Trapping mechanisms in a natural hydrogen play-based exploration - The Pyrenees case

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In Western Pyrenees (France), the Mauléon Basin has recently emerged as a prospective area for natural hydrogen exploration. Integrated academic and industrial investigations indicate that Play elements of a regional hydrogen system are present. Passive seismic acquisition (Maupasacq, 2018) combined with soil gas surveys documents active hydrogen generation at shallow depths (<10 km). The deformed sedimentary cover of the Pyrenean foothills provides potential structural and stratigraphic traps for hydrogen accumulations in free gas form.

Natural Hydrogen Play Elements

A major regional gravity anomaly (~600 km²; amplitude ~20 mGal) has long been recognized within the basin. Recent passive seismic tomography revealed a high-velocity body (Vp ≈8 km/s; ~300 km²), interpreted as shallow mantle material exhumed during Cretaceous rifting and subsequently incorporated into the Pyrenean orogenic wedge. Joint gravimetric and magnetic modeling supports the presence of partially serpentinized mantle rocks, consistent with ongoing hydrogen generation through water-rock interaction processes.

Hydrogeological observations further support an active system. Meteoric water circulation at depth is indicated by distributed microseismicity, the occurrence of fresh water tested in wells and numerous thermal springs along the northern structural belt. The inferred hydrogen “kitchen,” located at ~8-10 km depth, is connected to the sedimentary cover via major south-dipping thrusts, which act as efficient vertical migration pathways.

Legacy exploration data demonstrate the presence of reservoir–seal pairs of regional extensions. Jurassic dolomites and Barremian–Jurassic carbonate platforms are overlain by thick marl units that provide effective seals. Although matrix porosity is locally limited, dense fracture networks ensure reservoir productivity. Significant overpressure within Cretaceous series enhances pressure sealing capacity and may favor fluid migration and focalization.

Geophysical imagery enhanced through vintage data reprocessing and passive seismic acquisition

Recent reprocessing of vintage 2D seismic data highlights the value of legacy dynamite surveys with dense receiver spacing combined with most recent processing algorithms and high computing power. A dense passive seismic survey (450 sensors, 4 months) was conducted in 2024 to build high-resolution Vp and Vs models. Detection of 265 events enabled tomographic cubes with ~250 m resolution, significantly improving structural imaging, particularly through enhanced velocity contrast between Upper Jurassic reservoirs and Cretaceous series.

H2 exploration targets –Foothills play types

Exploration challenges extend beyond seismic imaging. Robust structural concepts, supported by appropriate geological analogs, are critical for identifying untested plays.

Although the precise timing of deformation remains insufficiently constrained, seismic interpretation supports an initial phase of syn-sedimentary deformation associated with early salt movement. This salt tectonic controlled both structural architecture and depocenter distribution. From the Late Cretaceous onward, onset of compression implied intense faulting and folding, overprinting earlier salt-related structures.

Implications for potential traps include diapir-related closures, salt overhangs, salt domes and salt walls, stratigraphic pinch-outs, unconformity-related traps, and classical fold-and-thrust belt structures. The

superposition of halokinetic and compressional deformation phases is expected to create complex 3D structural traps.
Target intervals deeper than ~2000 m are considered optimal, as under a present-day geothermal gradient of ~30 °C/km such conditions are expected to limit microbial activity and reduce the risk of hydrogen consumption.
All these elements support the presence of a working natural hydrogen system in the Mauléon Basin and define a range of structurally and stratigraphically controlled exploration targets.

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