GEOLOGICAL AND GEOPHYSICAL STUDY OF AN HYDROCARBON STORAGE IN SALT CAVERNS IN MANOSQUE (FRANCE)-EAGE-London 2013

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Introduction

The creation of an underground storage facility in salt leached caverns in Manosque for liquid hydrocarbons was decided in the mid-60s by the oil companies to meet regulatory obligations in terms of strategic reserve, imposed following the Suez crisis. This site and the related salt diapir, although relatively distant from any large pipeline was selected because of its proximity to refineries in the Mediterranean area. The GEOSEL-GEOMETHANE storage area is connected to the refineries and the Berre and Lavera harbours via three lines with a length of 97 km (Fig.1).

Storage development began in 1968 with the creation of 18 caverns and continued until 1978 to reach a total of 28 caverns with a total usable capacity of 8.5 millions m^3. Each cavern was formed by dissolving the salt in heights up to 400 meters at depths between 400 and 1500 m. Unit volume of each cavern ranges between 100 000 and 500 000 m^3. Whereas the original function of the Geosel storage was chiefly strategic storage of crude oil, its role has expanded; and GEOSEL has now also become an operational storage of crude oil and of "white products" such as diesel, gasoline, naphtha, etc. The GEOMETHANE storage facility with 7 caverns under operation and 2 new caverns under development is a natural gas storage with a working gas capacity of 300 millions Nm^3

Location

The studied area is located in the Alpes de Haute-Provence, Region Provence Alpes Côte d'Azur, on the eastern edge of the Natural Park of Luberon, France. *(cf. Figure 1)*

figure 1 *:Location of the studied area*

Available data

A total of 58 wells have been drilled in the area of the storage.
Seismic data were acquired in 2010-2011. The mileage of the five profiles acquired during this campaign is 60 km.

Well study

In 2010, a study of the recently drilled wells on the site helped to a better understanding of the mineralogy of the evaporitic series.
A multi-disciplinary methodology was used: mud log, description in situ of cores, thin slices analysis - X-ray analysis (figure 2) ,dissolution analysis and wireline logs analysis.

The Manosque salt is formed mainly of halite (NaCl) and anhydrite (CaSO4) in proportions ranging from 90% to 10% halite

In thin section, the following observations can be made:

- The halite facies present is granoblastic suggesting remobilization;
- Anhydrite is present either in the form of crystals of approximately 1 mm isolated in halite ,in a mosaic or in the form of massive crystals .It is closely associated with magnesium sulfate and potassium K2SO4 (MgSO4) 2 i.e. langbeinite;
- In the samples, a significant proportion of detrital minerals can be found: quartz (22.4%), illite and micas (31.6%), chlorite (7.2%), feldspar (1.8%) and plagioclase (3.2%). This suggests a power pool in a relatively high energy, feldspars and micas originating from the central Alps granites;
- The presence of illite chlorite and kaolinite also suggests a continental origin.

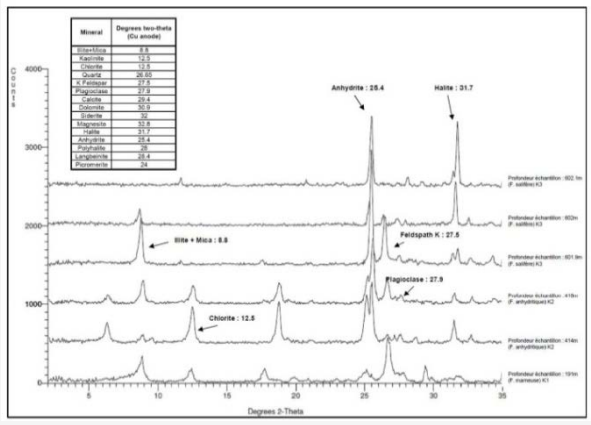


***Figure 2**: X ray analysis*

Petrophysics (figures 3 and 4)

Available data are Sonic logs (P and S), Litho Density (density and photoelectric effect, Neutron, Spectral gamma ray: Potassium ,Thorium and Uranium, resistivities for the upper section. Mineralogical analysis has been performed with the ELAN program.

Cross plot: The potassium Neutron density diagram shows clearly Langbeinite with high potassium content (8%).as well as Halite and Anhydrite.

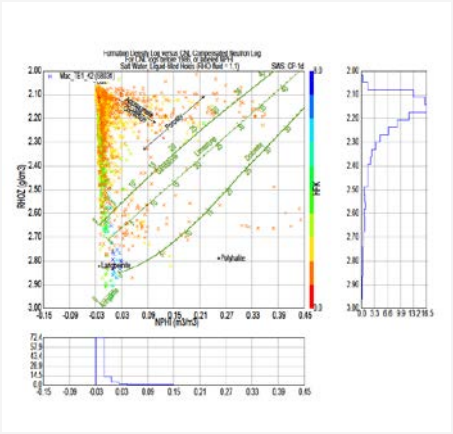


***Figure 3 :** Neutron-density potassium Cross-plot*

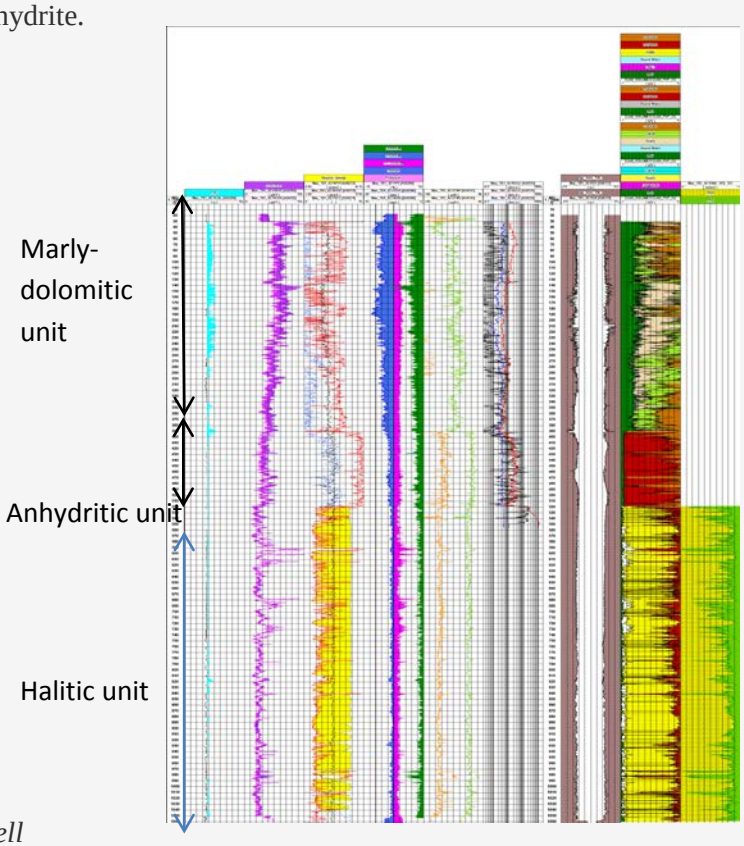


***Figure 4:** Petrophysical analysis of well*

Seismic interpretation

- The seismic interpretation allows to highlight two series (figure 5): The saliferous unit and the infra-saliferous. The strong variations in thickness observed are due to halokinetic movements related to two main constraints (stress components): Sliding along the general NW-SE dip (setting slip salt for slopes greater than 10% (roller-salt Bally (1980)) on the one hand, and the stress applied by overlying tertiary series on the other hand, explaining the sub vertical dips observed on the flanks of the structure. These slidings in the overburden are accompanied by occasional seismic crises.
  These movements have been initialized during Aquitanian and continue to Helvetian (Destombes -1962) up to actually …

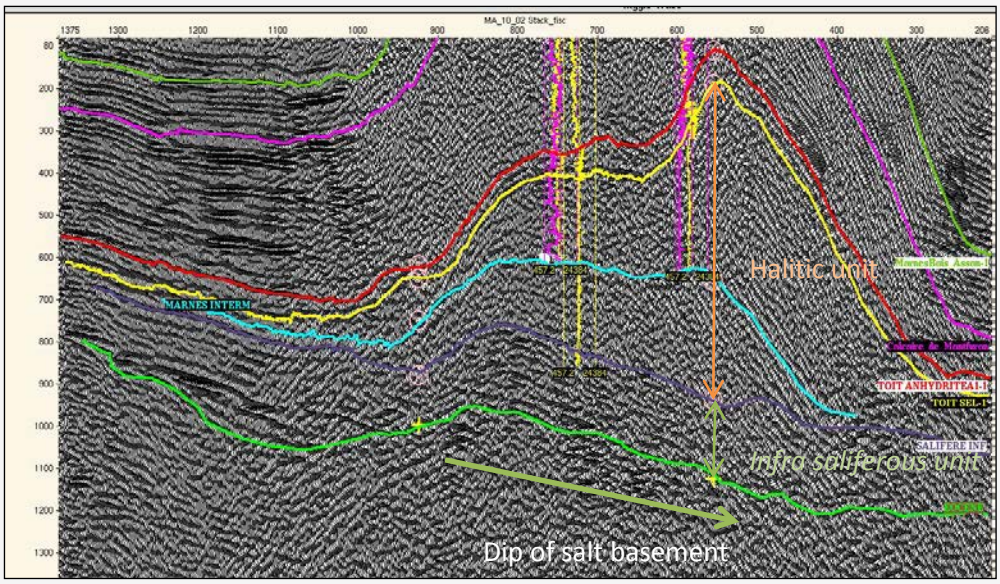


***Figure 5**: NorthWest – South East seismic section*

Integration with previous data

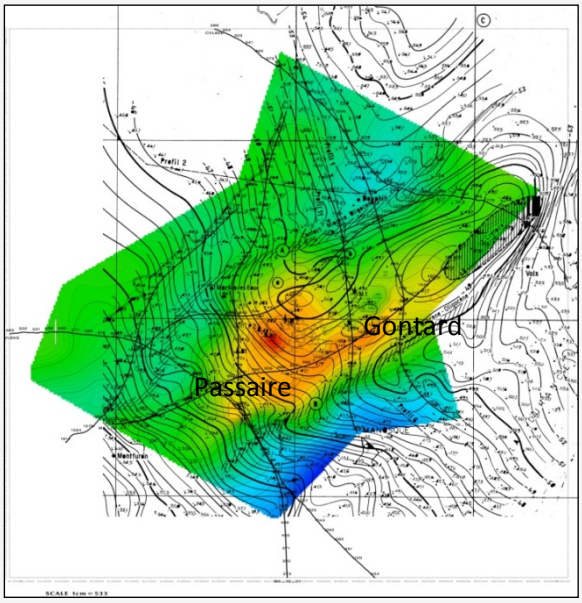
The Bouguer anomaly. superimposed on the depth contour map of the top of salt (figure 6) shows a good consistency. between the both methods. Structural direction is clearly South-West North-East. The total thickness of the saliferous formation reaches 2000m on the eastern flank.

The maximum thickness of the salt corresponds to the south-east ridge line, located at the top of the anticline.

The difference in structure between two areas: Passaire (tabular salt layer with protrusion of Patatonis due to compression), and the area Gontard (anticlinal ridge of the Mort d'Imbert), suggests-a maximum of deposition of the evaporites in the Passaire.area.(figure 6).

Seismicity

An examination of the seismicity map outside the storage since 1992 (figure 7) generated by the micro-seismic monitoring system of the site shows a concentration of events in the area of the anticline monoclinal of " La Mort d' Imbert". (Seismic crisis of 2010, whose epicenter was located on the East flank). Seismicity is related to gravitational sliding on the hill side related to the overburden consisting of layers of different rheological characteristics (marl-limestone) under the thrust of the saliferous.mass.



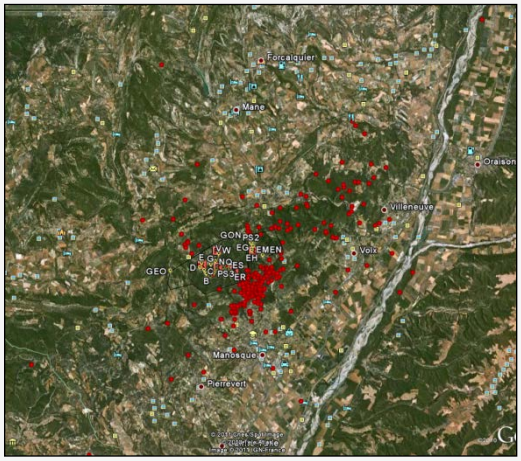


Figure 7

Figure 6

Figure 6*:Left: Superposition of the isobath map of the top of the salt with the Bouguer anomaly*

figure 7*: right :Seismic epicenters map between 1992 and 2010 (in red)*

Conclusions

The Salt of Manosque is of Oligocene age and was deposited after the Pyrenean orogenic phase. The Alpine orogeny of the late Miocene gave it its current appearance. The salt was deposited under lacustrine environment in arid climatic conditions in the basin of Manosque-Forcalquier in between Provencal and Luberon overthrusts.

The origin of the salt is Triassic (Keuper) and results of dissolution of outcrops uplifted by orogeny .tectonic movements, then evaporites, were deformed due to the tilting of the block inducing the sliding of the salt mass, and increasing locally the thickness of the salt depending on its initial deposit and structural location. The resulting thickness of the salt formation ranges between 200 to 1000 m. Insoluble laminates of metric size but which can sometimes reach up to several meters thickness are scattered through the salt mass. The average proportion of insoluble minerals is in the order of 15%.

This study allows a better understanding of the mineralogical composition of the Manosque salt. It explains the occurrence of potassium detected in the leaching brine. The structural map indicates the salt thickness distribution and can be used for locating new caverns. A clear relationship is established between seismic activity and halokinetic phenomena.

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