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Passive, broad-band seismic measurements for geothermal exploration : The GAPSS experiment

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Passive seismological imaging techniques based on either transient (earthquakes) or sustained (background noise) signals can provide detailed descriptions of subsurface attributes as seismic velocity, attenuation, and anisotropy. However, the correspondence between these parameters and the physical properties of crustal fluids is still ambiguous. Moreover, the resolving capabilities and condition of applicability of emerging techniques such as the Ambient Noise Tomography are still to be investigated thoroughly. Following these arguments, a specific project (GAPSS-Geothermal Area Passive Seismic Sources) was planned, in order to test passive exploration methods on a well-known geothermal area, namely the Larderello-Travale Geothermal Field (LTGF). This geothermal area is located in the western part of Tuscany (Italy), and it is the most ancient geothermal power field of the world. Heat flow in this area can reach local peaks of 1000 mW/m3. The deep explorations in this area showed a deeper reservoir (3000 to 4000 m depth) located within the metamorphic rocks in the contact aureole of the Pliocene-Quaternary granites; it is characterized by a wide negative gravimetric anomaly, interpreted as partially molten granite at temperatures of 800°C. From seismic surveys the K-marker K (pressurized horizons) was found at depths between 3 and 7 km. The structural grain of the geothermal field is characterized by N-W trending and N-E dipping normal faults whose activity lasts since the Pliocene.

GAPSS lasted from early May, 2012, through October, 2013. It consisted of up to 20 temporary seismic stations, complemented by two permanent stations from the National Seismic Network of Italy. The resulting array has an aperture of about 50 Km, with station spacings between 2 and 50 km. Stations are equipped with either broadband (40s and 120s) or intermediate-period (5s), 3-components seismometers. LTGF is seismically active. During the first 10 months of measurements, we located more than 1000 earthquakes, with a peak rate of up to 40 shocks/day. Preliminary results from analysis of these signals include: (i) The analysis of clustered microearthquakes likely resulting from re-injection processes, thus allowing for the detailed determination of the temporal and magnitude distributions which are likely indicators of induced seismicity; (ii) Seismic noise analysis for deriving the 0.05-0.5 Hz dispersive properties of the noise wavefield, which are inverted for shear-wave velocity profiles; (iii) The analysis of Shear-Wave-Splitting from local earthquake data, from which we found an anisotropic layer which correlates well with the K-horizon; (iv) Local-earthquake Travel-Time tomography for both P- and S-wave velocities, and (v) telesismic receiver function aimed at determining the high-resolution (<0.5km) S-velocity structure over the 0-10km depth range, and seismic anisotropy using the decomposition of the angular harmonics of the RF data-set. This latter technique decouples the P-to-S converted energy generated at isotropic discontinuity from energy generated within an anisotropic body. In this manner, we are able to precisely locate the source of the seismic anisotropy at depth. In this communication we present preliminary results from these analysis, I turn discussing their applicability to the exploration of geothermal resources.