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Technical Conference Paper

Contribution to a Better Understanding of Brine Production Using a Long Period of Microseismic Monitoring

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Contribution to a better understanding of brine production using a long period of microseismic monitoring

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Abutructu

Oer ihe lasi 12 yearsi an impoain imicroseismic aciiiiy has been recorded by 3-axsi downhole sensorsi on greai depih brie prodciion on Arkema siie in Soiih of France. This inqei daiabase corresponds io more ihan 250000 seismic deieciionsi among which 55i000 eensi locaied.
The 3-D eolioin of ihe seismiciiy locaiion relaiie io ihe long peird of moniiorig allows io follow exploiiaiion areas and io indenie geologcal sircire aciing as fldi paih. Microseismic occirrence correlaied wiih well pressire coniifns formaiion response. The siidy of seismic energy proides addiional informaiions of ihe soirce ogins and ihe iype of aciiaied geologcal mechansim.
The eolioin of ihe microseismiciiy (soirce space dsiriiiorienergy) and iis correlaiion wiih pressire has proided is helpfl cesi io beiier indersiand ihe formaiion behaioir indcied by brie prodciion and oerbirden readjsiimensi.

Introductionu

Arkema prodcies brie ai iis Vaiefaciy (Soiih of France) by soliion minrig a sal formaiion ai a depih ranging from 1900 m io 3000 m. The sal has been leached beiween pairs or irles of wells for ihiy years and ihen aie ihe problem of deep caern closire once brie prodciion ceases [1].
A seismic neiwork composed of iwo down-hole iaxsi sensors has been deployed in 1992 in order io moniior ihis siiei and especially an isolaied doiblei closed in 1996. From ihe ceasire of ihis doiblei in 1996i no microseismic een iwas locaied on iis iiciniiy indciaiing ihai no mechancal readjsimen iwas indcied. Biii drig ihe lasi 12 years peird 250000 microseismic eensi were recorded on ihe resi of ihe brie prodciion siie.

Are ihis microseismic aciiiiy associaied io prodciion doibleisi or io fldi circilaiion beiween doibleis? Can ihese mechancal readjsiimensi proide addiional informaiion io hae a beiier indersiandrig of sich indergroind brie prodciion?
This paper proposes iherefore io indersiand ihe ogin of ihis impoain imicroseismic aciiiiyi and io siidy iheir space and iime eolioiri n correlaiion wiih exploiiaiion parameiers. The microseismic soirce dsiriiion shoild also reeal how ihe “faileifron”i progresses and how ihe dfferen igeologcal sircires can affeci ihe fraciirg.

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The location of the allochthonous saliferous series allowed decoupling between two different superposed domains (figure 1):

- Below the lower thrust surface D1, the autochthonous is affected by the NW-dipping normal faults.
- Above the upper thrust surface (D2), deformation resulting from sliding was accommodated by the SE-dipping extending listric normal faults.

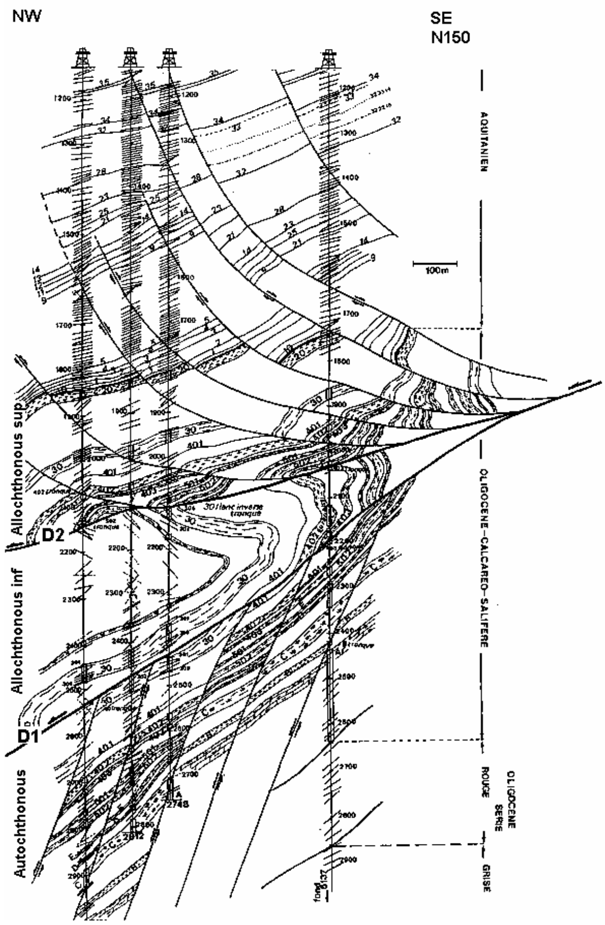

Figure 1 Geological structure saliferous syn-rift series

Microseismicity description

The seismic surveillance network in Arkema Vauvert site is composed of two down-hole triaxis sensors, one at 1390 m depth in a well part of the isolated closed doublet, and the other at 1780 m depth in a well situated inside the main part of the site (figure 2). This last sensor, situated in the center of the concerned activity zone, was used to locate the microseismicity.

All the seismic events recorded exhibit clear P and S wave onset, with a shear slip source mechanism induced by fracturing. The seismic hypocentral location is performed using the polarization analysis [3]. This method considers the P-wave incidence angle (3D particle motion), and the source-sensor distance (computed from the difference of P and S wave arrival time). The events location is then obtained with a ray tracing using the different velocity layers (Department of geophysics, Total, Pau). Regarding the uncertainty on the wave picking, on the angles computation, and the velocity used, the location error is estimated around 6 to 8 % of the distance. This uncertainty location by this method was validated by relocation of known downhole perfo shots.

Microseismicity location and evolution

From 1992 to 2004, the seismic database represents more than 55000 events located.

Period 1- From 1992 to 1998, microseismic activity started with only 1400 events located. The active zones are limited to the doublets themselves, and the main seismicity was situated on the east zone of the area. At that time, almost all the doublets were in production, and seismic activity was correlated with pressure drop down on each producing doublet.

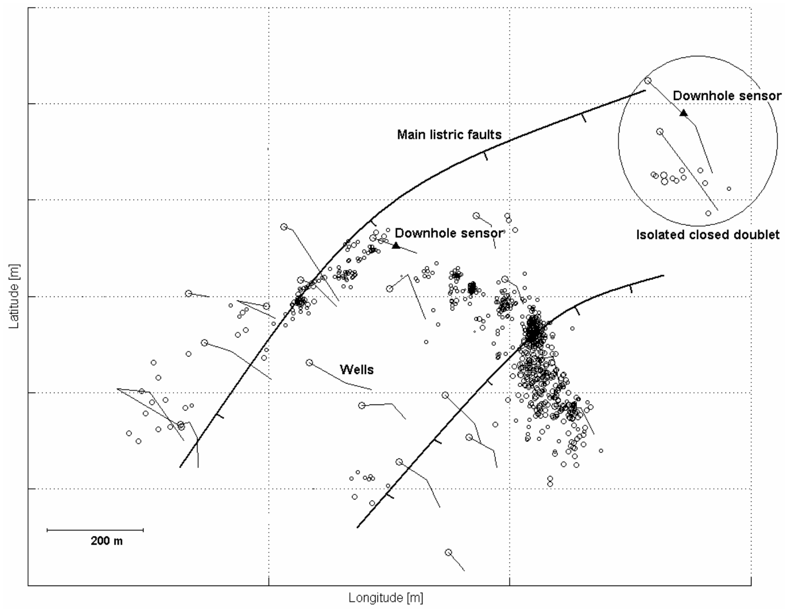

Figure 2 Seismic monitoring network and events location from 1995 to 1998

The leaching zone was then at a final phase located above the upper thrust surface (D2), at the top of the saliferous series (allochthonous sup). Microseismic activity was also located at the same depth, and the destabilized zone was then characterized by re-activation of geological structure like the listric faults.

Period 2- From 1999 to 2004, the areas of seismic activity evolved from intra-doublet to inter-doublet zones. East part doublets were no more producing, and in 1999 (figure 3), the seismic activity remained limited on a triplet wells on the West zone. From 2001 to 2004 (figure 4 and 5), events location showed a clear progression to an inter-well seismicity.
In 2004, regarding pressure evolution, all those doublets got also inter-connected (grey zone on figure 5). Only new producing peripheral doublets are disconnected from the other.

During this period, the induced seismic zone became larger and larger. The microseismic front extended Northward (direction of maximum regional strain), with remaining continuous activity on the back side. This seismic front will progress to the North, until the border of saliferous series (North-West seismicity on figure 5).
In terms of structural analysis (figure 6), the depth of the seismic source location clearly followed the upper thrust surface D2 (similar depth, and seismic extention normal to isobath). Brine movement used this thrust plane to create corridor of fluid circulation, generating a destabilized zone, which induced important remanent microseismicity. In 2004, even without injection (almost all connected doublets are stopped), the microseismic activity grew with time: over 130000 events were detected in one year.

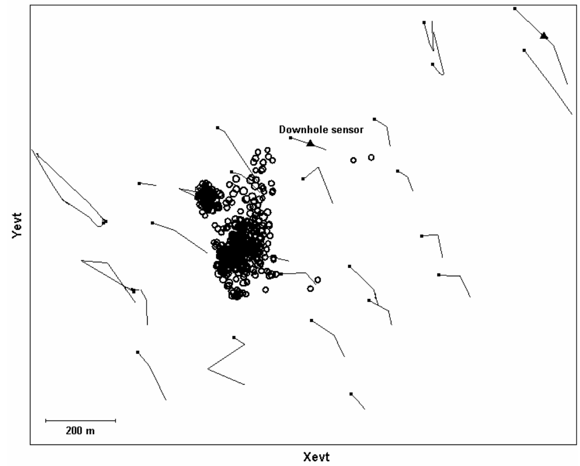

Figure 3 events location in 1999

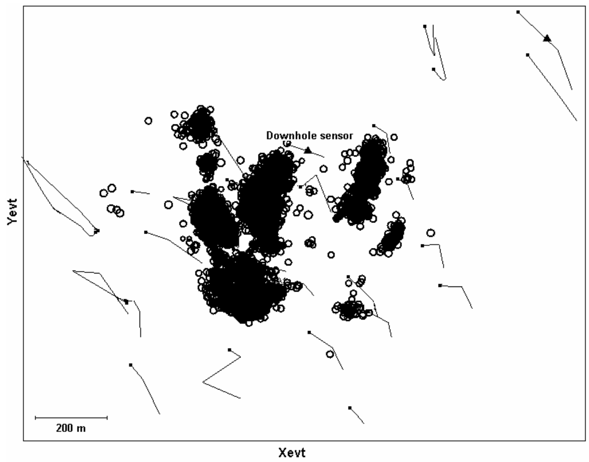

Figure 4 events location in 2001

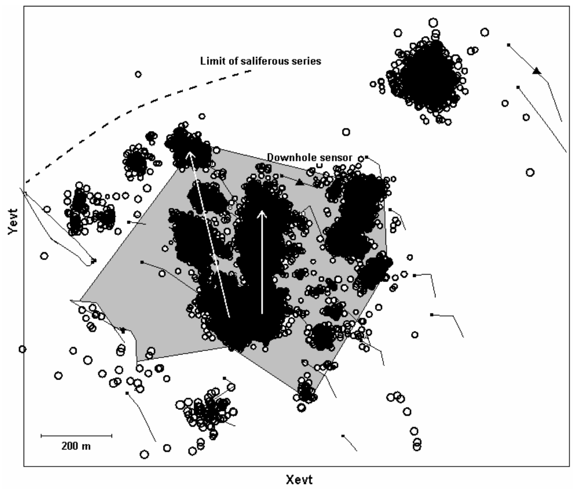

Figure 5 events location in 2004

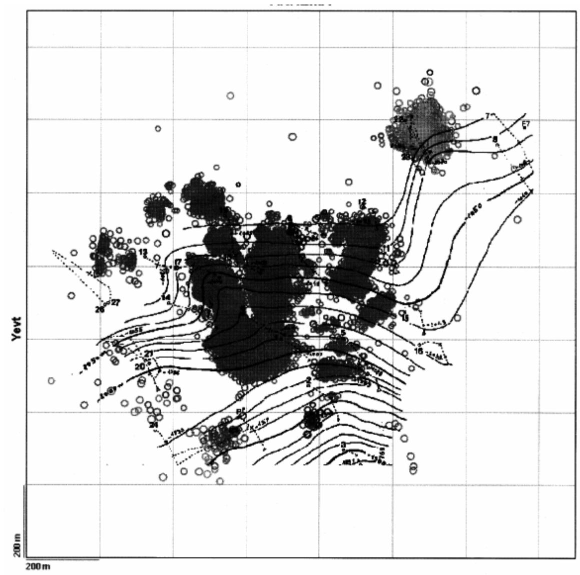

Figure 6 overlay of 2004 seismicity and isobath of upper thrust surface D2

The energy analysis of the seismic activity, also hilighted the difference of source mechanism between these two phases of seismicity. The b-value corresponds to the computed slope of events number versus their magnitude on a log scale (figure 7). The b-value is in theory raning between 1 and 2.5. It gives an indication of the relation between the “earthquake” size and its occurrence. It is generally accepted that b-value around 1 is observed for “natural” (tectonic) seismologic events, whereas b-value around 2.5 reflects higher density of small faults. In Vauvert case, during the first period, the b-value is equal to 1.4, representative of natural type seismicity (listric faults) focused intra-doublets. During the second period, b-value varies around 2.2, characteristic of important induced seismicity, with a continous inter-doublets activity.

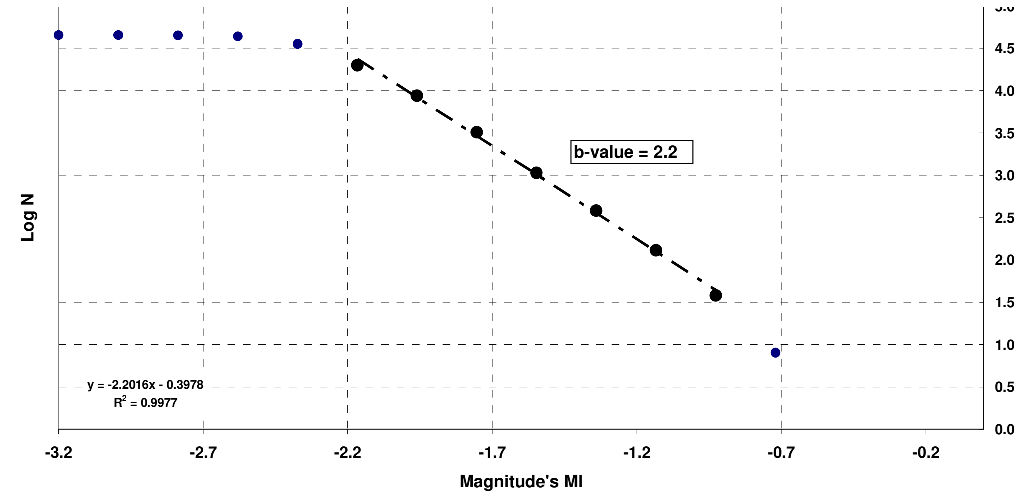

Figure 7 b-value computation of 2003-2004 seismicity

Correlation of seismicity with brine production events

Case 1- At the end of 2003, among the continuous remanent seismicity (≈200 events per day), a microseismic crisis appeared with 2900 events recorded in only 10 hours. This crisis corresponded to the near real-time creation of connection between one doublet and all the other wells already connected within the middle zone.
In order to initialize an intra-connection between the two wells inside doublet 1, the pressure increased until fracturing the salt formation (well A on figure 8 and 9). From our experience gained on frac job over this site, we know that just a few seismic events occur in the stimulated doublet zone. The same scenario happened here.
But, in this case, the high pressure front propagated toward the East direction to reach the connected area (well C) and induced this important seismic crisis, which occurred 40 hours after fracturing pressure (motion velocity of the pressure front=2-3 m/hour). Then, 52 hours after doublet 1, the pressure of well C showed the same behavior with a pressure increase. From this date, doublet 1 is connected to the pressure of the rest of the seismic active zone (grey zone in figure 5).

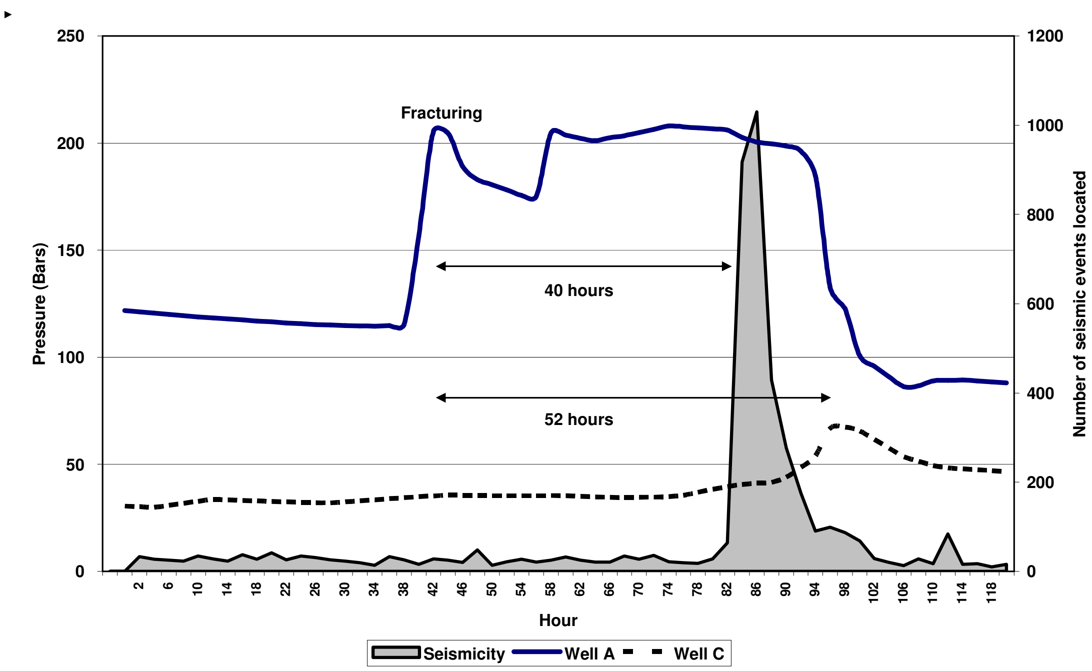

Figure 8 Pressure and seismicity correlation

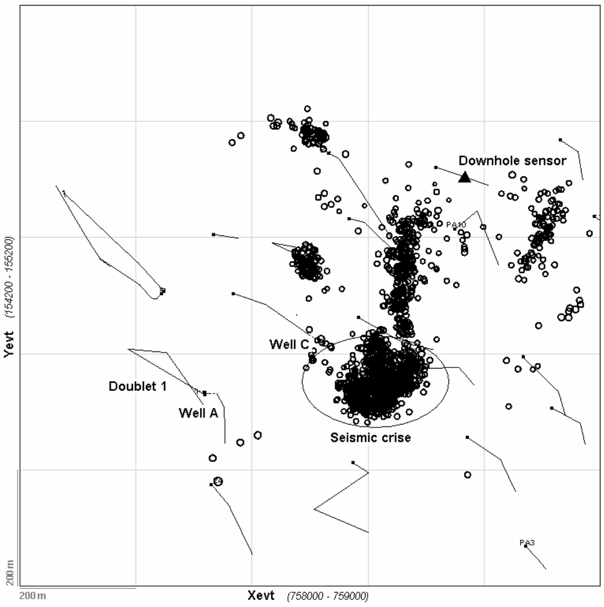

Figure 9 location of seismic crisis

Case 2- A new doublet was in activity in the North of the site. After horizontal drilling and fracturing job, this doublet has produced brine. From early 2004 measurements, the brine production zone was located under the thrust plane D2, in the allochthonous inferior series. At that period, the acquisition system used to record about 10 events per day, located at similar depth than leaching zone (zone 1, figure 11).

After doublet inversion of injection wells on 28/09/04 (figure 10), well E pressure was increased in order to reach the production pressure. This progression stopped because of a sudden drop of pressure. This fracturing phenomenon induced an important seismic crisis (9000 detections in 5 days), located on the thrust plane D2 (zone 2, figure 11). Actually, the seismic activity highlighted the creation of intra-doublet connection using the thrust plane D2. From this date, the destabilized zone has been focused on the plane D2, with a remanent seismicity of 20 events per day. Fluid circulation has been also using the same corridor to produce brine.

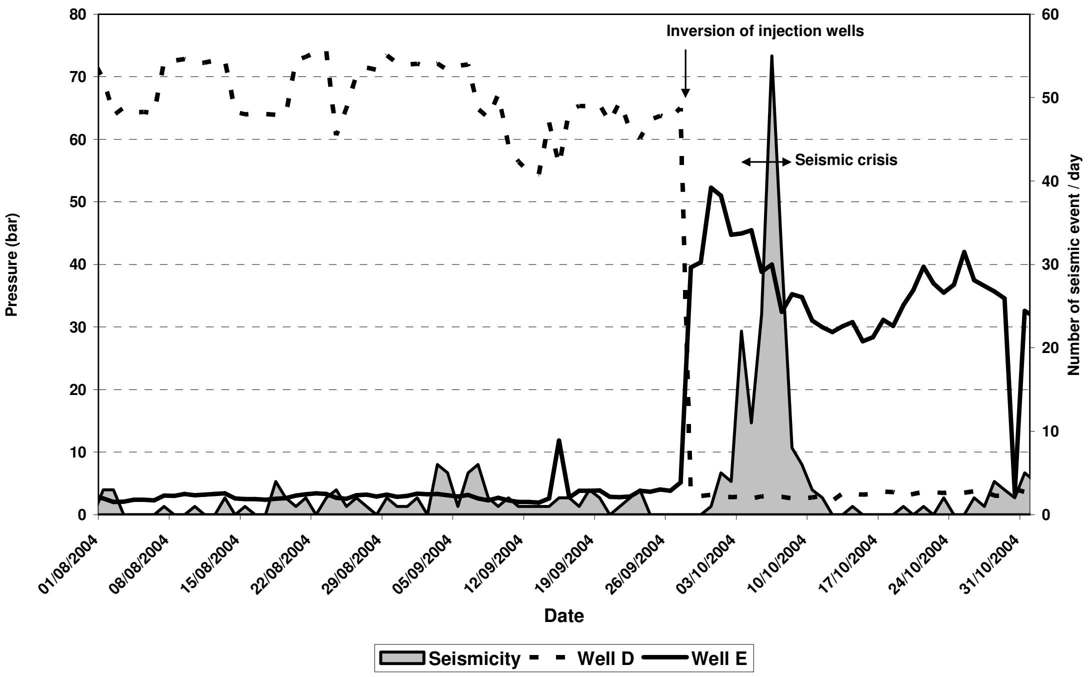

Figure 10 Pressure and seismicity correlation

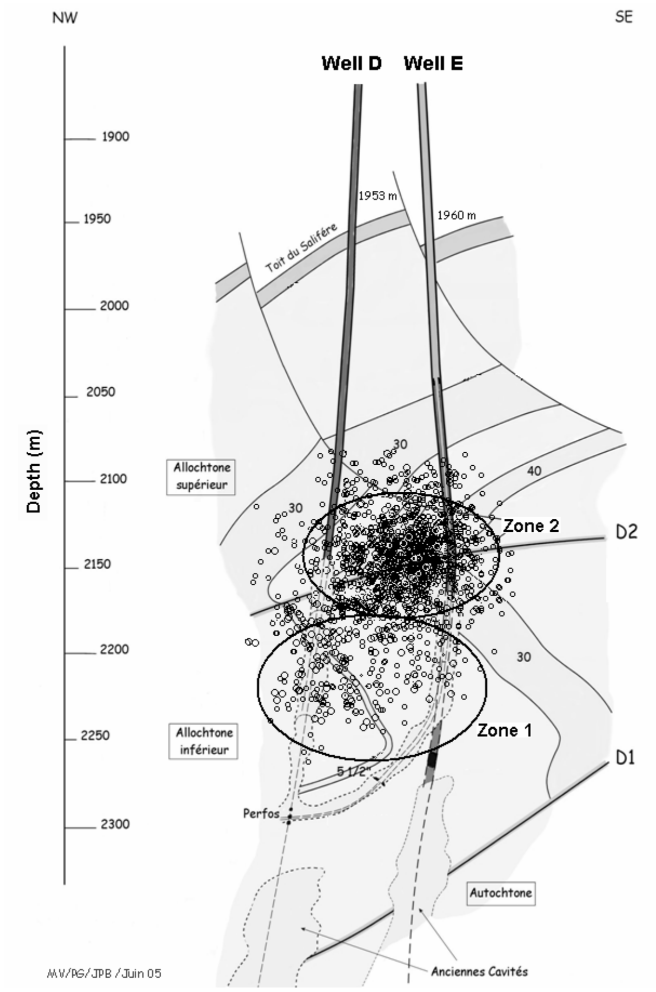

Figure 11 Cross section and seismic events location

Conclusion

The downhole network deployed in Vauvert site and the associated permanent microseismic surveillance carried out over the last twelve years has enabled to collect a substancial database of 250,000 seismic detections, among which 55,000 were located.

The primary objective for having deployed such a network was to monitor isolated well doublet closure after brine production. No seismicity was recorded then. As a secondary goal, could the microseismicity study, over a large period, provide a better understanding of brine production ? The study of such unique database has exhibited characteristics which point out distinct mechanical behaviours within the overburdens.

Two distinct datasets of microseismic activity have been highlighted, directly related to the different exploitation steps of the site. In a first stage, during brine production, the seismicity remains limited to the wells vicinity, corresponding to geological structural activity (listric faults) : the intra-doublet seismicity. After this phase, we observe a progressive connection within the network of doublets : the inter-doublets seismicity. Within this family, the microseismic study allows to track -almost in real-time- the propagation of the zone destabilized by salt dissolution, hence to follow the creation of fluid circulation corridors (along thrust plane).

The b-value trend confirms the existence of two types of seismicity : one linked to "natural" (tectonic) seismologic events (intra-doublet), the other reflecting higher density of small faults (inter-doublets).
These microseismic results are consistent and validated with well pressure evolution. By combining pressure and microseismic informations, we were ought to illustrate that fracturing phenomenon occurred, using pre-existing geological structures.

We want to stress on the fact that the objective of this whole project would never have been fulfilled without long-term surveillance. Therefore, in order to take full advantage of the experience learned over such a great database, it is important to carry out this surveillance in the future to go on the study of the destabilized zone movement. It should be interesting to transform Vauvert site as a pilot site to validate microseismic concepts with different tool generations.

Acknowledgements

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