# Exploration and exploitation of the low-enthalpy geothermal resources in the Alpine Chain

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**Abstract:** This work suggests the general criteria for the investigation and the exploitation of the thermal resources present in the Alpine chain. The evaluation of the deep-seated aquifers from which geothermal waters can be extracted is done by means of a multidisciplinary approach that combines geological, hydrogeochemical and economic feasibility studies.

**Key words:** Alpine chain, low-enthalpy geothermal resources, SIG project, marketing analysis

## Introduction

The Alpine chain consists of pre-Triassic basement sheets, Mesozoic carbonatic and terrigenous cover sequences that underwent different grades of metamorphism during the Cretaceous and Tertiary orogenies (Steck & Hunziker, 1994; Escher & Beaumont, 1997 and references therein).

Low-enthalpy geothermal resources in the Central and Western Alps are represented by both springs and inflows in deep Alpine tunnels (Vuataz, 1982, 1997; Bianchetti et al., 1993; Rybach, 1995). The circulation of thermal waters in a mountainous context like the Alpine chain is generally related to the presence of high-permeability zones along which meteoric waters can reach relevant depths and that allow their rapid upflow where morphological and structural conditions are adequate (Martinotti et al., 1999).

The thermal outputs are generally used for balneological purposes and recreation centers which are of great economic importance (Figure 1). However, the efficiency of the geothermal energy is usually limited because, at least in Italy, the available temperature is the discharge temperature of the thermal springs which are in general affected by dilution with cold groundwaters and/or heat loss through conduction.

Geological, hydrogeological and geochemical studies suggest that the real potential of the alpine thermal systems is much higher than that estimated by means of the outlet parameters (i.e., temperature, flows rate, and salinity). Only few geothermal wells have been drilled during the last years, which increase conspicuously the geothermal potential of the target

*Scientific paper*

areas. However, the growing interest of the private sector in this field, especially for tourism, seems to encourage the development of research projects.
To this aim, it is essential to investigate each thermal system from both the technical/scientific and the economic potential point of views. This approach has to be organized in complementary steps in order to individuate the geothermal systems whose utilization is of economic interest.

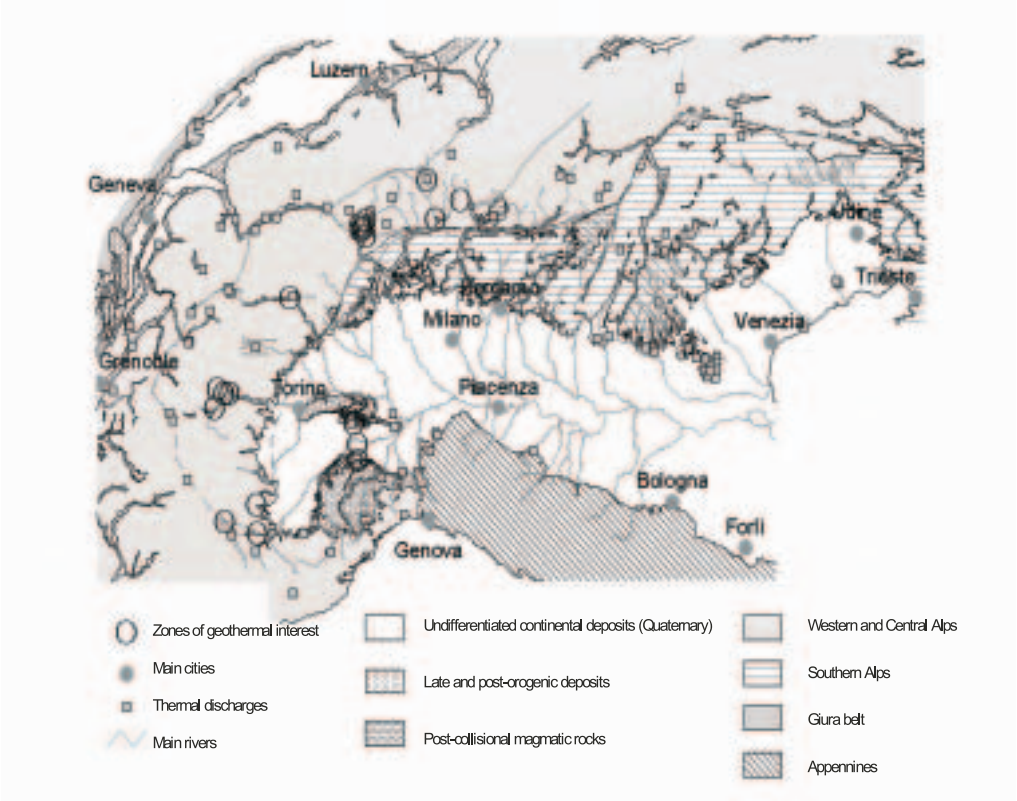


**Figure 1.** Geological sketch map of the Western and Central Alps with the location of the main thermal discharges.

## EVALUATION OF THE GEOTHERMAL RESOURCES

The evaluation of the deep aquifers from which the low-enthalpy geothermal waters can be extracted is a deciding factor for managing the exploitation systems. Since only low-enthalpy resources are known in the alpine framework, their exploitation is addressed to direct uses, such as heating, bathing, and horticulture. The activity might be organized in the following work-stages:

- *Stage 1*: localization of the main geothermal resources through a bibliographic research for elaborating a geological sketch map representing all the thermal springs and

warm inflows in deep tunnels. This map, together with all available data on cold and warm water discharges, tunnels inflows and drillholes, allows the identification of local thermal anomalies and/or the areas of potential geothermal interest;

- *Stage 2*: evaluation of the potential future uses of each thermal system (e.g., bathing, horticulture, and space heating) through a marketing analysis targeted to the quantification of the possible users of the thermal resource;
- *Stage 3*: on the basis of the results reached in the first two stages of the project, the third stage is aimed to investigate the most interesting thermal systems. It includes:
  - A detailed geological and hydrogeological mapping (scale 1:10.000 – 1:5.000), in order to characterize the litho-structural traps with suitable geometry and permeability enabling the occurrence of thermal circuits;
  - A geochemical survey of the cold and warm springs of the studied area, in order to identify the presence of thermal aquifers at depth and to evaluate some of their features. Since the discharge temperatures of thermal waters are generally lower than those present in the deep aquifers of provenance because of mixing with shallow groundwaters and conductive heat loss, geothermometry is essential to estimate the equilibrium temperature between the aqueous solution and the minerals present in the deep reservoir;
  - A preliminary evaluation of the subsoil flow of warm waters by means of geophysical techniques and shallow exploration boreholes.

These complementary steps are essential for modelling the reservoir behaviour during production focused to the management of the exploitation systems and to the evaluation of the durability of the usable resource.

At present, the compilation and the cartographic representation of more than one hundred thermal and mineral spas present in the Italian, French and Swiss part of western and central Alps was carried out by the SEA Consulting in order to assess the future projects of geothermal exploitation. This update of previous synthesis works (Vuataz, 1982; Dazy et al., 1987; Cataldi et al., 1995) includes several new data chiefly acquired through recent drilling activities (mainly deep tunnel construction) and other activities addressed to the exploitation of thermal and mineral waters. Furthermore, the creation of a SIG project allows correlating all the geothermal data (thermal spring localization, heat flow values and subsurface temperature distribution) with geological formations and structural conditions.

## Discussion

All known geothermal resources are of low-enthalpy type ant their presence is clearly related to the structural, tectonic, and lithological setting of the alpine chain. The experience and the know-how acquired so far show that growing exploitation of these geothermal resources is possible under satisfactory technical and economic conditions.

Systematic geothermal investigations, aimed to the acquisition of geological, geochemical, hydrogeological, and thermal parameters (rock temperatures, thermal gradients, heat flow values) allow identifying quite well all those areas, which are potentially important for geothermal energy utilization. The maximum temperatures that can be encountered in the deep aquifers are estimated by means of geothermometric techniques. Most of the geothermal investigations are intended for the further exploration of already known centers in order to increase their capacity or for tapping new aquifers. Furthermore, sites of thermal interest can be identified on the base of their geological and structural characteristics and therefore, geothermal studies might be extended to areas without any surface manifestations. The occurrence of geothermally promising areas can be of great economic importance for the local inhabitants.

## REFERENCES

BIANCHETTI, G., ZUBER, F., VUATAZ, F.-D. & ROUILLER, J.-D. (1993): Hydrogeologische und geothermische Untersuchungen im Simplontunnel. *Beiträge zur Geologie der Schweiz*; Geotechnische Serie, Vol. 88, pp 1-75.

CATALDI, R., MONGELLI, F., SQUARCI, P., TAFFI, L., ZITO, G., & CALORE, C. (1995): Geothermal Ranking of Italian Territory. *Geothermics*; Vol. 24, No. 1, pp. 115-129.

DAZY, J., DRAY, M., JUSSERAND, C., PASQUALOTTO, M. & ZUPPI, G.M. (1987): Caractérisation isotopique des eaux thermominerales des Alpes du nord Franco-Italiennes. In: *Isotopic techniques in water resource development*; IAEA (ed.), pp. 3-24, Vienna.

ESCHER, A. & BEAUMONT, C. (1997): Formation, burial and exhumation of basement nappes at crustal scale; a geometric model based on the Western Swiss-Italian Alps. *J. Struct. Geol*; Vol. 19, pp. 955-974.

MARTINOTTI, G., MARINI, L., HUNZIKER, J.C., PERELLO, P. & PASTORELLI, S. (1999): The Geothermal Ressources of the Ossola-Simplon Region. The Piedilago Case History. *Eclogae Geologicae Helvetiae*; Vol. 92, pp. 295-305.

RYBACH, L. (1995): Thermal waters in deep Alpine tunnels. *Geothermics*; Vol. 24, No. 5-6, pp. 631-637.

STECK, A. & HUNZIKER, J. C. (1994): The Tertiary structural and thermal evolution of the Central Alps - Compressional and extensional structures in an orogenic belt. *Tectonophysics*; Vol. 238, pp. 229-254.

VUATAZ, F. D. (1997): Natural variations in human influences on thermal water resources in the Alpine environment. *Proceeding 33th Conf. Int. Soc. Hydrothermal Tech*, pp. 1-6, Hakone Japan.

VUATAZ, F. D. (1982): Hydrogéologie, géochimie et géothermie des eaux thermales de Suisse et des régions alpines limitrophes. *Matériaux pour la géologie de la Suisse;* Série Hydrogéologie, Vol. 29, pp. 1-174.