Geophysical Research Abstracts
Vol. 21, EGU2019-4443, 2019
EGU General Assembly 2019

Three ML $\geq$ 5 into the Cavone oilfield (Central-Northern Italy) during the 2012 Emilia sequence: is there possibility of energy tuning due to the injection/extraction activities and related stress changes?

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The Cavone oilfield is located on top of the Mirandola anticline, the bulge of an imbricated and buried fault-and-fold system. The oil production in Cavone began in 1982 with twenty-two wells. Since 1992, an increasing amount of water has been extracted with crude oil and re-injected mostly via the Cavone 14 well. Wastewater reinjection activities continued until before the mainshock. The effects of the depletion and injection activities have been studied by using seismological, numerical and probabilistic approaches by scienti[U+FB01]c commissions engaged by public and private stakeholders. They reported complementary and contrasting scenarios on the potential trigger mechanism ascribable to the exploitation of the oil[U+FB01]eld. Further analytical and numerical models found negligible or negative stress changes due to the exploitation activity in the hypocenter area of the May 20th event, excluding stress changes from injection and production activities as potential triggers of the 2012 earthquake sequence.
Although the two large mainshocks occurred at some distance from the oil field (15 to 7 km), several M5 earthquakes occurred mostly within the exploited anticline a few hours after the second large shock. The main goal of this study is to better understand if there have been any individual and/or overlapped effects able to promote or mitigate the energy release by the M5 earthquakes within the Cavone oilfield. We focus our attention on the stress changes due to the two main-shocks, to the injection/extraction activities and on the earthquakes-sources type. We re-analyze about 1800 earthquakes collected during the 20 May to 30 June 2012 in the area hit by the Emilia seismic sequence by integrating three different permanent and temporary networks, focusing on the area below the Cavone field and Mirandola anticline structure. Starting from absolute 3D locations, we compute high-resolution relative locations by integrating cross-correlation and double-difference methods. We then analyzed the Full Moment Tensor (Non-Double-Couple components) parameters (e.g. Mw, plunge and azimuth of T-P-B axes, style of faulting, orientation of nodal planes) of a selected sub-set of earthquakes by using high resolution locations and velocity models; the key parameter in phase input-data is the area (and related polarity) of the first P-wave Ground Displacement pulse (time domain, vertical components) computed for each event and for each station.
We also study the static stress changes between the largest 20 and 29 May earthquakes by refining main source geometries and computing the Coulomb Failure Function (ΔCFF). In addition, we calculated the ΔCFF induced by both mainshocks on the close faults as the western lateral ramp of the Mirandola thrust and on the reservoir, in order to evaluate the stress changes eventually induced by the mainshocks on the structures and their interaction with the Cavone oil filed. Finally, we used the high-quality locations to compute a 3-D velocity Vp and Vp/Vs model by L.E.T. tomography. Vertical and horizontal slices provide high quality images where the main features of tectonic structures, earthquakes distribution and migration could be investigated together with the stress changes and the analysis of the earthquakes sources and mechanisms.