Multiphysics for industrial gas exploration – The Fonts-Bouillants case study

Mesures multiphysiques pour l’exploration de gaz industriel – Le cas d’étude des Fonts-Bouillants

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Abstract. Helium is key in numerous industrial sectors. Production in western Europe is still absent despite criticality of helium as a resource. 45-8 Energy, implementing multiple geophysical methods in its Fonts-Bouillants exploration license, located in France, intended to couple geophysics with geological and geochemical information to characterize more accurately the subsurface before drilling. The area has been underexplored until license awarding in 2021 and therefore brand-new data acquisition was the only path to uncertainties reduction. A finely tuned acquisition campaign of electric resistivity tomography, reflection seismic, electromagnetic methods, followed by a thorough transverse interpretation phase, enabled 45-8 Energy to step up with a successful shallow drilling campaign. Geophysics was key to implement boreholes which turned out to be discoveries and key to unlock funds to build the first helium production unit in western Europe. Adventure shall continue with upcoming deeper drilling campaign, revealing full potential of the exploration permit by mid-2024.

Résumé. L’Hélium est une ressource clé pour de nombreux secteurs industriels. Pour l’heure, malgré sa criticité, aucun site de production n’existe en Europe de l’Ouest. 45-8 Energy, s’appuyant sur de multiples méthodes géophysiques sur le permis des Fonts-Bouillants, en France, avait pour but le couplage de toutes les sources d’informations pour servir une caractérisation plus précise du sous-sol nivernais. Jusqu’à l’attribution du permis d’exploration en 2021, la zone était largement sous-explorée et l’acquisition de nouvelles données était la seule option permettant la réduction des risques. Une campagne d’acquisition de profils de tomographie en résistivité électrique, sismique réflexion et méthodes électromagnétiques, suivie par une minutieuse phase d’interprétation transverse, a permis à 45-8 Energy de poursuivre par une campagne de forage fructueuse. La géophysique a permis de réaliser des forages peu profonds qui se sont révélés être des découvertes et de démarrer la construction de la première unité de production d’hélium en Europe occidentale. L’aventure se poursuivra avec la prochaine campagne de forages profonds, qui révèlera tout le potentiel du permis d’exploration d’ici à la mi-2024.

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1 Introduction

Helium is a little-known resource which is nevertheless, essential for manufacturing of many commodities that are used every day such as internet (fiber optics), computers or cell phones (semiconductors and processors), or in other more specific applications such as medical (MRI scanners), airlifts, leak detection, gas chromatography or diving.

Helium is derived from natural radioactive decay of Uranium and Thorium [1]. Rocks containing these two elements can therefore generate helium that can eventually migrate toward a reservoir rock overlain by a seal in a trapping geometry: this is a helium accumulation. Helium is usually accompanied by a dominant vector gas (>95% of the volume) facilitating the migration from source rock to the trap. Such vector gas is usually nitrogen, carbon dioxide, methane or a mix of them.

Today, 100% of helium in western Europe is imported from overseas (mostly from USA, Algeria or Qatar where is represent a small portion of the gas mix of natural gas fields) whereas European helium consumption currently accounts for nearly 25% of global supplies.

At a time when long-distance transport duration is becoming uncertain and, in a world, where real efforts shall be made to reduce carbon footprint, securing affordable helium has become a real challenge for the many consumers.

Producing helium locally would therefore directly cope with such issues in Europe and contribute to jugulate regular helium shortages as well as the rising price of the resource. It is for this reason that 45-8 Energy, a French-based company, embarked six years ago on helium exploration and production in Europe.

2 The Fonts-Bouillants exploration license

Bibliographic research [2 – 9] and geochemical field measurements came first in the Fonts-Bouillants area (Figure 1). That was opportune timing to sample springs, review results from ancient boreholes nearby and perform soil gas sampling campaigns. These first steps were sufficiently encouraging to trigger an application by 45-8 Energy in 2019 for an exploration permit to evaluate the joint exploitation of helium and carbon dioxide, 2 gases naturally seeping from the fault of St Parize (SPF). The fault has been highlighted for years by the Franch Geological Survey (BRGM) over 20km and is oriented N10.

The license, located in France, in a transition zone between the north of the Central Massif and the southern edge of the Paris Basin has been awarded in 2021 (Figures 1 and 2). Sparse gravimetry and magnetism data, a geological map and soil and spring gas sampling were not sufficient to steer upcoming exploration in that underexplored zone. Lack of outcrops makes also the structural characterization uncertain or even hypothetical, thus justifying the use of multiple geophysical methods to draw up a predictive geological model of the subsurface.
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![Figure 1: Location of the Fonts-Bouillants exploration license (France Geological map at the 1M scale), modified after [10].](image1.png)

![Figure 2: Simplified geological sketch presenting the South Paris Basin and Fonts-Bouillants exploration license context (no vertical or horizontal scale), after [10].](image2.png)
3 Geophysical acquisitions and results

Conducting a diversified geophysical acquisition program has enabled 45-8 Energy to benefit from different methods since 2021.

Large scale potential methods (i.e., gravimetry and magnetism) have been summoned first to characterize the structural scheme identifying what could correspond to a system of horsts and grabens, as described by the geological map provided by the Franch Geological Survey (BRGM). Localizing the SPF with more accuracy was another outcome of that first stage of exploration.

That very same stage allowed to define zones of interest and to locate deployment of Electrical Resistivity Tomography (ERT) profiles, 2D and 3D seismic surveys. Controlled Source ElectroMagnetics (CSEM) and audiomagnetotelluric (AMT) surveys were also acquired but did not drive borehole location selection. Figure 3 shows data gathering, including overlapping ERT profile and 2D seismic, a nearby borehole, a spring occurrence and gravimetry, as conclusive data set to influence exploration and hence upcoming drillings. Seismic interpretation benefited from that “co-calibration” with combined geophysical methods.

Thus, thick and nearly conformable seismic reflectors were found below the calibrated and known Triassic / Early Jurassic sequence (described in the geological map and found in several nearby boreholes) (Figure 4). These markers are interpreted as Permian and/or Carboniferous series, as described and encountered in the nearby Brecy Basin (to the West) and La Machine Horst (to the East). The initial geological model was then reviewed and turned from a shallow granitic basement context to a thick Paleozoic depocenter hidden by the Mesozoic cover. It also revealed thick (>100m) Tertiary series bounded by the SPF showing that fault was reactivated during the Limagnes rifting.

Figure 3: Gathering of all sources of information to steer geological interpretation.
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Figure 4: Example of interpreted 2D seismic image acquired in the Fonts-Bouillants area (in ms), after [10].

Figure 5: 3D seismic imprint onto the geological map (scale 1/50000) published by the French Geological Survey (BRGM) (left), and 3D rendering of the seismic interpretation of Base Triassic horizon and faults planes (right), modified after [10].

4 Shallow borehole drilling campaign

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5 Production pilot: the first helium production in Western Europe!

The implementation of a pilot production facility is underway. Such a unit will separate and purify helium on one side and food-grade CO2 on the other side. Pure CO2 is actually a sought-after resource used in beverage or freezing industries; capturing it prior to reaching the atmosphere will therefore enable a valuation instead of an inevitable natural geological rejection through the SPF.

6 Deeper exploration potential

The Paleozoic series have not yet been recognized. They correspond to deeper objective and shall be revealed by mid-2024 with a deeper drilling program. 45-8 Energy expects higher helium content if targeted structures are effectively gas-bearing. That could unlock a significant helium production project in Europe and secure French production for several years.

7 Conclusions

Thanks to the multiple geophysical acquisitions, the geological model has considerably evolved and enabled first discoveries with the first shallow drilling campaign, and second to locate deeper exploration wells. The shallow discovered gas accumulation unlocked a first production pilot project that will represent the first ever produced helium in France (and by extent in western Europe), a first step prior to a larger exploration drilling campaign to be carried out in 2023/2024.

References