SPATIAL AND TEMPORAL EVOLUTION OF A MICROSEISMIC SWARM INDUCED BY WATER INJECTION IN THE ARKEMA-VAUVERT SALT FIELD (SOUTH OF FRANCE) FOR i-DUST 2010, Apt, France

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ABSTRACT

We investigate the microseismic activity induced in the Arkema-Vauvert salt field by water injections. We focus particularly on the determination of the focal mechanisms providing information on the faults geometry and fracturing process. First, we perform preliminary tests showing that the determination of the double-couple focal mechanism from the two 3-components permanent sensors deployed in the field is reliable. Next, we study the swarm of microseismicity induced by the activity of the PA22-PA23 doublet. The spatio-temporal evolution of the microseismicity during 21 months is correlated to the water-injection operations. Most of the focal mechanisms are "dip-slip" fault type in accordance with geological structures identified in the reservoir.

INTRODUCTION

Arkema produces brine at its Vauvert production facility (in southern France). Brine is produced by solution mining a salt layer between 1900 and 3000 m in depth. The layer consists of about one-half rock salt and another half of insoluble rock (anhydrite and clay) [1]. The production of the salt is carried out by water circulation within fractured zones between an injection well and a brine production well, forming a doublet [2]. As a result of this activity, more than 125,000 microearthquakes (-3 < Mw < -0.5) have been located from 1992 (monitoring start date) to the end of 2007. This seismicity is recorded by two permanent 3-components borehole sensors (M0 and M1).

PRELIMINARY TESTS

We study a data set of 15 earthquakes recorded by the two permanent borehole 3-components sensors plus a temporary borehole tool-string (A3) composed of four 3-components sensors [3]. The earthquakes are located using the P- and S-wave arrival times and the P-wave polarization. The double-couple focal mechanisms (FM) and the associated uncertainties are computed by inverting the amplitudes of the direct P, Sv and Sh direct waves [4]. Fig. 1 displays the FM given by the P, Sv Sh amplitudes of the permanent stations M0 and M1 plus the P amplitudes of the temporary tool-string (inversion #1) and the FM given by the P, Sv and Sh amplitudes of the two permanent stations only (inversion #2). The FM of the events located between the two permanent stations are globally similar in inversion #1 and in inversion #2. This indicates that the determination of the double-couple FM from the data of the two permanent stations is reliable for events located between them.

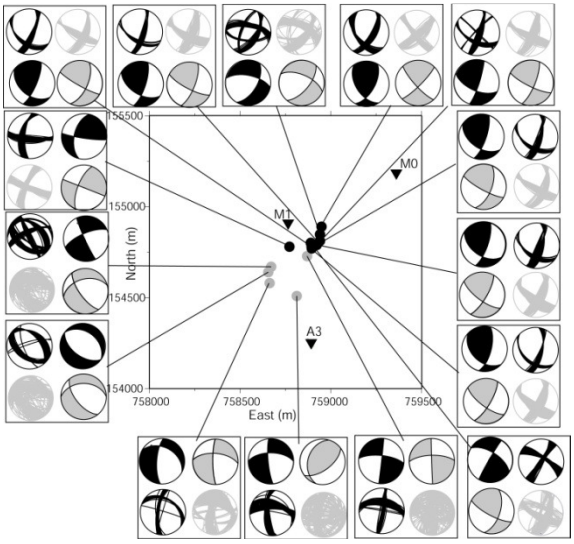

Fig. 1 Focal mechanisms and associated uncertainties given by the inversion #1 (permanent stations plus temporary tool-string, black) and by inversion #2 (permanent stations only, grey). Black dots indicate the earthquakes whose the FM is constrained by the inversion #2 (between the permanent stations) and grey dots the earthquakes whose the FM is unconstrained (outside the permanent network).

ANALYSIS OF THE PA22-PA23 SWARM

We study the microseismic activity related to the exploitation of the well-doublet PA22-PA23 and located

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between the permanent stations. During 21 months (January 2004 – September 2005), 1214 events have been located around the thrust fault D2 (Fig. 2). The analysis of locations and pressure of the wells PA22 and PA23 underlines (1) three distinct periods in the seismicity related to the injection operations and (2) a hydraulic connection between the wells through a major thrust fault (D2).

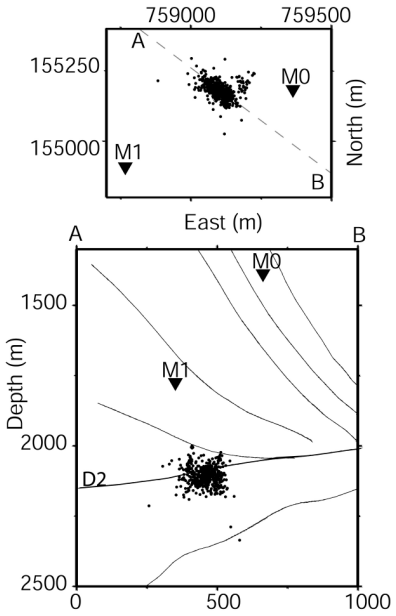

Fig. 2 Map and cross-section of the microseismicity (1214 events) induced by the exploitation of the doublet PA22-PA23. Fault planes identified in the field are represented by the black segments on the cross section.

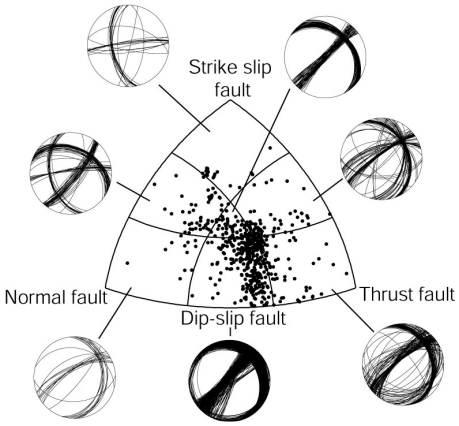

Fig. 3 Focal mechanism of 532 events (black dots) plotted in a ternary diagram [5]. The diagram is divided in 7 areas corresponding to a type of focal mechanism. The stereodiagrams display the focal mechanisms of the events enclosed in each area of the ternary diagram.

The double-couple FM are determined for 532 events and plotted in a ternary diagram [5]. These FM globally correspond to a "dip-slip" fault type with sub-horizontal NE-SW and sub-vertical N-S nodal planes (Fig. 3). These results may indicate (1) ruptures along the major sub-horizontal NE-SW thrust fault D2 or (2) ruptures along N-S sub-vertical stratigraphic planes of insoluble rocks intercalated in the salt series.

Although we obtain an estimation of the geometry of the active faults, the configuration of the permanent network deployed in the field (two 3-components sensors) prevents to investigate more in details the rupture process responsible of the microseismicity. Additional stations would be required to improve the velocity model, the locations and the focal mechanisms. A denser seismic network could also allow determining the moment tensors and investigating non-double-couple rupture process.

CONCLUSIONS

(1) The determination of the double-couple focal mechanism from the two 3-components permanent sensors deployed in the Vauvert salt-field is reliable for events located between them.
(2) The spatio-temporal evolution of the microseismicity related to the exploitation of the doublet PA22-PA23 is correlated to the water-injection operations.
(3) Most of the focal mechanisms are "dip-slip" fault type in accordance with geological structures identified in the reservoir.
(4) The configuration of the permanent network (two 3-components) is a limitation for a detailed study of the seismicity. Additional stations are recommended for the understanding of the rupture process in the field.

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