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Long-term behavior of wastewater injection induced seismicity at the Costa Molina 2 well in the Val d'Agri oil field (Southern Apennines, Italy).

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The Val d'Agri basin in the Southern Apennines hosts the largest onshore oilfield in Europe. Co-produced saltwater is re-injected at ∼3 km depth b.s.l. in the Costa Molina 2 (CM2) well located at a marginal portion of the carbonate reservoir. The re-injection started on June 1st 2006 and has continued since then without major interruptions: injection rate and well-head pressure reached maximum values of 2800–3000 m3/d and 13–14 MPa, respectively.
Injection induced seismicity (IIS) has been observed since the beginning of disposal at CM2. During the first 12 days (1-12 June 2006) high-quality recordings from a dense temporary seismic network run by INGV allowed the detailed observation of a swarm of 109 induced micro-earthquakes (0.0<ML<1.7, with a completeness magnitude MC of 0.4), occurring between 3.5 and 4.5 km depth on a unknown NE-dipping fault located just below the CM2 well. The seismicity rate is strongly correlated with the hourly well-head injection pressure furnished by the local oil company ENI.
After the removal of the temporary network on 13 June 2006, IIS has continued to be recorded by the ENI monitoring network consisting of 13 trigger mode stations This network allowed the detection of 214 micro-earthquakes (0.1<ML<2.0, MC =1.1) occurred between 13 June 2006 and 31 December 2013, within 5 km from CM2. A large part of the 2006-2013 IIS was also recorded by six INGV permanent stations of the National Seismic Network located within 30 km from the injection well. A 3D velocity model obtained by a reservoir-scale LET survey indicates that the injection reservoir is characterized by a widespread network of conductive fractures that favors the rapid transmission of pore pressure perturbations from the wellbore to the nearby high-permeability fault zone. The presence of continuously recording permanent stations run by INGV offers the opportunity to search for undetected earthquakes in proximity to CM2 well by using the cross-correlation (CC) matched filter technique. Our goal is to reduce the MC of the 2006-2013 catalog and to extend it up to 2017. We selected 88 templates characterized by best SN-ratio from the 2006-2013 catalogue and searched for matching events within the continuous data stream of the two closest INGV stations located at 15 and 16 km distance from CM2 well.
Using a CC coefficient threshold of 0.6 and visually inspecting the newly detected events, we were able to identify about 400 additional earthquakes. The extended catalog was used to compute the following long-term observables: i) Seismicity rate; ii) Vp/Vs ratio; iii) Shear wave anisotropic parameters (delay-time and polarization-direction); iv) Attenuation parameters. Moreover for events showing clear P-and-S-wave arrivals for at least 3 stations we computed absolute locations using the 3D tomographic model and double-difference locations for better imaging of the activated fault geometry and investigating the spatio-temporal evolution of the IIS. The 2006-2017 long-term extended catalogue has been compared to the daily injection data for a better insight of IIS occurring at CM2.