Adapting conventional hydrocarbon workflows to enhance renewable resources exploration: Fonts-Bouillants case study

Introduction

A more responsible production of gases such as Hydrogen, Helium and Carbon dioxide to supply Energy sector and Industry is key in a context of international supply chain crisis and climate change. To answer that need, a transition is underway globally and more specifically in Europe to explore and produce locally, from the subsurface, these critical gases.
In Europe, exploration is at its early stages, developing and adapting workflows from the legacy of technics developed by the Oil and Gas exploration. One example of these is the Fonts-Bouillants project in France, which has involved a full set of geophysical data acquisition campaign. A thorough investigation of these data is proposed to detect, estimate and understand the distribution of natural gases accumulations.

Geological context

The Fonts-Bouillants area is located onshore in the Paris Basin, approximately 270 kilometers south of Paris. In the past, the area was used to produce sparkling water due to the high concentration of gases in the underground water. Today, Fonts-Bouillants is the first project in France to explore the potential for helium and carbon dioxide.

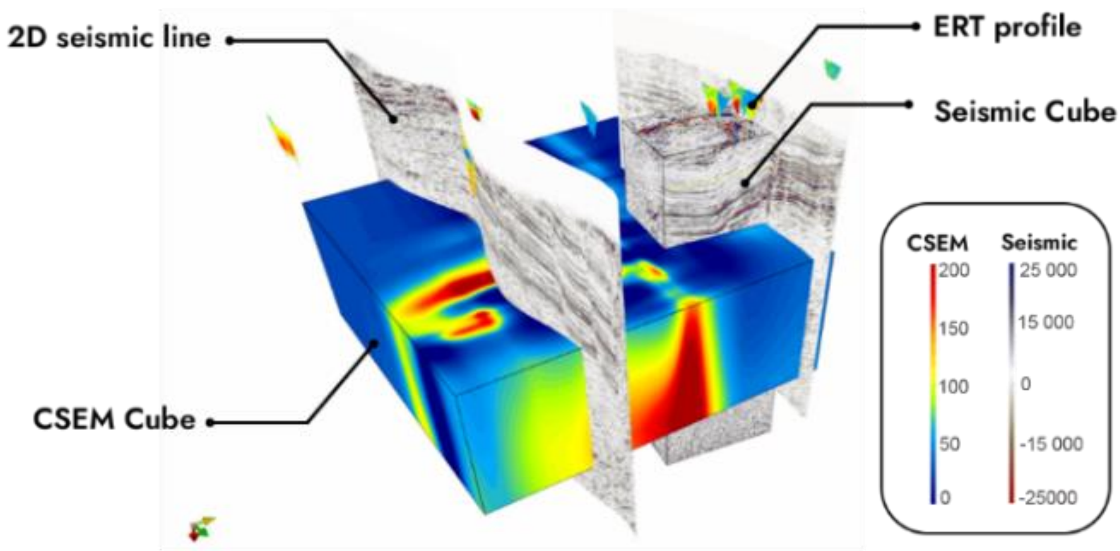

Figure 1: *3D view of the data set used in the study: a seismic cube, two 2D seismic lines, a Controlled Source Electromagnetic CSEM) cube and 6 Electrical Resistivity Tomography (ERT) profiles.*

This study is primarily based on the integration of the Fonts-Bouillants 3D seismic cube acquired in 2021, 2D seismic lines, a CSEM cube, and ERT profiles (Figure 1). The seismic cube covers formations from the Permian to Holocene periods and is centered around the Saint-Parize fault, which is known to be the focal point of gas emissions to the surface. A thorough understanding of the structural framework stands out as a critical factor to consistently assess gas accumulation in this area. As there are no deep wells available, the intensely studied Paris Basin to the Northwest and freshly acquired data on site are inputs to perform an assessment of the subsurface.

Method

Within a global workflow, considering and honoring information coming from all data set, the entire seismic volume has been interpreted using a comprehensive and semi-automated approach combining structural and stratigraphic analysis.
The fault network modelling relies on a hybrid process that allows to pinpoint the highest probability of the fracture occurrence in the seismic signal. Advanced structural gradient attributes are created from input multi-trace attributes to enhance the visualization of fractures and extract 3D fault objects. The process involves calculating the Fault Plane attribute which represents the probability of vertical component of the deformation and the Fault Thinning attribute which represents the skeleton of deformation. The fault network is then extracted, analyzed, filtered and eventually used as guide to structurally constrain the semi-automated horizon interpretation.

Seismic horizons (Peak, Trough, Zero Crossings, and potentially Inflection Points) are simultaneously auto-tracked across the full seismic volume, chronostratigraphically sorted and subsequently used as geometrical constraints to generate a signal-driven relative geological time model (RGT model). The RGT model has been refined to ensure consistency between the reflection events and the auto-tracked horizons, as well as to represent an accurate continuous stratigraphic framework. Due to the importance of faults for migration pathways, particular attention has been paid to the surface terminations against them (Figure 2).

The Saint-Parize Fault, suspected to act both as a fluid migration pathway and a barrier, is also seen on the seismic as major discontinuity of reflector amplitudes. Due to this discontinuity occurrence and the low signal-to-noise ratio, some approximations based on seismic patterns were used to correlate the two compartments. Using the surface data and the more regional study of the Paris basin, an approximation of the different formations from both sides of the fault was possible. With this approximation, that is possible to move from a relative geological time model to an absolute geological time model (Figure 2b – Figure 2c).

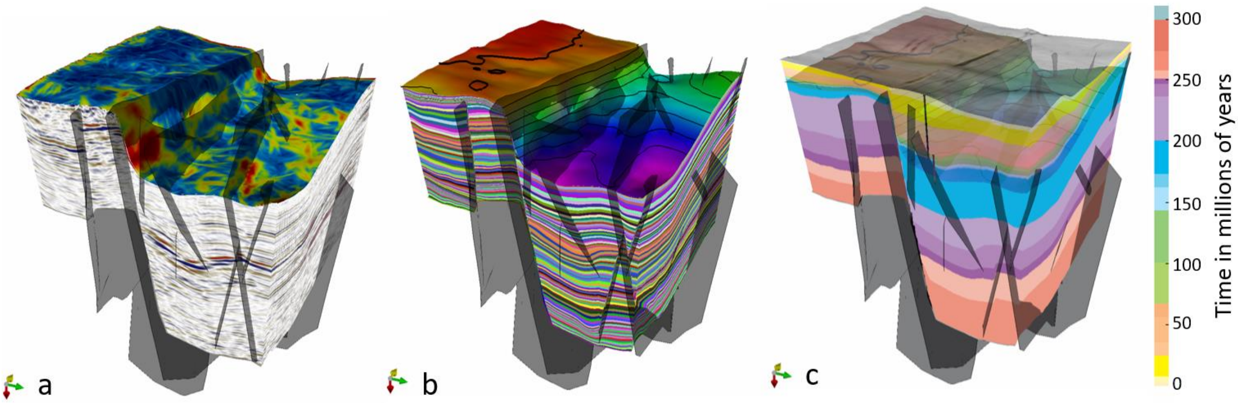

Figure 2*: a) Input seismic cube draped with Fault Thinning attribute highlighting the probability of fracture occurrence on the top surface, b) output relative geological time model with z-value on the top surface and c) Absolute geological time model (colours are in accordance with the geological time scale, ages are estimated from surface data and regional geology).*

Interpretation and results

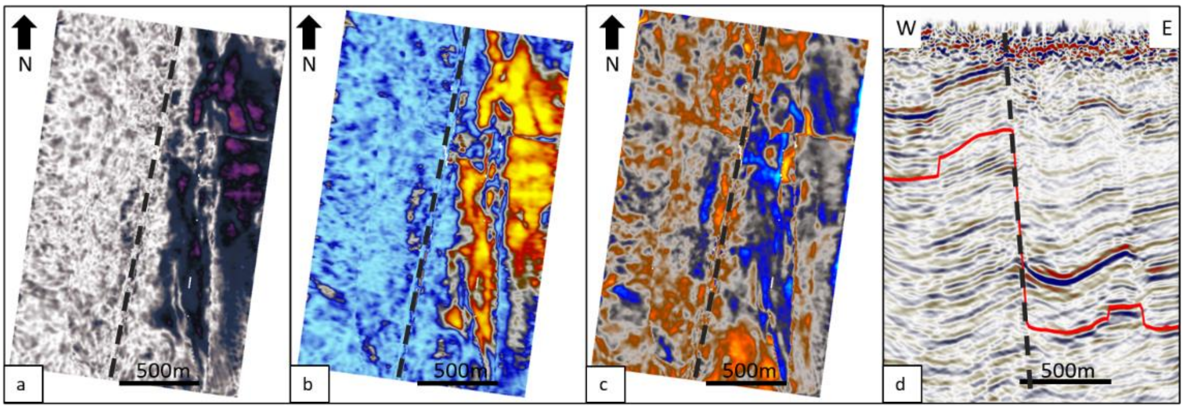

Figure 3: *a) RMS amplitude, b) Sweetness, c) Relative Acoustic Impedance maps highlighting a potential area of interest on the hanging wall of the fault (eastern tilted block), d) seismic cross-section showing the intersection of horizon in a), b), c)in red with the seismic cube.*

The continuous stratigraphic framework derived from the seismic (RGT model) gives access to an unlimited number of isochronous surfaces enabling to strata slice the seismic cube at a sub-sample resolution. The whole batch of extracted isochrones is mapped with a series of attributes derived from seismic traces and from the RGT model. Three attributes produced from the seismic traces are here computed to enhance physical property contrasts in different ways: Root Mean Square amplitude (windowed high amplitude maximum), Sweetness (energy signature changes driven by trace envelope and instantaneous frequency) and Relative Acoustic Impedance (estimation of apparent acoustic impedance variation) (Figure 3). Relative Acoustic Impedance values are interrogated from cross-correlated high values of RMS and Sweetness, both in vertical sections and stratal slices. This multi-attribute workflow emphasizes zones of higher probability of carbon dioxide and helium gases accumulation, lately correlated with high CSEM values.

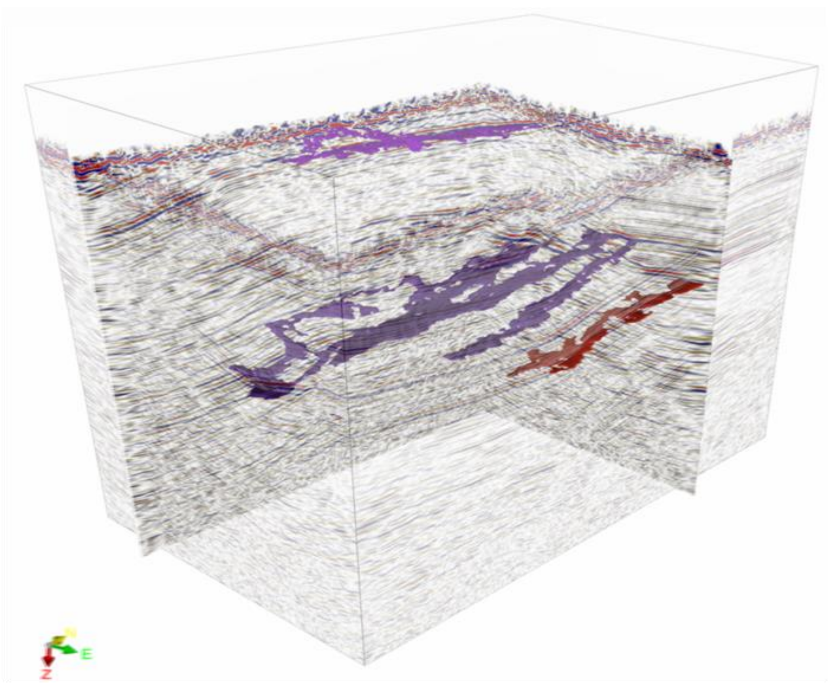

Figure 4: *3D viewer showing the survey in transparency, and the three areas of highest potential of gas in place.*

Multi-attribute seismic expressions are ultimately converted into three Geobodies, eventually classified as shallow gas stock (light purple-colored) and deeper gas stock (dark purple and pink-colored) (Figure 4). The shallow stock has recently been drilled and therefore confirmed helium-rich reserves.

Two accumulations are found against the Saint-Parize fault in the Triassic sandstones, which confirm the emanations observed at the surface. However, the accumulations are impacted by secondary faulting which is hardly visible in seismic due to the low signal to noise ratio. The 3D gradient an attribute derived from the RGT model, is here computed to enhance the fault network and especially smaller scale fractures. This attribute is sensitive to variations of the model in 3D, highlighting both structural and sedimentary events through the seismic volume. Its analysis allows refining synthetic and antithetic faults which can then be used as constraints for more accurate RGT model and to more precisely delineate geobodies around the minor faults.

Conclusion

The comprehensive seismic interpretation approach based on semi-automated faults and horizons extraction processes and driven by the exploitation of a signal-driven relative geological time (RGT) model unlocks new perspectives of nonmetal and noble gases detection from seismic expressions. The successful application of this method on the Fonts-Bouillants project highlights a high potential for helium, hydrogen and carbon dioxide extraction, essential for further drilling campaigns and replication of the method on other projects.

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