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Shallow geothermal properties maps of the Italian underground soil: a lithological approach

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OBJECTIVES

Background

Shallow geothermal resources are used worldwide to produce thermal energy, supporting the decarbonization process. **Mapping ground thermal properties** can enable the identification of large areas' shallow geothermal potential and enhance the exploitation of geothermal resources on a national scale. The thermal properties of the ground are closely related to the type of sediments located in shallow subsoils. The interpretation of stratigraphic logs allows us to identify the main lithotypes in the drilling sites' proximity. **The lithological classification of the subsoils** leads to deriving mean values of shallow geothermal properties, such as **thermal conductivity** and **geothermal potential**.

Goals

A large stratigraphic database has been considered for producing **maps on a national scale**, the information about each drilling site has been analyzed and categorized, and the mean thermal conductivity and the mean geothermal potential have been computed without considering the groundwater input. The results are **dry thermal conductivity and dry geothermal potential maps of the shallow subsoils**.

DATASET

We analyzed the **ISPRA (*Italian Institute for Environmental Protection and Research*) database of drilling sites**. The database provides generic and non-standardized lithological descriptions for each site (Table 1), and some information lacks or does not reach an appropriate depth (Fig. 1). We split the database into two datasets: the stratigraphic tables of the ***primary dataset*** **(depth > 70 m)** have been considered for logs classification and maps elaboration, while the ***auxiliary dataset*** **(depth < 70 m)** has been used only to provide supporting information (Fig. 2).

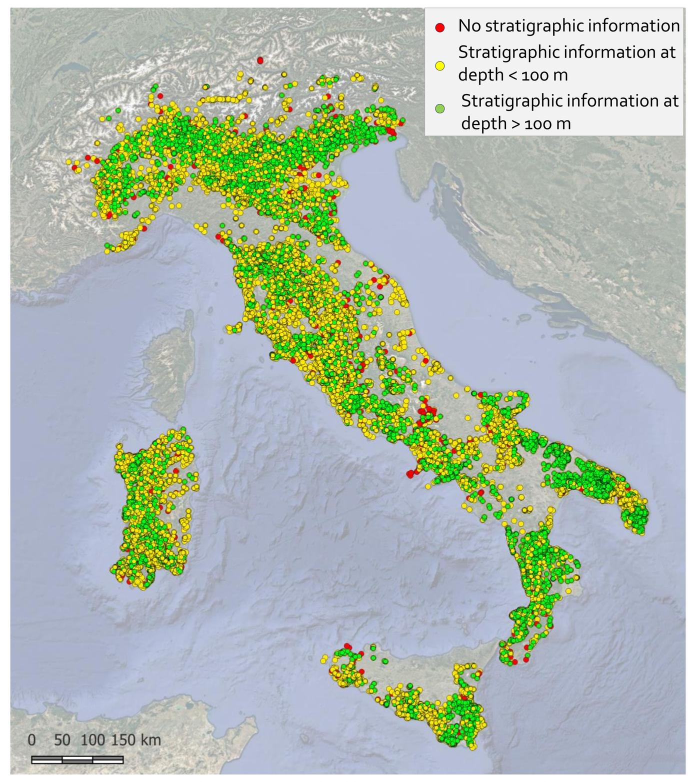

Fig. 1 - *Database of drilling sites resulting from hydrological or civil engineering works (ISPRA - Italian Institute for Environmental Protection and Research).*

n	From [m]	To [m]	Thickness [m]	Geologic age	Lithological description
1	0,00	2,00	2,00		BROWN-REDDISH SANDY-CLAYEY SOILS
2	2,00	28,00	26,00		FROM GREY SILTY SAND TO REDDISH FINE-GRAINED SAND, WITH BIVALVE SHELLS-ENRICHED LAYERS IN THE BOTTOM PART
3	28,00	35,00	7,00		GREY SAND WITH FOSSILIFEROUS LENSES, BLACK TURBIDITE LAYERS, AND TRAVERTINE ENCRUSTATIONS
4	35,00	37,00	2,00		GREY CLAYEY SAND AND GREY CLAYEY-SANDY SILT
5	37,00	39,00	2,00		YELLOWISH CAVERNOUS TRAVERTINE
6	39,00	41,00	2,00		COMPACT GREY TUFF
7	41,00	44,00	3,00		GREY-WHITISH CALCAREOUS SILTY SAND WITH GRAVEL AND CEMENTED ARENACEOUS LAYERS
8	44,00	47,00	3,00		GREY-WHITISH CAVERNOUS TRAVERTINE
9	47,00	57,00	10,00		SAND AND GRAVEL WITH GREY-GREENISH CEMENTED ARENACEOUS LAYERS, BIVALVE SHELLS FRAGMENTS AND GREY SILTY-CLAYEY INTERCALATIONS
10	57,00	87,00	30,00		GREY-BLUE SILTY CLAY

Tab. 1 - *Example of stratigraphic table as provided by the ISPRA database: the lithological descriptions are provided in a not-standardized form.*

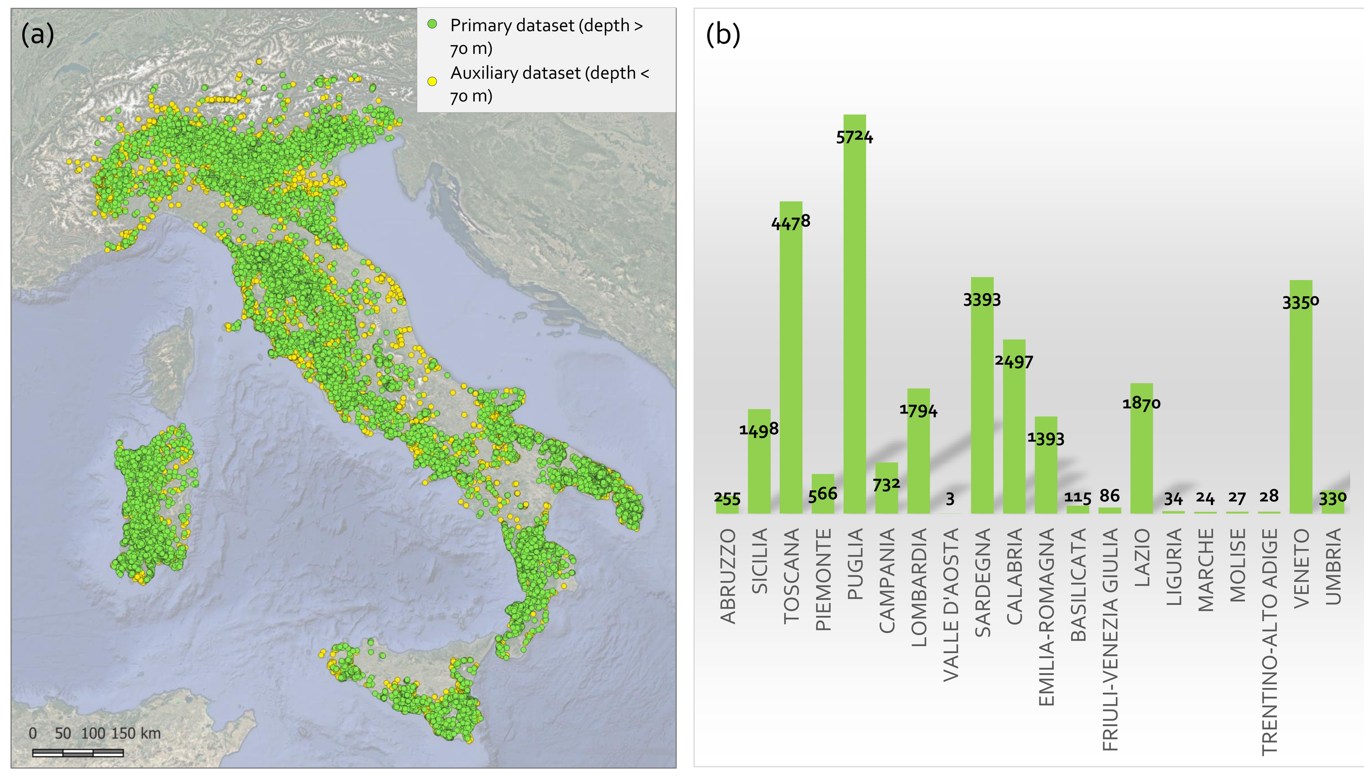

Fig. 2 - *a) Considered drilling sites for geothermal mapping purposes. All the stratigraphic information of the primary dataset has been analyzed. The auxiliary dataset supplied further information to interpret those lithological descriptions of the primary dataset that were unclear. b) Distribution of the drilling sites belonging to the primary dataset.*

METHODOLOGY

FROM LITHOLOGICAL DESCRIPTION → to → LITHOLOGICAL CLASSES ← to ← ASSIGNING THERMAL CONDUCTIVITY AND GEOTHERMAL POTENTIAL

	Lithological description	Lithotype	Id
...	BROWN-REDDISH SANDY-CLAYEY SOILS	COATING	0
...	FROM GREY SILTY SAND TO REDDISH FINE-GRAINED SAND, WITH BIVALVE SHELLS-ENRICHED LAYERS IN THE BOTTOM PART	SAND	2
...	GREY SAND WITH FOSSILIFEROUS LENSES, BLACK TURBIDITE LAYERS, AND TRAVERTINE ENCRUSTATIONS	SAND	2
...	GREY CLAYEY SAND AND GREY CLAYEY-SANDY SILT	SAND	2
...	YELLOWISH CAVERNOUS TRAVERTINE	TRAVERTINE	13
...	COMPACT GREY TUFF	TUFF	4
...	GREY-WHITISH CALCAREOUS SILTY SAND WITH GRAVEL AND CEMENTED ARENACEOUS LAYERS	SAND	2
...	GREY-WHITISH CAVERNOUS TRAVERTINE	TRAVERTINE	13
...	SAND AND GRAVEL WITH GREY-GREENISH CEMENTED ARENACEOUS LAYERS, BIVALVE SHELLS FRAGMENTS AND GREY SILTY-CLAYEY INTERCALATIONS	SAND	2
...	GREY-BLUE SILTY CLAY	CLAY	5

Id	Lithotype	Thermal conductivity [W/(m·K)]	Geothermal potential [W/m]
0	Coating	0,45	20
1	Pumice	0,40	25
2	Sand	0,42	40
3	Peat	0,40	40
4	Tuff	1,12	25
5	Clay	0,46	40
6	Limestone	2,80	65
7	Gravel	0,39	30
8	Sandstone	2,27	55
9	Vesuvian lavas	2,65	50
10	Basalt	1,70	45
11	Marls	2,10	50
12	Dolomite	3,84	70
13	Travertine	2,22	55
14	Mudstone	2,79	50
15	Gypsum	2,02	55
16	Schist and Phyllite	2,00	60
17	Gneiss	2,90	65
18	Granite	3,40	85
19	Granodiorite and Diorite	2,55	65
20	Quartzite and Metaquartzite	5,90	70
21	Diatomite	3,37	70
22	Obsidian	1,30	35
23	Andesite	1,90	45
24	Rhyolite	3,30	85
25	Marble	2,10	55
26	Peridotite	4,00	70
27	Gabbro	1,90	45

The **lithological descriptions of the *primary dataset*** (including more than 28000 drilling sites) **have been reclassified and harmonized to obtain 28 classes** that summarize the lithological variation in Italian shallow underground soils. For this purpose, **we divided the *primary dataset* into different subsets**, each of them containing close-located drilling sites, for a maximum of 1000 elements. We analyzed the lithological descriptions of each subset, using the *auxiliary dataset* to supply information for those descriptions that were unclear, not fully explained, or lacking.
Based on the lithological classification, we estimated the **vertical trend of thermal conductivity** within the perforation sites and the related **geothermal potential** concerning closed-loop geothermal probes. The obtained trends have been used to compute the **mean thermal conductivity** of the subsurface and the **mean geothermal potential at 70 m depth** (Fig. 3). We finally interpolated the point data to produce the **geothermal properties maps** (Fig. 4, Fig. 7).

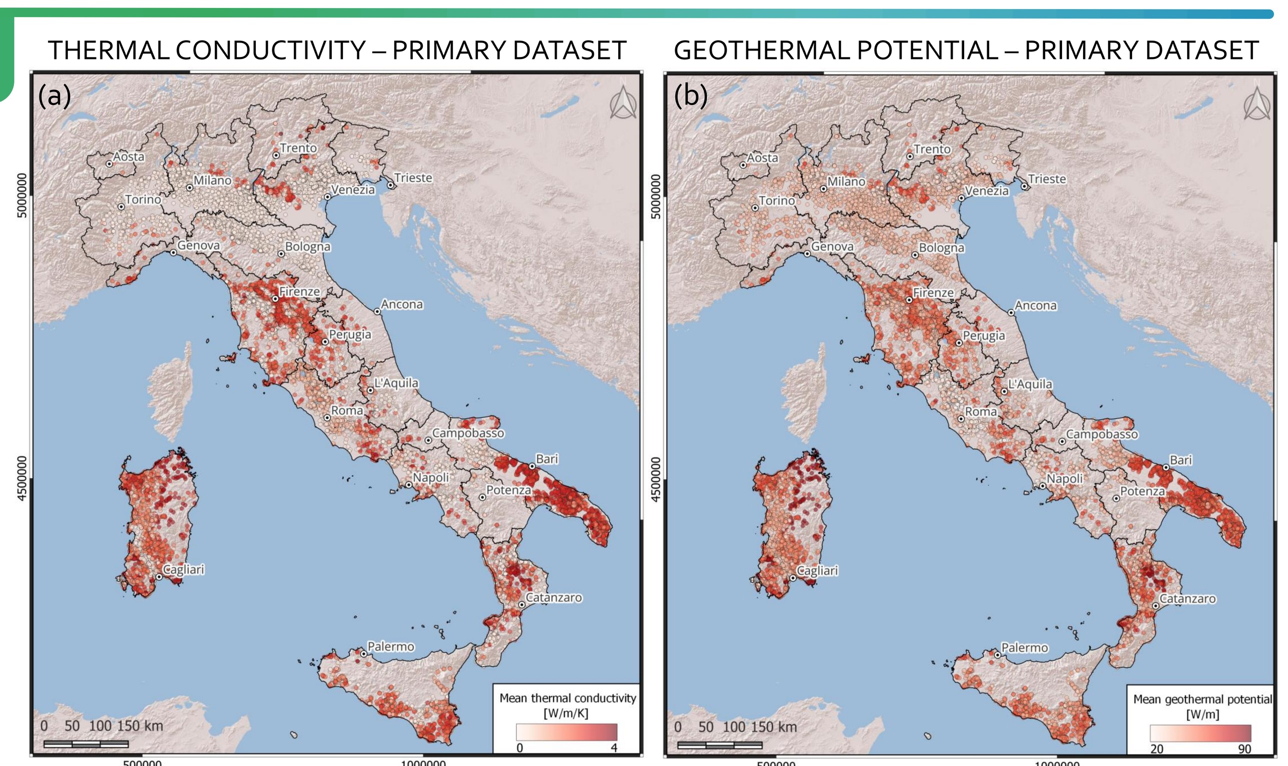

Fig. 3 - *a) Mean thermal conductivity for each drilling sites belonging to the primary dataset. b) Mean geothermal potential for each drilling sites belonging to the primary dataset. The values are weighted averages on depth=70 m (Reference System: WGS 84 / UTM zone 32N).*

RESULTS

SHALLOW THERMAL CONDUCTIVITY MAP

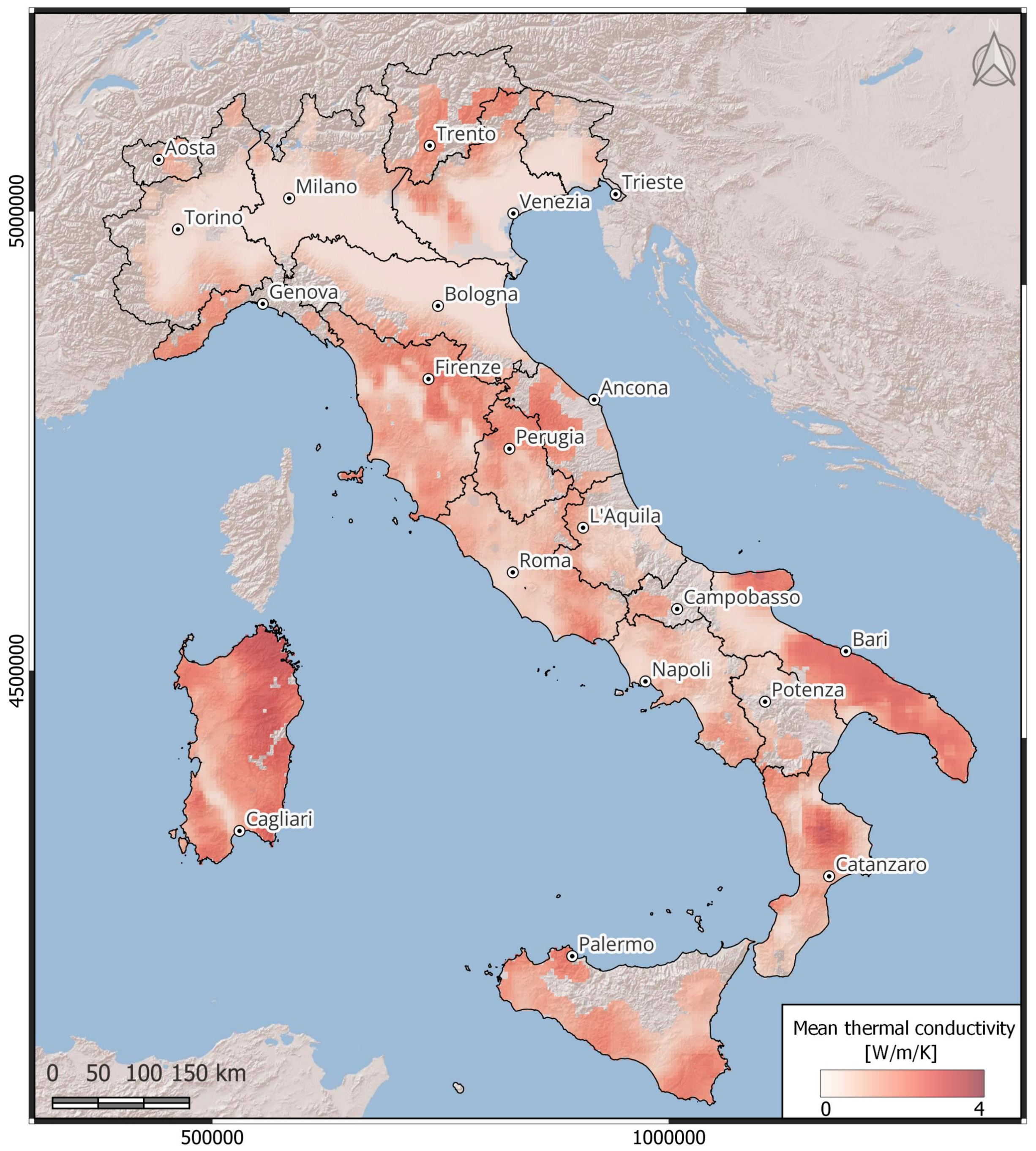

Fig. 4 - *Mean thermal conductivity of shallow subsoils (depth = 70 m), without considering the groundwater input (dry conditions). The map has been produced by interpolating thermal point-like data (Fig. 3-a). Non-mapped areas are not covered by an appropriate amount of data (Reference System: WGS 84 / UTM zone 32N).*

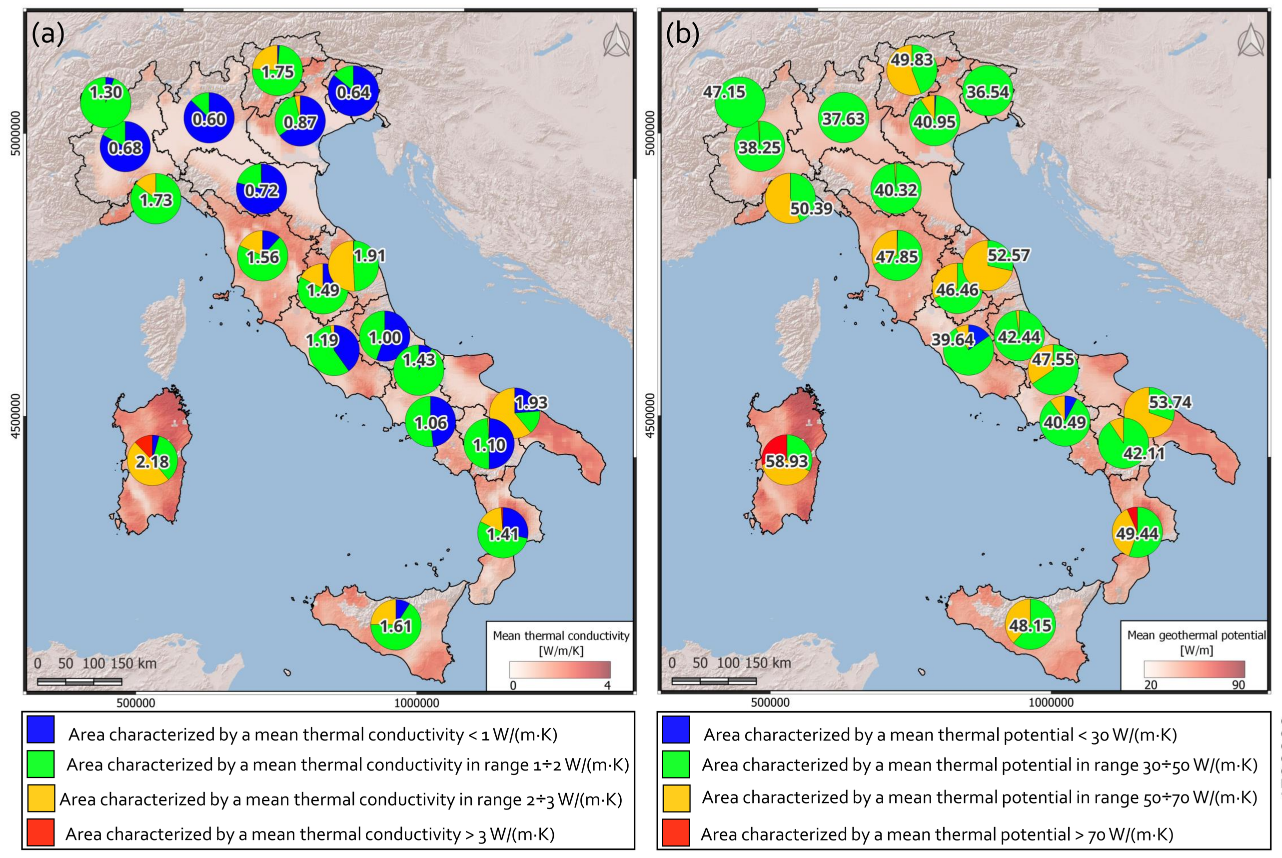

Fig. 5 - *Geothermal properties' distribution into the Italian regions: a) mean thermal conductivity; b) mean geothermal potential. The pie chart of each region shows the amounts of the area characterized by a certain range of values. The plotted numbers indicate the mean regional values.*

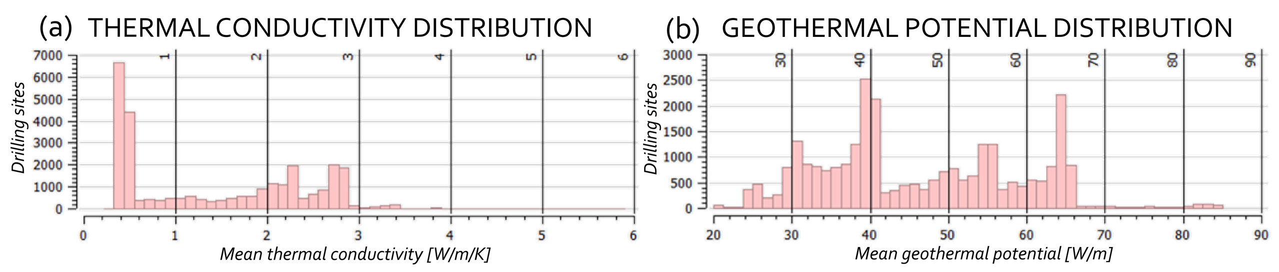

Fig. 6 - *Geothermal point-like data distribution into the Italian area: a) mean thermal conductivity; b) mean geothermal potential. The ordinate indicates the number of drilling sites for each range of values in the histogram.*

SHALLOW GEOTHERMAL POTENTIAL MAP

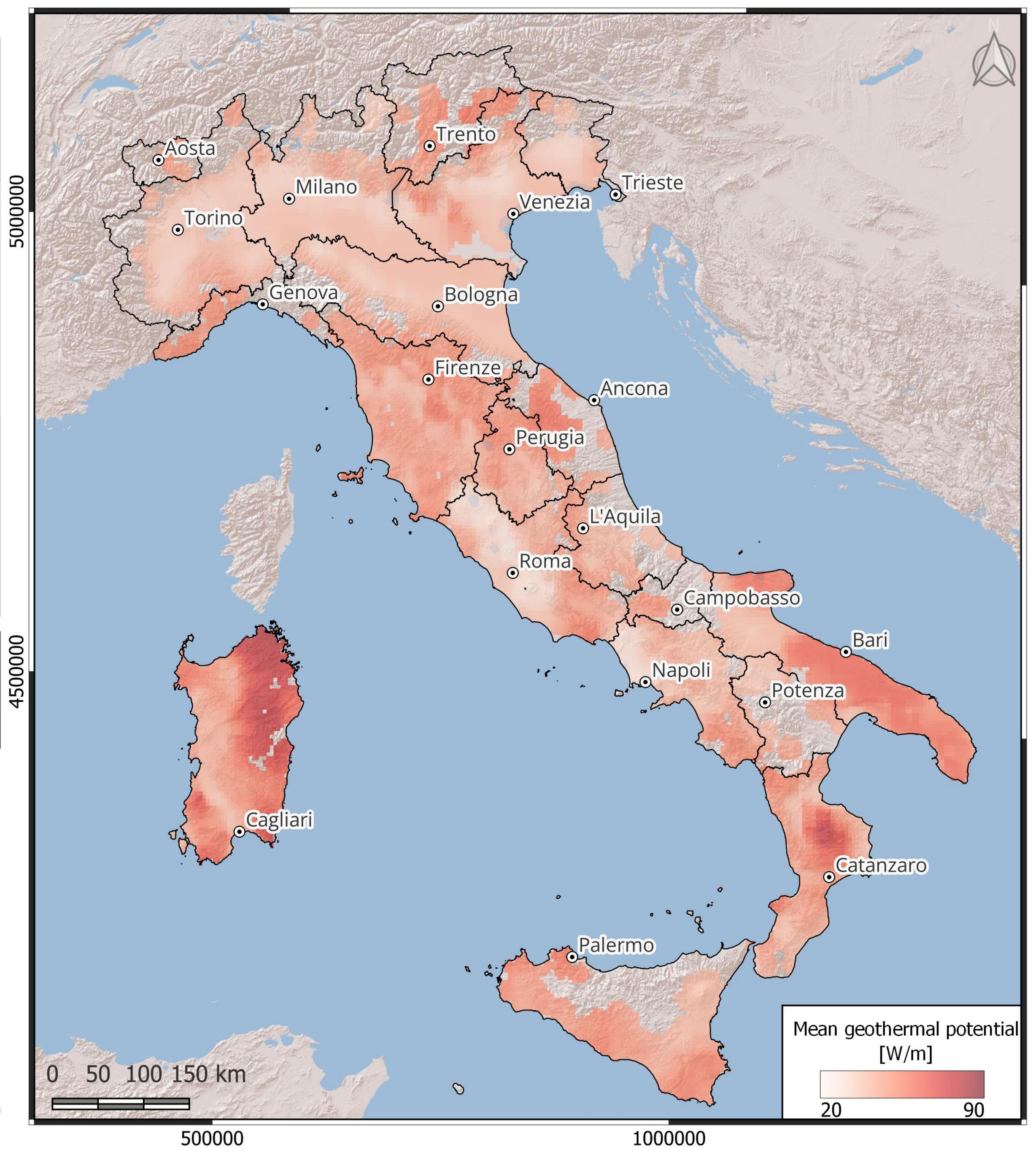

Fig. 7 - *Mean geothermal potential of shallow subsoils (depth = 70 m), without considering the groundwater input (dry conditions). The map has been produced by interpolating thermal point-like data (Fig. 3-b). Non-mapped areas are not covered by an appropriate amount of data (Reference System: WGS 84 / UTM zone 32N).*

NEXT STEPS

Both thermal conductivity and geothermal potential have been mapped starting from literature-available tabulated values. Those values don't take explicitly into account the groundwater input. Since the groundwater flow can especially affect the geothermal potential more steps are needed, such as:

- to find **a proper relationship between thermal conductivity and geothermal potential** based both on the property of the subsoil and the property of the groundwater flow;
- to produce **new geothermal maps**, both in dry and wet conditions (i.e., **considering the groundwater input**);
- to produce geothermal **maps for different ranges of depth** obtaining vertically-detailed information;
- to compute **numerical simulations about a selected study area** and compare the results to the geothermal potential maps.

LINKS

Explore the maps
https://atlanteintegrato.rse-web.it/

Read the abstract
https://meetingorganizer.copernicus.org/EGU25/EGU25-10574.html

Download the report
https://www.rse-web.it/rapporti/

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