Towards the evaluation of the geothermal potential of Italy

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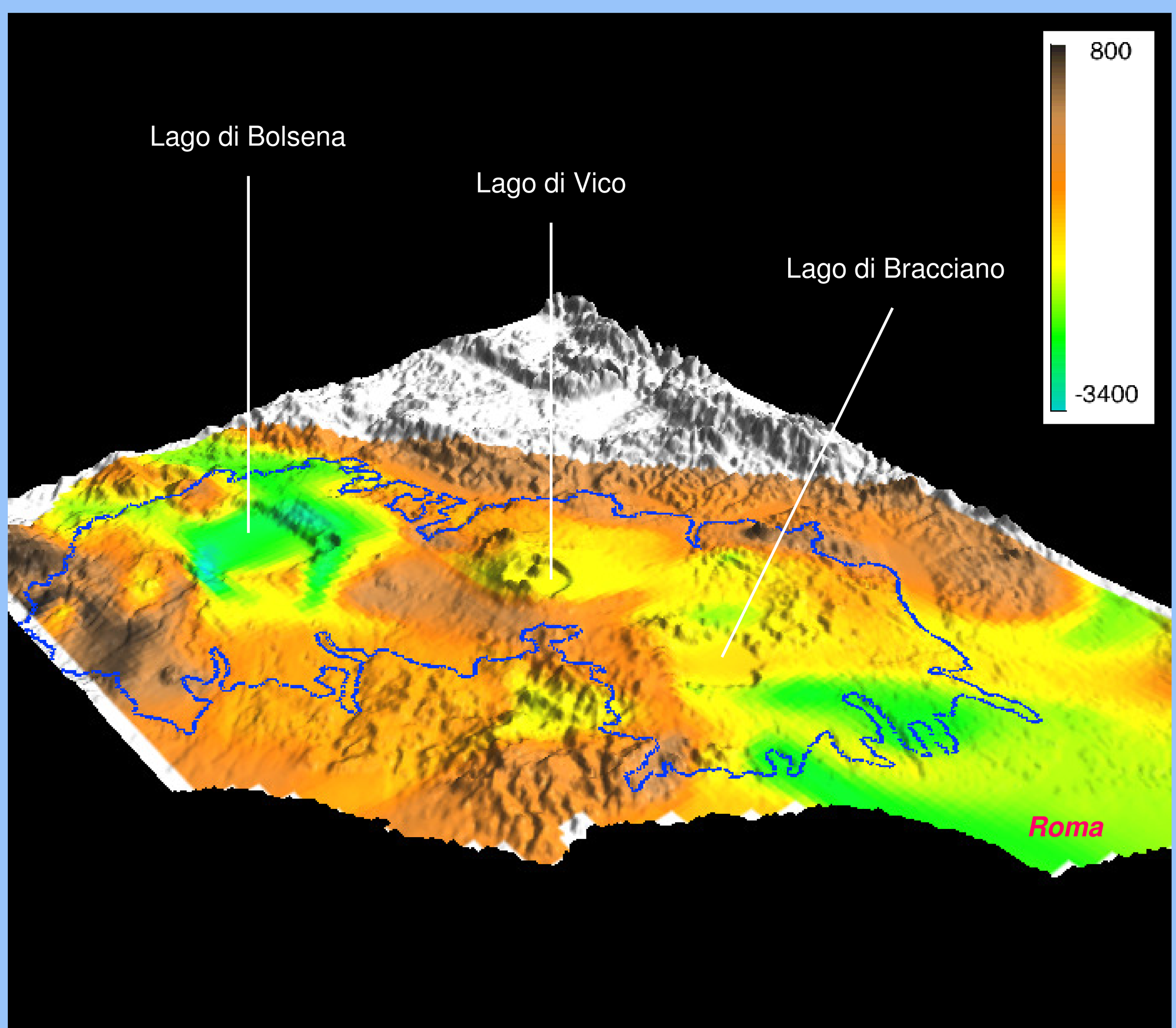
The methods proposed in the past to evaluate the geothermal potential of a given area can be grouped in the following four classes: (a) ***the heat-flow method***; (b) ***the volume method***; (c) ***the planar-fracture method*** and (d) the ***magmatic-heat-balance method*** (Muffler, 1973; Bodvarsson, 1974; Nathenson and Muffler, 1975; Renner et al., 1975; Smith and Shaw, 1975; Muffler and Cataldi, 1978; Cataldi et al., 1978; Cataldi and Squarci, 1978; Cataldi and Celati, 1983; Wohletz and Heiken, 1992).

They were critically re-examined by Marini et al. (1993) who: (1) modified the volume method by taking into account the geochemical data available for shallow groudwaters and gas emissions from soils; (2) calibrated this method based on the production data available for the geothermal fields either under exploitation or explored through deep drilling (Larderello, Travale, Bagnore, Piancastagnaio, Torre Alfina, Latera, Cesano and Mofete); (3) applied the modified volume method to several areas of Italy for which geochemical data are available.

In the ***original volume method***, the heat stored underneath the considered area, until a given depth (which depends on economical and technological parameters), is computed for each of the recognisable geological-hydrogeological units, by means of simple heat balances (e.g., Cataldi et al., 1978). This exercise requires knowledge of the following parameters: volume, porosity and temperature of each unit, density and heat capacity of the rocks, density and heat capacity of the fluids and reference temperature (usually 25°C). A recovery factor is then used to compute the extractable geothermal energy.

In the ***modified volume method***, the areas of high CO_2 flux (recognisable at the surface based on the presence of high-P_{CO2} waters and/or CO_2-rich gas emissions from soils) are used to bound the extension of geothermal reservoirs. This approach is based on the fact that a continuous flux of deep CO2 occurs through all known geothermal systems of medium-high enthalpy in the same manner as the heat flux (e.g., Mahon et al., 1980; Marini and Chiodini, 1994; Gambardella et al., 2004).

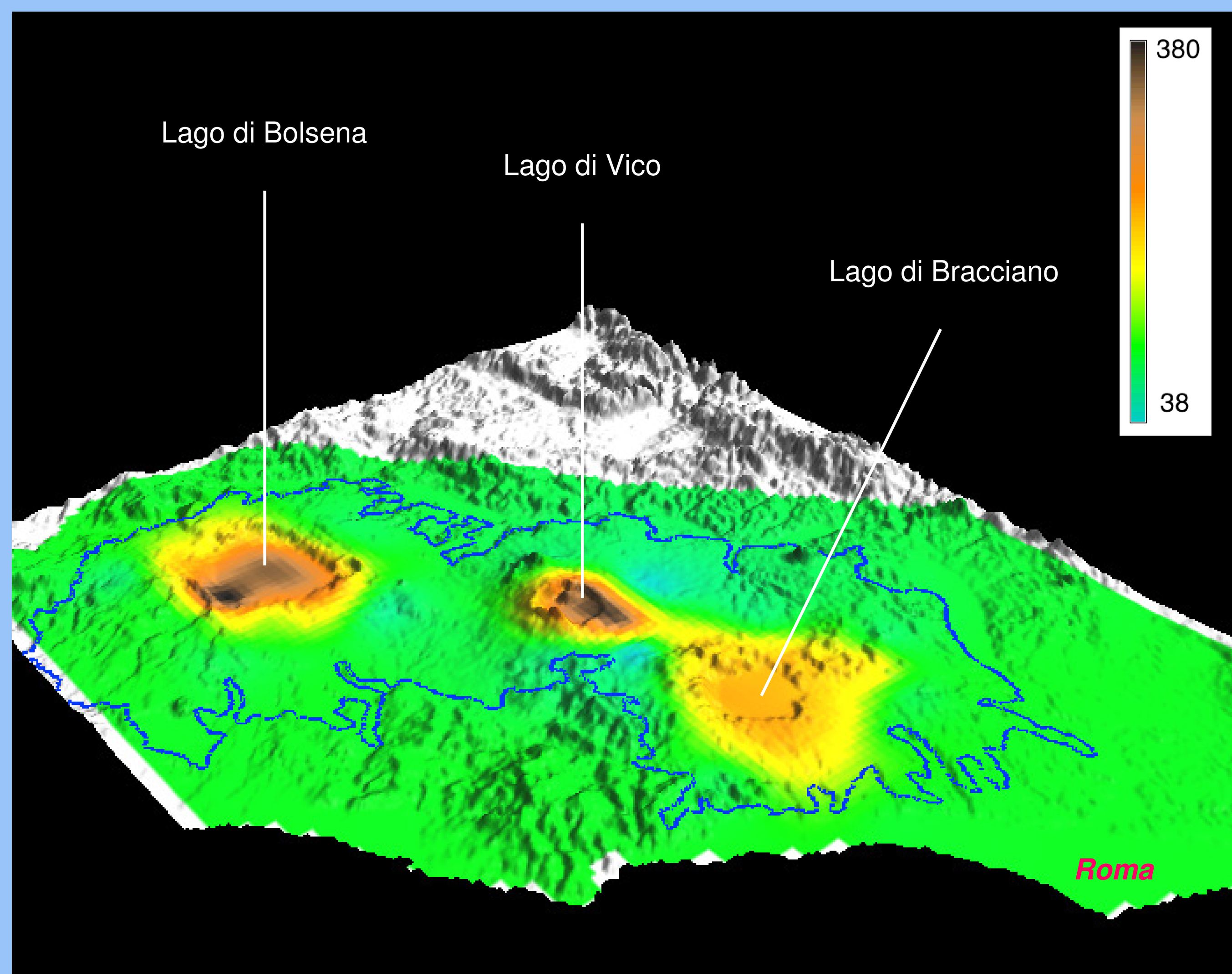


Depth of the top of the potential geothermal reservoir (from Buonasorte et al., 1995)

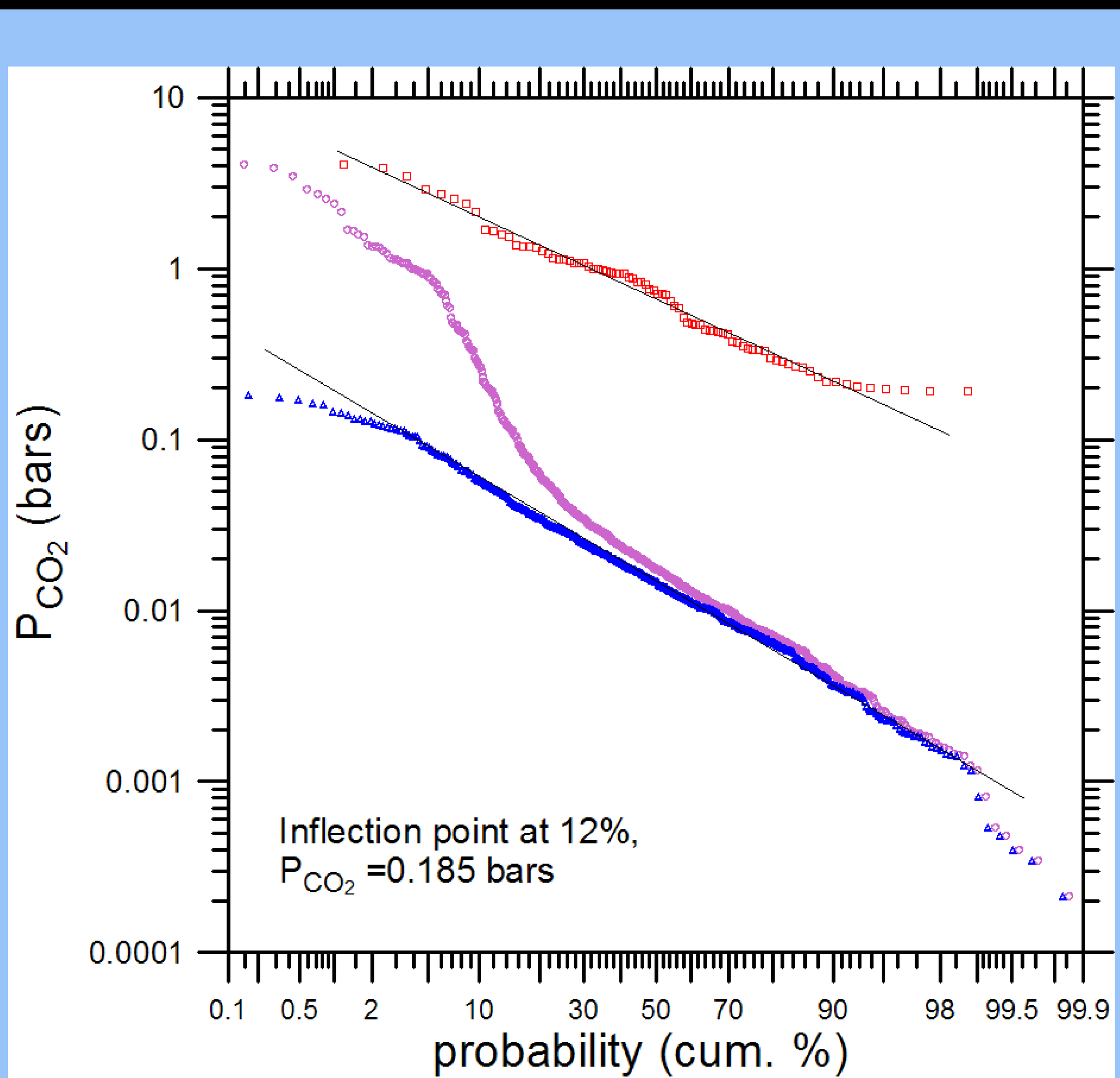
Application of the modified volume method in the Bolsena-Vico-Bracciano area of Central Italy

Here we present an example of application of the modified volume method in the Bolsena-Vico-Bracciano area of Central Italy, comprising the Vulsini-Vico-Sabatini volcanic complexes. It is carried out through the superposition of the maps depicting the geographical distribution of the following parameters:
(a) depth of the top of the potential geothermal reservoir (from Buonasorte et al., 1995);
(b) temperature at the top of the potential geothermal reservoir (from Buonasorte et al., 1995);
(c) P_{CO2} in shallow groundwaters (from Gambardella et al., 2004).

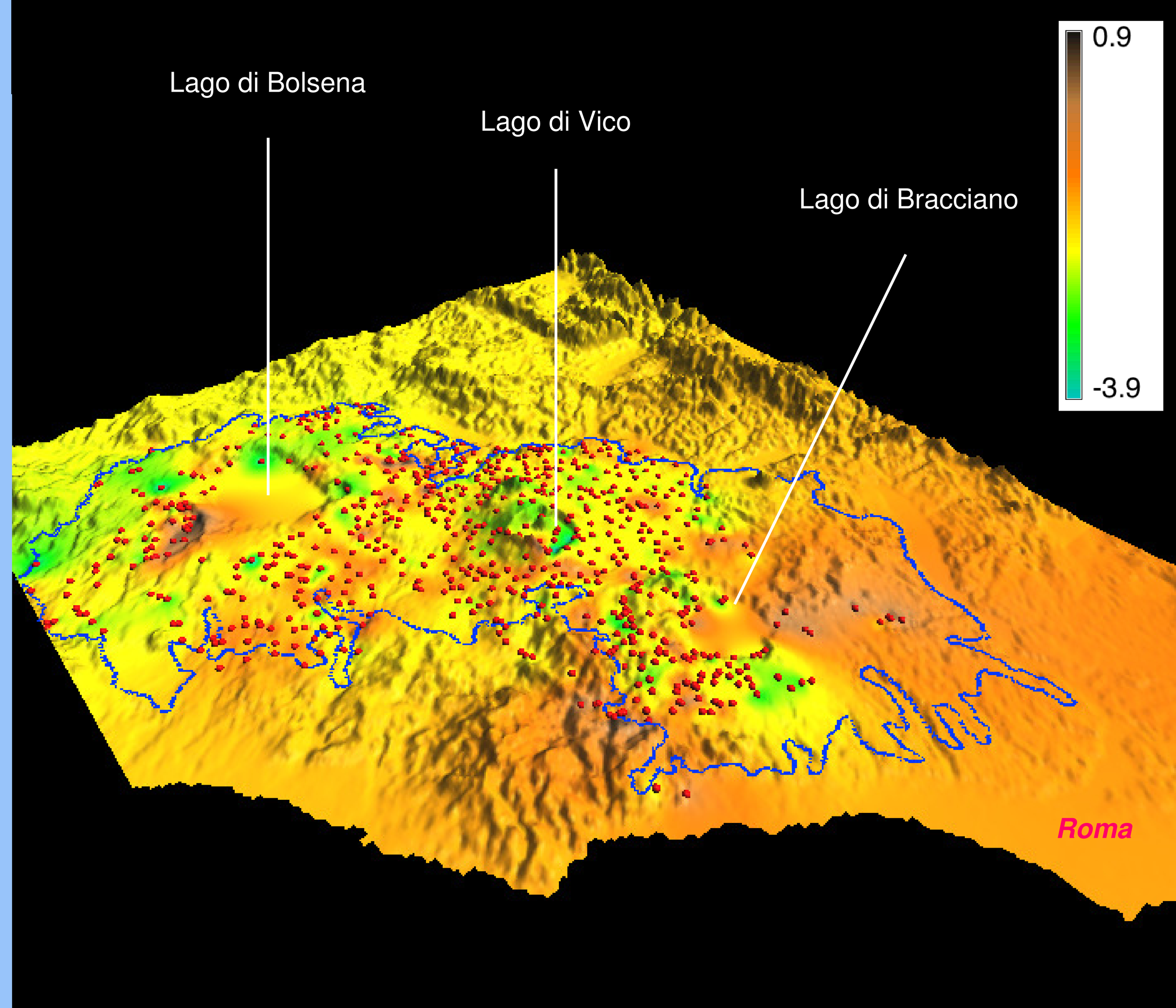
Suitable assumptions (Marini et al., 1993) are adopted to quantify the total volume of the geothermal reservoir and its productivity.



Temperature at the top of the potential geothermal reservoir (from Buonasorte et al., 1995)



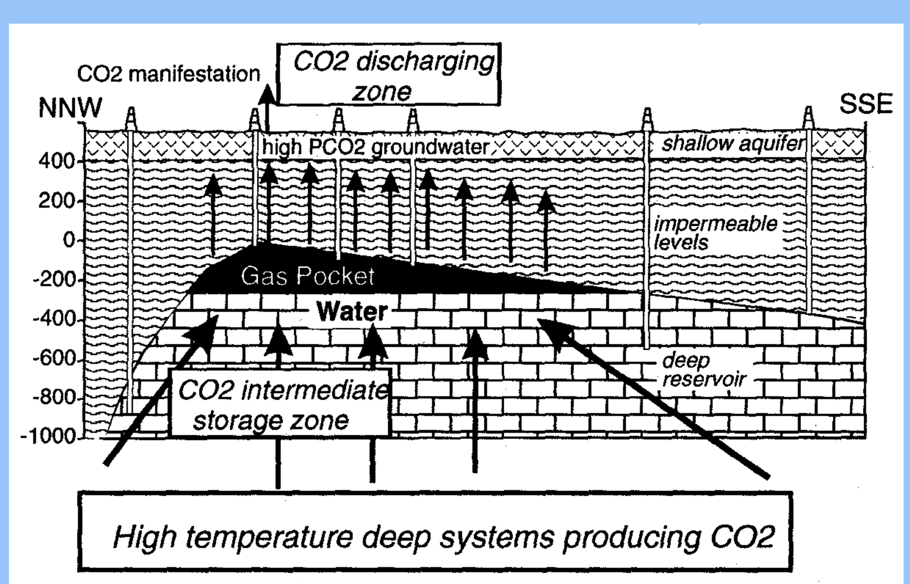
This exercise leads to the identification of:
(1) a total extractable thermal power of 440-550 MWt from conventional geothermal reservoirs with temperature higher than 200°C;
(2) a total extractable thermal power of 1070-1540 MWt from conventional geothermal reservoirs with temperatures of 45-90°C.



Log CO_2 partial pressure of shallow groundwaters

The log-probability plot of the P_{CO2} of shallow groundwaters circulating in volcanic rocks of the Vulsini-Vico-Sabatini volcanic complexes shows a bimodal distribution (purple-violet). Partitioning allows one to recognise the presence of two families of different origin:
(1) deep CO_2, generated through magmatic degassing and/or thermometamorphic reactions in red, and
(2) background (shallow) CO_2 produced through decay of organic substances and root respiration in soils.
The deep CO_2 accumulates in geothermal systems and is released from their upper parts thus entering the overlying shallow groundwaters (Marini and Chiodini, 1994; Gambardella et al., 2004).

Natural gas emissions from soil near Umbertide (Umbria) coloured by using a smoke bomb (photo courtesy by Giovanni Chiodini, INGV-Napoli).



From Barelli et al. (1978)

Conclusions and researches to be carried out in the future

Application of the modified volume methods to other Italian areas for which geochemical data are available allowed Marini et al. (1993) to identify:
(i) geothermal resources with T ≥ 200 °C at depths lower than 3 km, for a total of 4690-5330 MWt
(ii) geothermal resources with 100 < T < 200 °C at depths lower than 1.5 km for a total of 800-990 MWt.
In order to apply this approach to areas where low-enthalpy geothermal resources are present (e.g., the sedimentary basin of the Po Valley in Northern Italy), research must be focussed towards the identification and use of permeability-indicator(s) other than carbon dioxide.