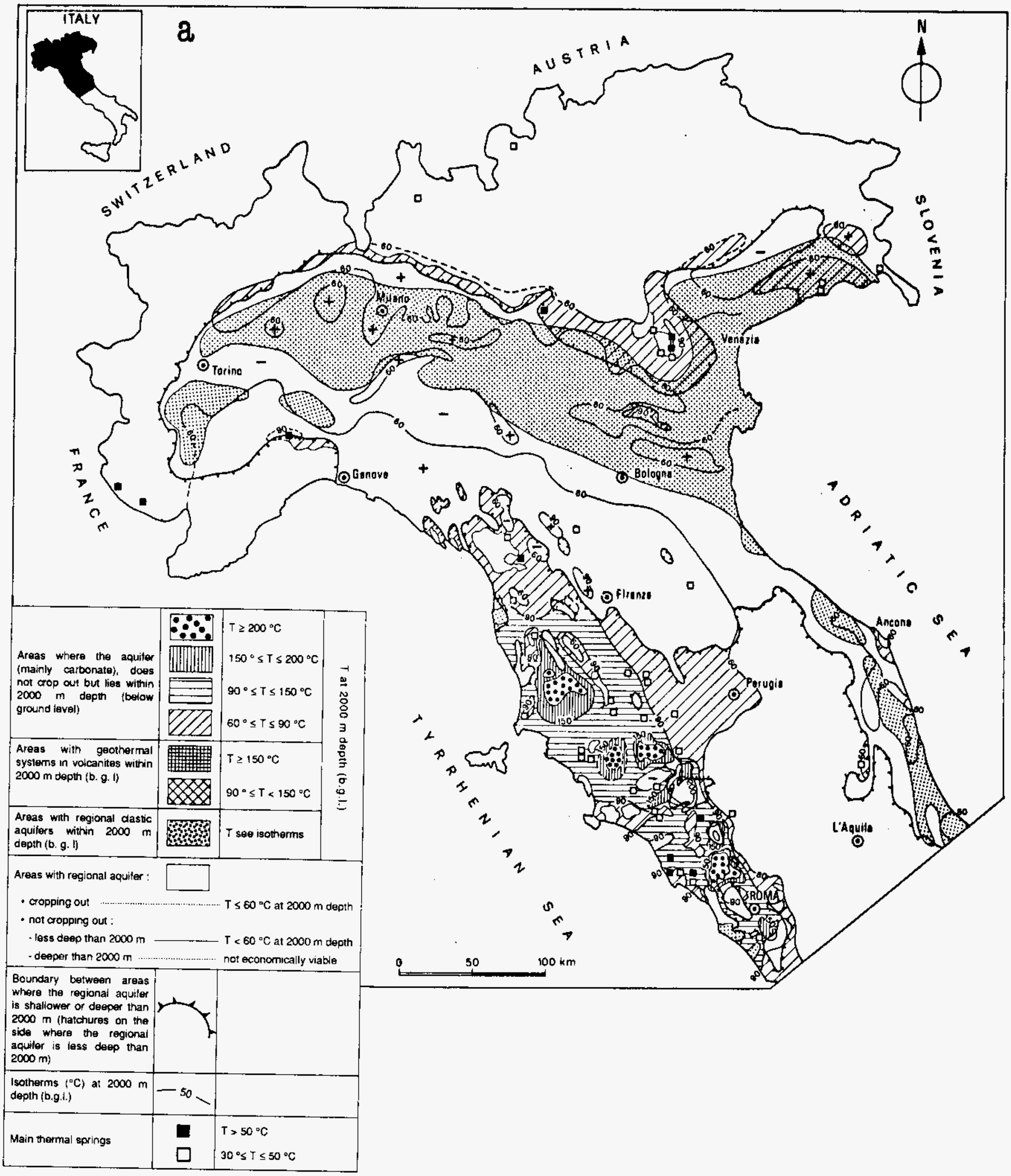

Figure ?a - Geothermal resources map of *northern* Italy showing the distribution of temperature at 2000 m depth (below ground level). and the distribution of aquifers. Rankings of arras are shown by various patterns.

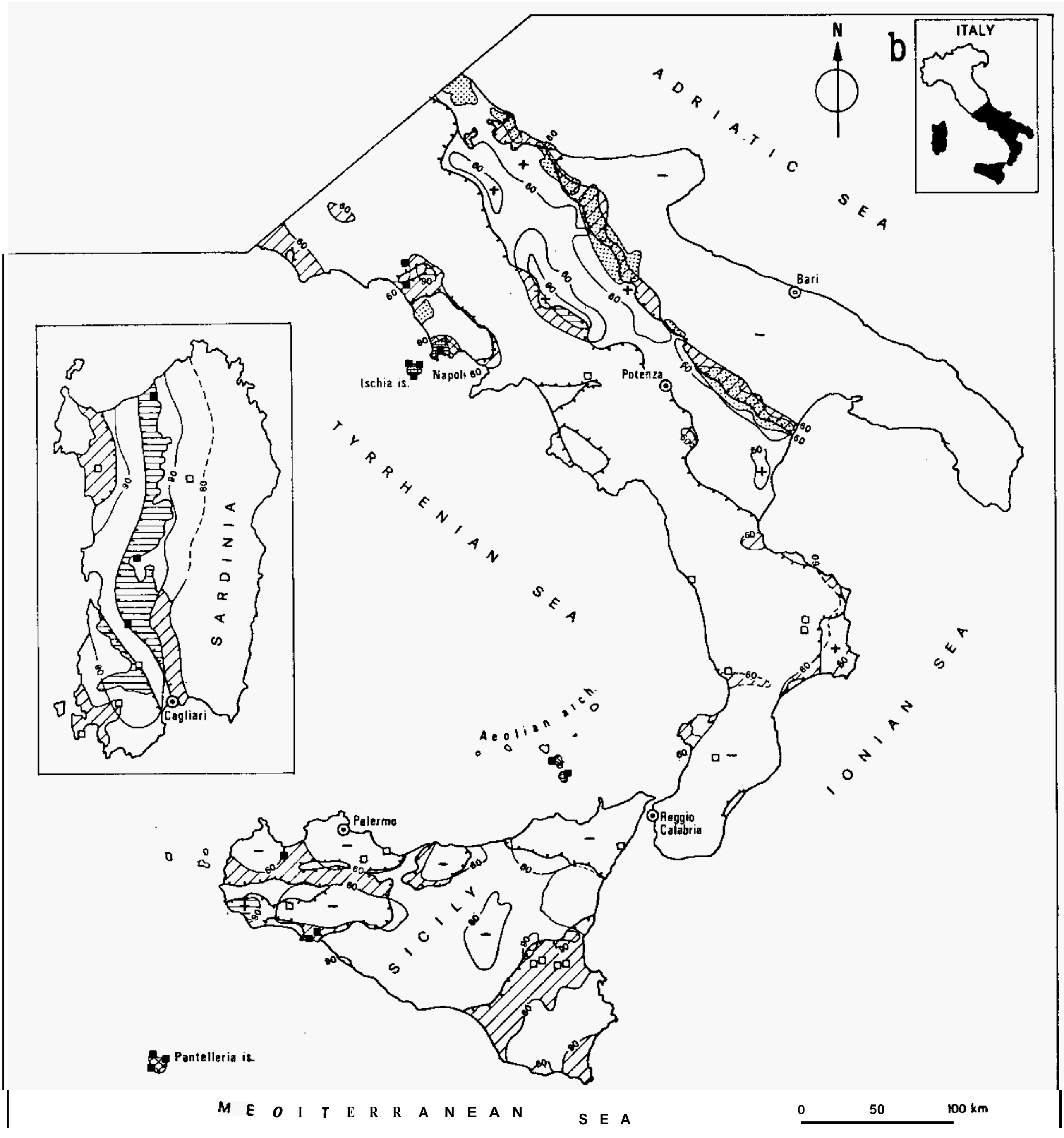

Figure 2b - Geothermal resources map of *southern* **Italy showing the distribution of** temperature at 2000 m **depth (below ground level), and the distribution** of aquifers. **Rankings** of **areas are shown by various** patterns.

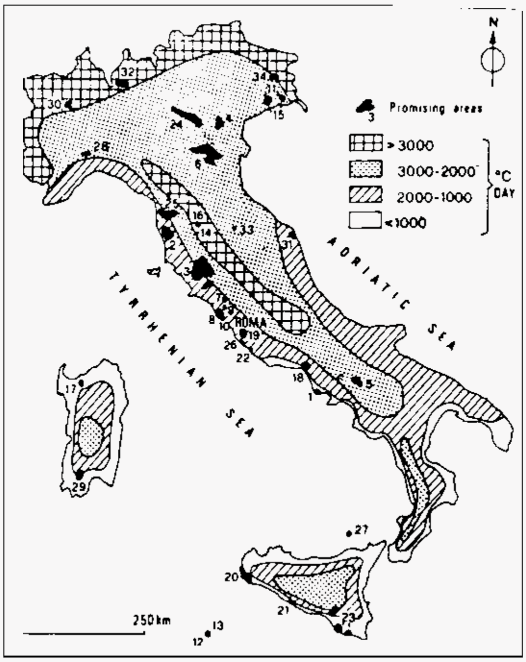

Figure 3 - Areas mast likely to contain geothermal fluids that could be used in direct heal applications in Italy. This areas are superimposed on climatic zones. The climatic **zones** are expressed in "C day and indicate their approximate thermal requirements.
°C day = [(19°C - mean temperature) x number of cold days]. Promising areas are identified on Table 1.

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	AREAS	TEMP. (°C) (reservoir)	DEPTH OF POTENTIAL RESERVOIR (m)	RESOURCES	TYPE Of RESERVOIR
1	PHLEGREAN FIELDS	250	1200	PV	VOLCANIC
2	VAL D'ERA	150/200	1500/2000	PV	CARBONATE
3	GROSSETO (MONTE LABBRO-GROSSETO-S.FILIPPO-ROCCALBEGNA)	100/150	1000/2000	PV	CARBONATE
4	EUGANEI HILLS-ABANO	100	500/2000	PV	CARBONATE
5	AVELLINO PROVINCE	100	1500/2000	PV	CARBONATE
6	FERRARA-MIRANDOLA	80/100	1700/2000	PV	CARBONATE
7	VITERBO (BAGNACCIO)	60	300	PV	CARBONATE
8	CIVITAVECCHIA (TOLFA)	50/80	300/1000	PV	CARBONATE
9	VITERBO (VICO)	70	700	PV	CARBONATE
10	VITERBO (ISCHIA DI CASTRO - CANINO)	50	400	PV	CARBONATE
11	GRADO - TAGLIAMENTO RIVER	50	400	PV	CLASTIC
12	PANTELLERIA ISLAND	240	600	PR	VOLCANIC
13	PANTELLERIA ISLAND	140	300	PR	VOLCANIC
14	SIENA (ACQUA BORRA)	70	600	PR	CARBONATE
15	GRADO - TAGLIAMENTO RIVER	70	800	PR	CARBONATE
16	SIENA (PALAZZETTO)	110	1300	PR	CARBONATE
17	COGHINAS (SARDINIA)	100	1000	PR	GRANITIC
18	ROCCAMONFINA-SUIO	100	2000	PR	CARBONATE
19	ROME - ALBANI HILLS	90	1600	PR	CARBONATE
20	TRAPANI	90	2000	PR	CARBONATE
21	SCIACCA	90	2000	PR	CARBONATE
22	FOGLIANO	80	1000	PR	CARBONATE
23	IBLEI (GELA-CALTAGIRONE-RAGUSA)	80	2000	PR	CARBONATE
24	SIRMIONE - ADIGE RIVER VALLEY	70	1500	PR	CARBONATE
25	PISA PLAIN (PISA-PONTEDERA-PALAIA -CASCIANA)	70	800/1000	PR	CARBONATE
26	LATINA	60	1400	PR	CARBONATE
27	EOLIE (LIPARI) ISLANDS	200	1000	PS	VOLCANIC
28	ACQUI SPAS	150	2000/3000	PS	UNKNOWN
29	CAMPIDANO (SARDINIA)	100	2000	PS	UNKNOWN
30	IVREA	80	2000	PS	UNKNOWN
31	ANCONA	80	2000	PS	CARBONATE
32	COMO-BERGAMO VALBREMBANA	70	1500	PS	CARBONATE
33	BAGNI DI ROMAGNA SPAS	70	2000/3000	PS	UNKNOWN
34	UDINE	60	1000	PS	CARBONATE

RESOURCES: PV =PROVEN; PR = PROBABLE; PS = POSSIBLE

Table 1 - Areas most likely to contain geothermal fluids that could be used in direct heat applications. Excludes the promising areas on the margins of the geothermal fields exploited for electric generation. Some of the zones listed in the Table are already in production for direct uses. Locations are shown on Figure 3.