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Data integration and conceptual modelling of the Larderello geothermal area, Italy

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The Larderello geothermal field, located in southern Tuscany (Italy), is one of the most important long-living hydrothermal system in the world. The inner zone of the Northern Apennines is characterized by high heat flow, well constrained by several hundred measurements deriving from both shallow boreholes and deep exploration wells. It is widely accepted that the interplay among extensional tectonics, thinning of the previously overthickened crust and lithosphere, and magmatism related to crustal melting and hybridism, controlled the NW-SE trending geothermal anomaly occurring in southern Tuscany.
At Larderello, the geothermal exploitation started at the beginning of the last century from the shallow evaporite-carbonate reservoir (about 700 – 1000 m b.g.l. on average) hosting a super-heated steam with temperature ranging from 150°C to 260°C. A deep exploration program was carried out in the early 1980s. Deep boreholes found a super-heated steam-dominated system hosted in the metamorphic basement (about 2500 – 4000 m b.g.l), characterized by temperatures ranging from 300°C to 350°C. In the SW part of the Larderello area (Lago locality), a temperature exceeding 400°C was measured down to 3000 m b.s.l. The 2D and 3D seismic exploration activities provided evidences of a seismic marker, locally showing bright spot features, defining the top of a deeper reflective crustal interval, named as “K-horizon”. The K-horizon has not yet been drilled, but some boreholes approached it. This seismic reflector exhibits interesting positive correlation with the maximum peak of the hypocentre distribution of low-magnitude earthquakes and, at the same time, its shape coincides with the thermal anomaly distribution, in plain view.
The review and updating of the velocity and resistivity models suggest the existence of over-pressurized fluids, likely of magmatic and/or thermo-metamorphic origin, which originate the seismic velocity anomalies. The upward migration and storage of the fluids can be controlled by: i) structural conduits crossing a multi-layered crust affected by magmatic intrusions; ii) mechanisms controlling the fluid migration in different rheological settings; and iii) self-sealing processes of magmatic hypersaline fluids arising from the brittle/ductile transition. Our study is addressed to the better understanding of the structure of the deepest part of the Larderello geothermal field, by integrating structural, geological, geochemical and geophysical data. Based on downward temperature extrapolation, fluid inclusions and geothermometers analyses, the possible occurrence of super-hot fluids, in super-critical conditions, nearby the K-horizon is envisaged. The final goal is to achieve a comprehensive understanding of the geological structure and the physical conditions (pressure and temperature) of the deep reservoir including also the zone corresponding to the K-horizon, to characterize the supercritical geothermal system as well as the deep crustal processes that work in synergy leading to the regional anomaly.