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Local Earthquake Tomography of the Larderello-Travale Geothermal Field

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Located in central Tuscany (Italy), the Larderello-Travale Geothermal Field (LTGF) is one of the major vapor-based geothermal fields in the world. Currently, its running capacity amounts to about 10% of the global geothermal electric energy production, and it contributes to almost 2% of the Italian power needs in Italy. LTGF is among the most studied and well-known geothermal systems, for what concerns both its geological features and sustainability and efficiency of the whole exploitation cycle.

This local earthquake tomography (LET) study provides a new 3D velocity model of the upper crust beneath the geothermal field based on inversion of P-wave travel-times from micro-seismicity (M<3) observations. The dataset was obtained in the frame of a specific experiment (Geothermal Area Passive Seismic Sources - GAPSS) carried out by Istituto Nazionale di Geofisica e Vulcanologia (INGV) during May 2012 and November 2013. The experiment consisted in the deployment of ~23 temporary stations complemented by 2 permanent stations belonging to the Italian national seismic monitoring array. The initial dataset consisted of about 2600 earthquakes, whose waveforms were repicked using a semi-automated procedure in order to obtain a highly precise and consistent dataset of traveltimes observations. A representative subsets of events (reference dataset) was then selected considering the quality of the observations, source magnitude and hypocentral distribution. This reference dataset was manually re-picked and used for the subsequent tuning of an automatic picker in terms of timing and quality estimation of the time pickings. We adopted an innovative, iterative picking procedure whose results were subsequently used as input for the advanced MannekenPix (MPX) algorithm. The final, repicked high-quality dataset was then used to find a minimum 1D model for the study area.

After numerous resolution tests, we found that the best resolution was achieved with a model parameterized by a grid whose nodes are spaced by 5 km and 2.5 km along the horizontal and vertical directions, respectively. Using the SimulPS_14q inversion procedure, a final model is achieved after 5 iterations with an 80% variance reduction and a solution RMS on the order of 70 ms with an average input error uncertainties of 60 ms.

The inversion's results are compared with some available cross-sections from active seismic profiles. The 3D P-velocity structure seems to be more affected by the geothermal features than by lithological boundaries. In particular, the 5.2 km/s P-wave velocity isoline correlates well with a regional high-reflectivity horizon (the so-called K-horizon) which is thought to delineate the 450°C isotherm. Our results clearly outline the main dome-shaped, Pliocene granitic intrusion as well as the abundant presence of fluids, imaged as low-velocity anomalies beneath the most active wells. Overall, these data open new perspectives on application of LET imaging techniques for the exploration of the geothermal resource at crustal depths.