IGG

Institute of Geosciences and Earth Resources

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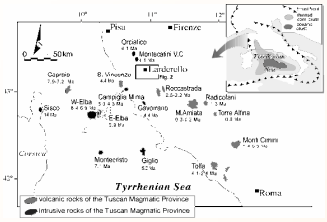
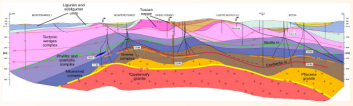
The contribution of IGG to the exploration of the Larderello geothermal area: a multidisciplinary approach

Definition of the contact metamorphic isogrades, ages of granites and contact metamorphic rocks



Location map of igneous and volcanic rocks of the Tuscan Magmatic Province and related ages. Upper right corner: simplified sketch of the geodynamic framework of the Italian peninsula.

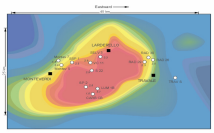
Metamorphic and granitic rocks hosting the deep geothermal reservoir have been studied from various perspectives. Geochemical and petrographic methods have been applied to core samples to study magmatic and hydrothermal minerals and fluid inclusions, and together with geophysical methods were applied to study the signature of geothermal fluid circulation. These studies provided important information regarding the geothermal system and its evolution with time.



Geological structure of a long-living geothermal system

Two main seismic reflectors present below the geothermal area host two different fluids: (1) superheated steam in the upper H-horizon (reached by drillholes) and (2) supercritical fluid in the deeper K-horizon. The productive layers of the deep geothermal reservoir occurs in correspondence of the H-horizon, located at the top of pre-Quaternary granites and within the surrounding contact metamorphic aureoles.

Bertini et al., Terranova (2006)



Ages of granites and contact metamorphic rocks

New and published ages (at 2001) of granites and contact metamorphic rocks at Larderello, compared with the isobaths of a main seismic reflector (K horizon).

The sampling depth varies between 2200 and 4300 m b. g. l., and the temperature ranges between 260 ° and 400 °C.

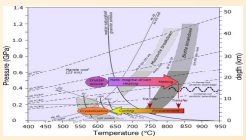
Gianelli & Laurenzi, Geotherm. Res. Counc. Trans. (2001)

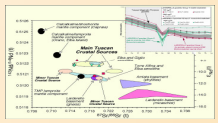
Granite intrusions

Several intrusions (monzogranites and syenogranites) of Pliocene to Quaternary ages (3.8 - 1.0 Ma) have been drilled at depth of 2000-4600 m. The magmas were produced by crustal melting that was triggered by sequential intrusion of mafic magmas at about 15-20 km depth. The acidic magmas derived from two types of melting (muscovite- and biotite-breakdown), and were characterized by rapid melting and transfer of anatectic magmas in the shallow crust (Sr isotope disequilibrium).

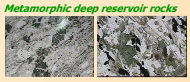
The high B, F and Li content found in the intrusions extend the "life" of magma and complete crystallization is reached at about 550°- 650°C temperature. Prolonged life of geothermal system can be attributed to the sequential emplacement of granite magmas in the shallow crust coupled with the emplacement of mafic magmas at depth and with the regional thermal anomaly (mantle upwelling).

Dini et al., Lithos (2005)

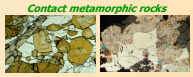




Metamorphic deep reservoir rocks



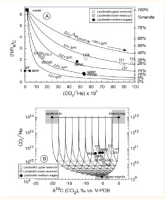
Contact metamorphic rocks



Granites

Stable, C and Noble Gases isotopes in present days and paleofluids in order to define the source and evolution of fluid phases

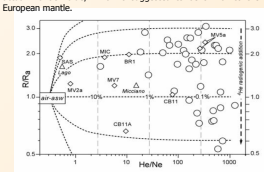
Present-day geothermal fluids: C isotopic composition



The CO2 ($\delta^{13}C$ from −1.4 to −7.1‰ versus V-PDB) is mainly of crustal origin. The carbon isotopes of methane ($\delta^{13}C$ from −20.9 to −31.7‰) and other hydrocarbons indicate a complex thermogenic origin. The temperatures obtained with the CH_4–CO_2 isotope geothermometer are in rough agreement with those observed in deeper geothermal wells. The CH_4/C_2H_6 ratios show a tendency towards partial equilibrium with increasing temperature.

Gherardi, et al. Geothermics (2005)

Plots of R/RA and $\delta^{13}C$ (CO_2) vs. $CO_2/^3He$ for Larderello gases.
A-Mixing lines between mantle gases (R/R_A = 6.4,$CO_2/^3He$ = 1.5×10^9) and several crustal components characterised by constant helium ratio (R/R_A = 0.02) and variable $CO_2/^3He$ ratios.
B-Mixing lines between organic sediments, upper mantle and marine limestones end-members.
The end-members values: $\delta^{13}C$ (CO_2) = −20, −5, and 0‰; and $CO_2/^3He$=1×10^{12}, 1.5×10^9, and 1×10^{21}.

Present-day and paleo fluids: He isotopic composition

A deep magma source, refilled by periodic gas input from the mantle, is the most likely source of ^3He-enriched fluids and the anomalously high heat flow. The nearly constant value of R/Ra clearly indicates that input of fresh mantle material has occurred up to recent times. Clear evidence of mixing between mantle and crustal fluids indicates that the high R/Ra is the lower limit of the actual mantle value, which is suggested to be similar to the subcontinental European mantle.