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"Natural Hydrogen in the Monzón-1 well, Ebro Basin, Northern Spain"

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A Webinar Presentation to the European Federation of Geologists February 2, 2023

Webinar Outline

Natural Hydrogen ("Gold"/"White")

- Does Natural Hydrogen Exist?
- Geological Factors Promoting Natural Hydrogen Accumulation
- Natural Hydrogen Exploration

Natural Hydrogen in the Monzón-1 Well

- Evidence of Hydrogen Presence
- Reservoir, Seal & Trap
- Hydrogen surface seepage
- Monzón Natural Hydrogen Discovery

Conclusions

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Natural Hydrogen Overview

Does Natural Hydrogen Exist?

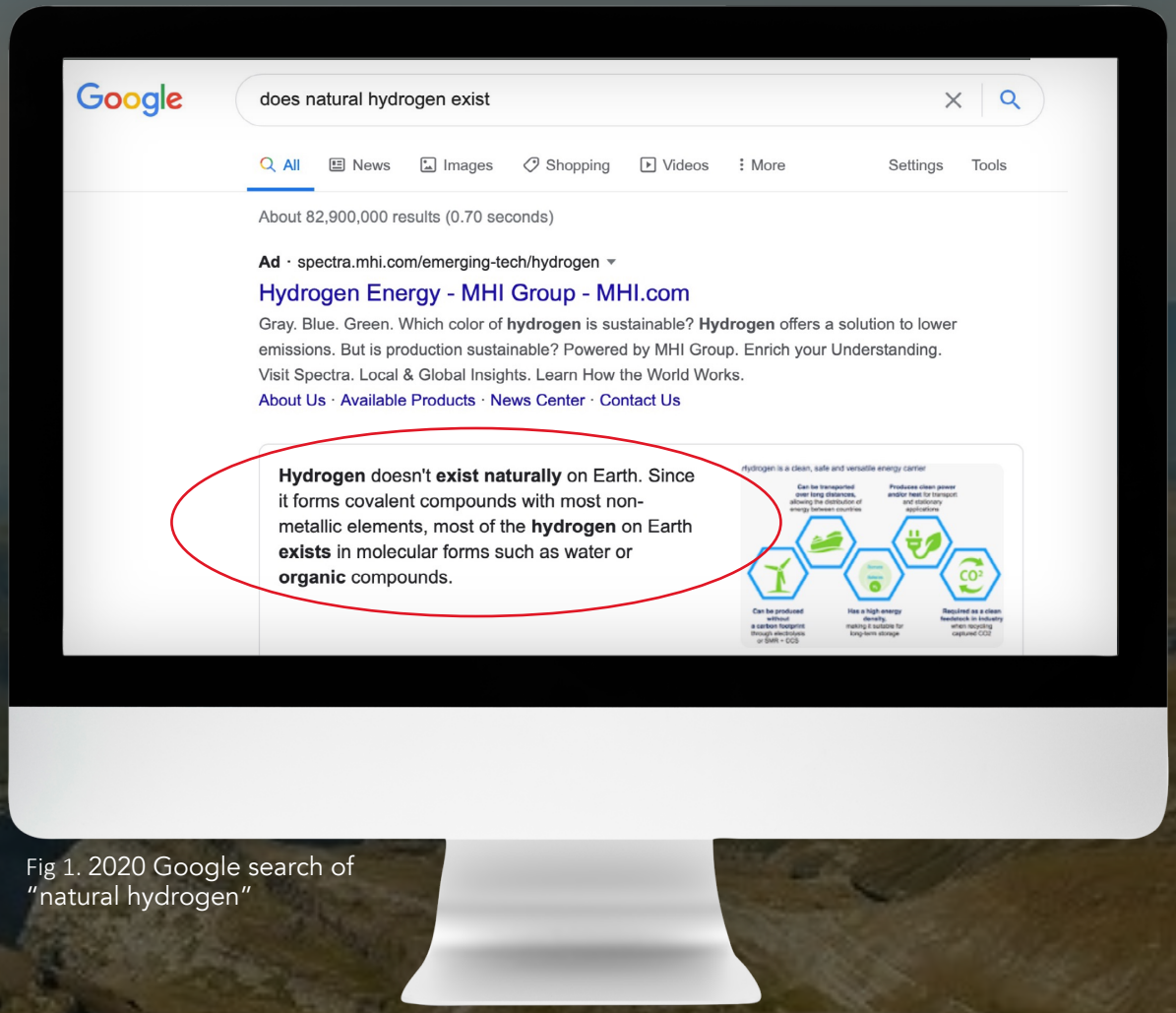


Fig 1. 2020 Google search of "natural hydrogen"

Google in early 2020 thought not…..

Unequivocally YES it does!

Hundreds of natural hydrogen seepages worldwide:

- Chimaera, Turkey 2500 years old!
- "Los Fuegos Eternos" (the eternal flames), Philippines discovered 200 years ago 41.4 - 44.5% hydrogen!
- 1888 first hydrogen analysis in a natural gas!

HOWEVER concept of natural hydrogen existing is embryonic - no exploration strategy nor resource assessment methodologies.

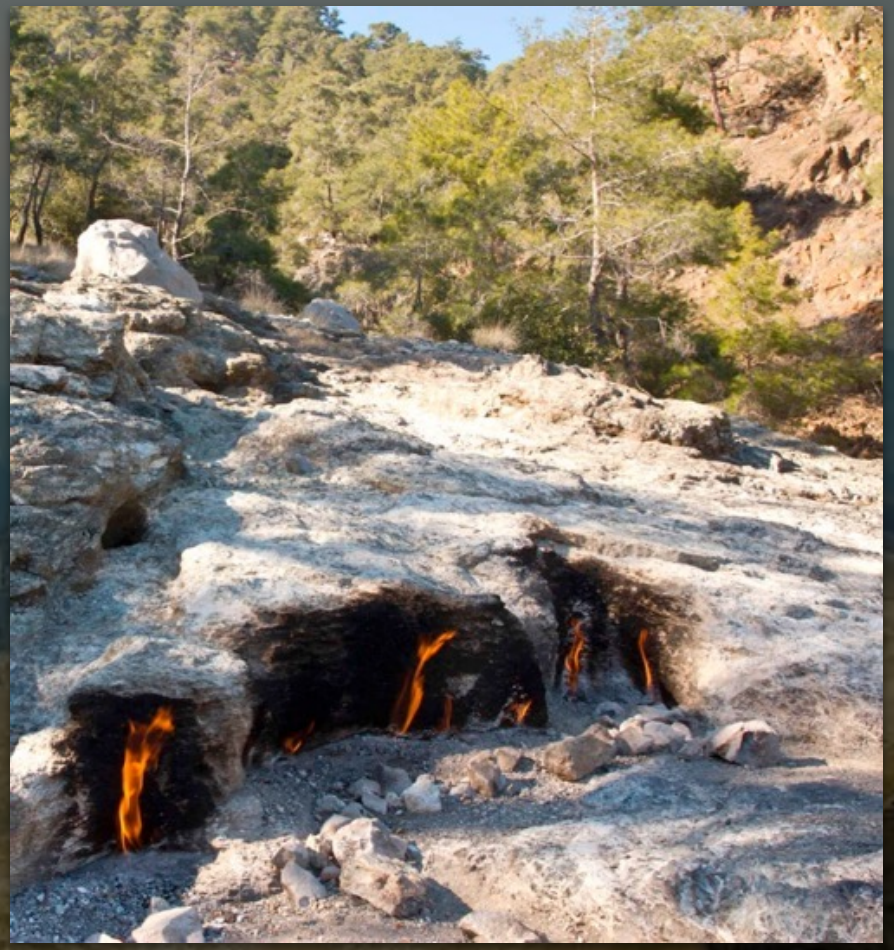


Fig 2. Natural hydrogen seepage, Chimaera, Turkey

Why is Natural Hydrogen Thought Not to Exist?

- Hydrogen diffuses rapidly in air, is very reactive and rapidly consumed by microorganisms.
- Existing ***prejudice*** – "…free hydrogen in nature is rare."
- ***No one looks for it!***

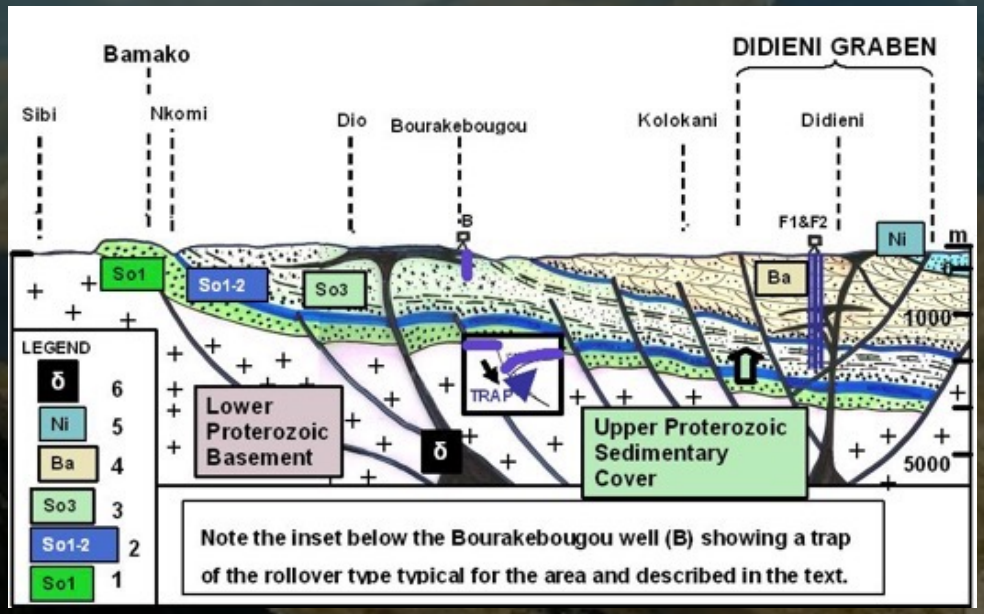


Fig 3. Intra-cratonic crystalline basement diagram of Mali

HOWEVER the discovery of trapped natural hydrogen in the Taoudeni Basin, Mali challenges the above.

Geological Factors for Natural Hydrogen

Specific subsurface conditions are needed for hydrogen to accumulate in commercial quantities:

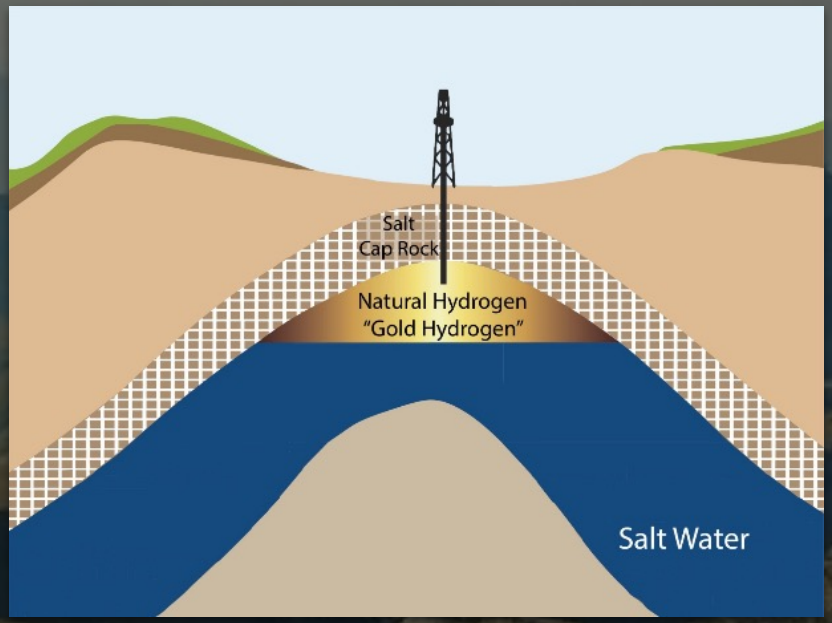


Fig 4. Simplified diagram of a typical natural hydrogen reservoir

Source
- Biogenic
- Chemical
- Radioactive

Reservoir
A porous/permeable rock to allow the hydrogen to accumulate and flow

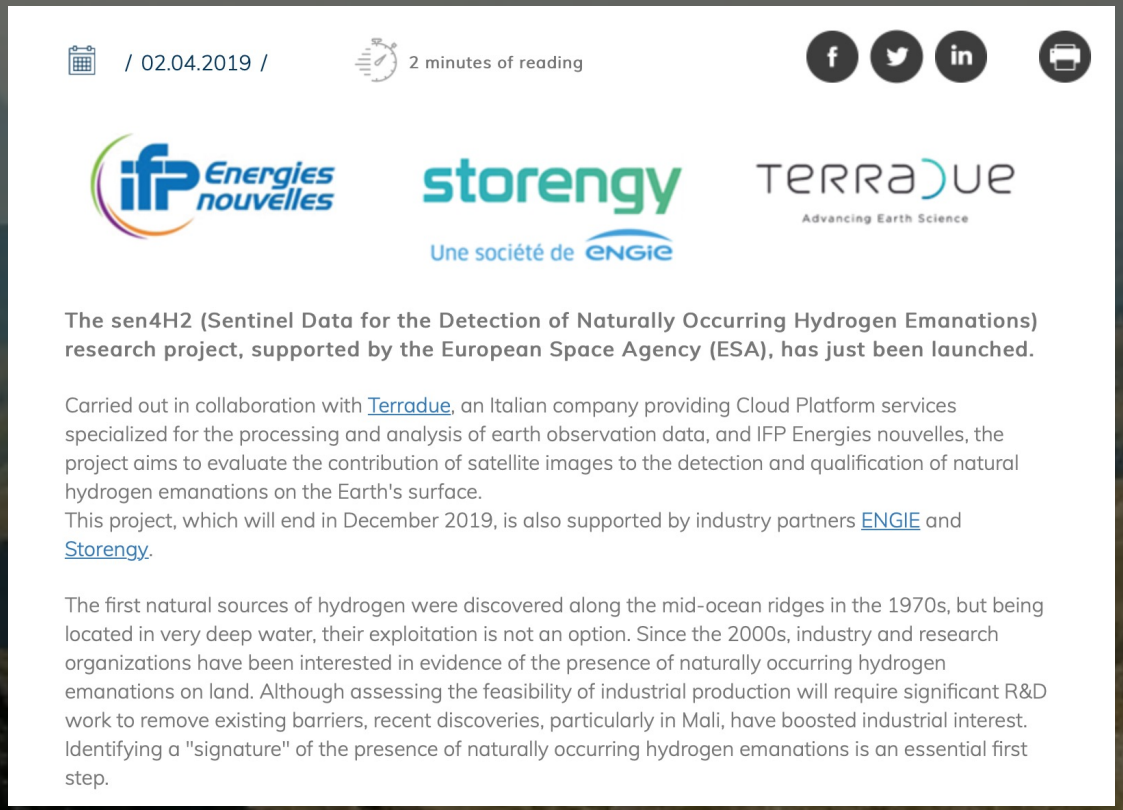
Seal
Very tight/impermeable "seal" (e.g. halite)

Oxygen Absence
Burial depths >3,000m

The accumulation of natural hydrogen shares <u>many similarities</u> with those of hydrocarbons.

How to Explore for Natural Hydrogen

Let's follow the hydrocarbon route……



/ 02.04.2019 / 2 minutes of reading

The sen4H2 (Sentinel Data for the Detection of Naturally Occurring Hydrogen Emanations) research project, supported by the European Space Agency (ESA), has just been launched.

Carried out in collaboration with Terradue, an Italian company providing Cloud Platform services specialized for the processing and analysis of earth observation data, and IFP Energies nouvelles, the project aims to evaluate the contribution of satellite images to the detection and qualification of natural hydrogen emanations on the Earth's surface.
This project, which will end in December 2019, is also supported by industry partners ENGIE and Storengy.

The first natural sources of hydrogen were discovered along the mid-ocean ridges in the 1970s, but being located in very deep water, their exploitation is not an option. Since the 2000s, industry and research organizations have been interested in evidence of the presence of naturally occurring hydrogen emanations on land. Although assessing the feasibility of industrial production will require significant R&D work to remove existing barriers, recent discoveries, particularly in Mali, have boosted industrial interest. Identifying a "signature" of the presence of naturally occurring hydrogen emanations is an essential first step.

Fig 5. IFP Press release on natural hydrogen

- Surface **seepage** of hydrogen ("Fairy Circles") ✅
- Mapping **hydrogen anomalies in soils** ✅
- Look for hydrogen in **existing wells** ✅
- Use existing geological and geophysical data and interpretation for sub-surface **prospect** generation ✅
- Drill a concept testing well! ✅

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Natural Hydrogen in the Monzón-1 Well

Natural Hydrogen in the Monzón-1 Well

Location

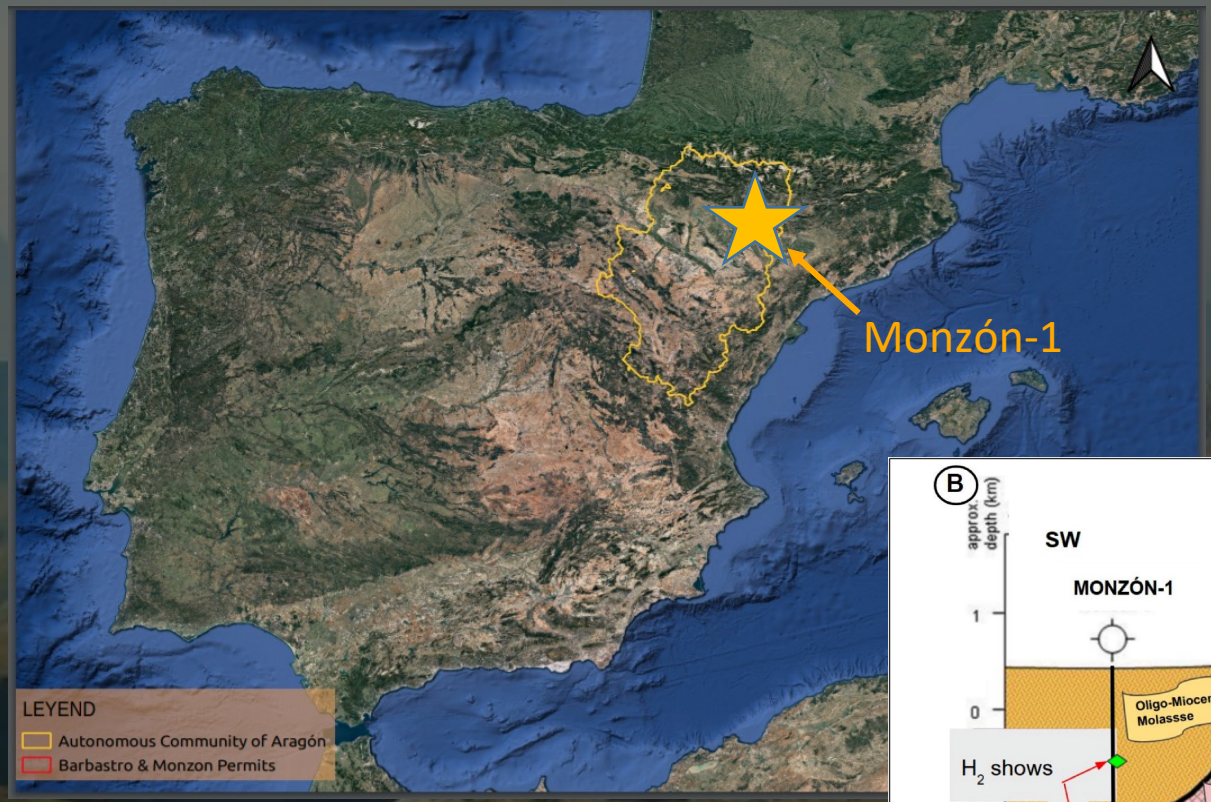
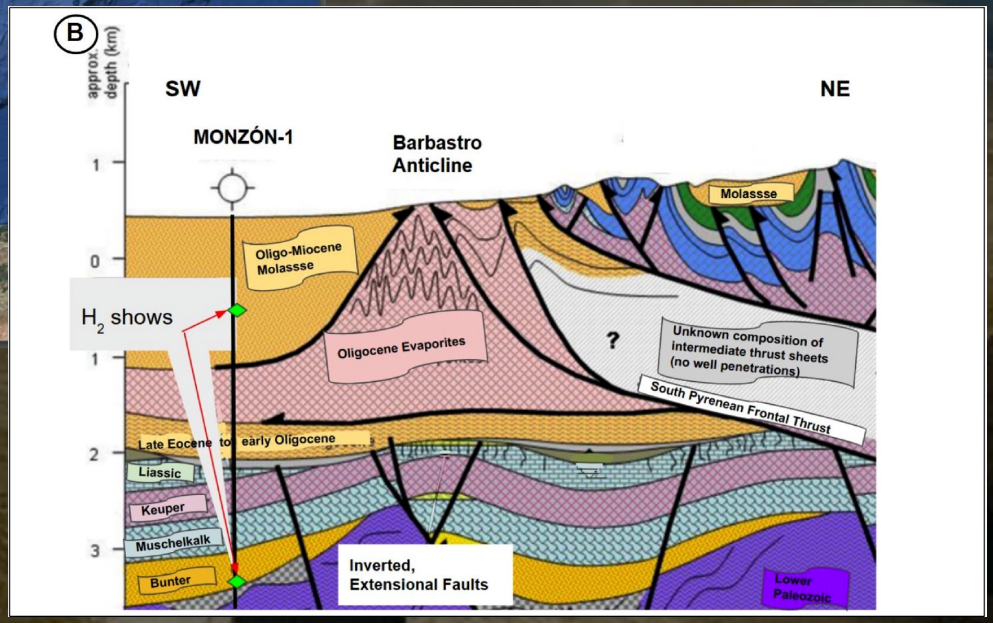


Fig 6. Map of Spain illustrating location of Monzón-1 well

Located in the northern Ebro basin, Aragón, Spain.

Drilled to explore for oil and gas by ENPASA in 1963.



Well encountered significant hydrogen shows while drilling.

Natural Hydrogen in the Monzón-1 Well

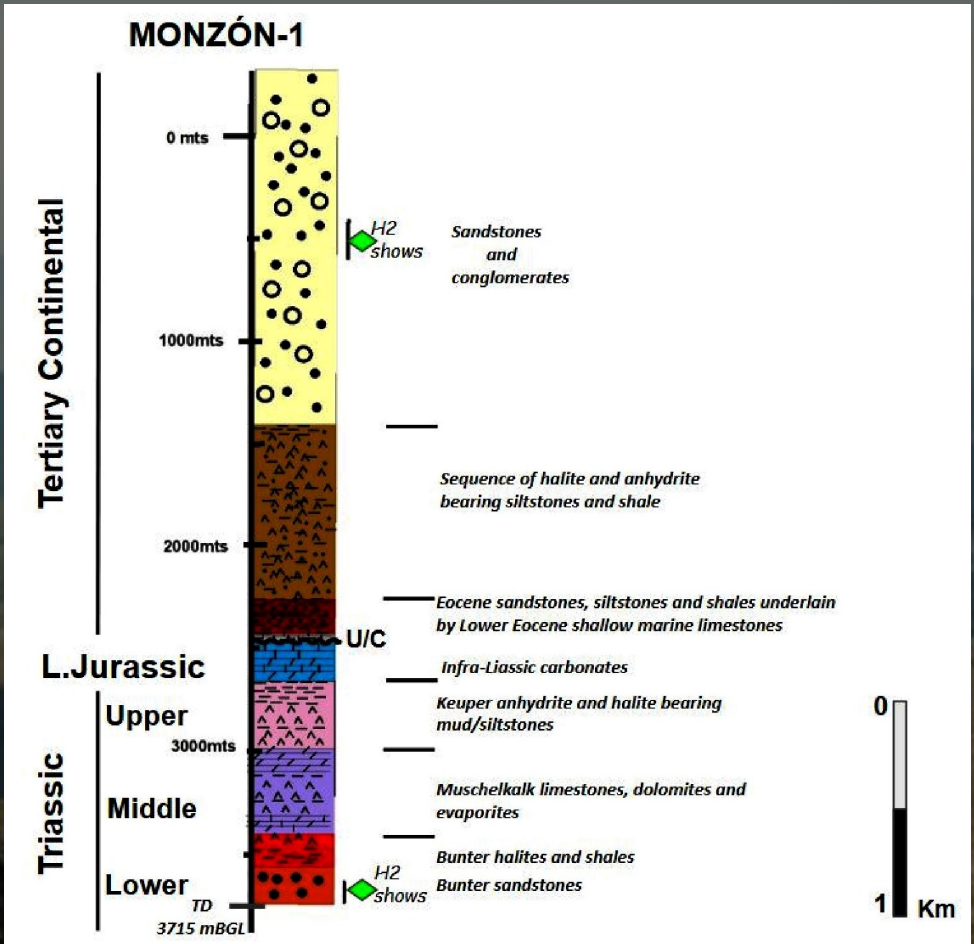


Fig 7. Borehole stratigraphy of Monzón-1 well

TD 3715m in Triassic Bunter Sandstone

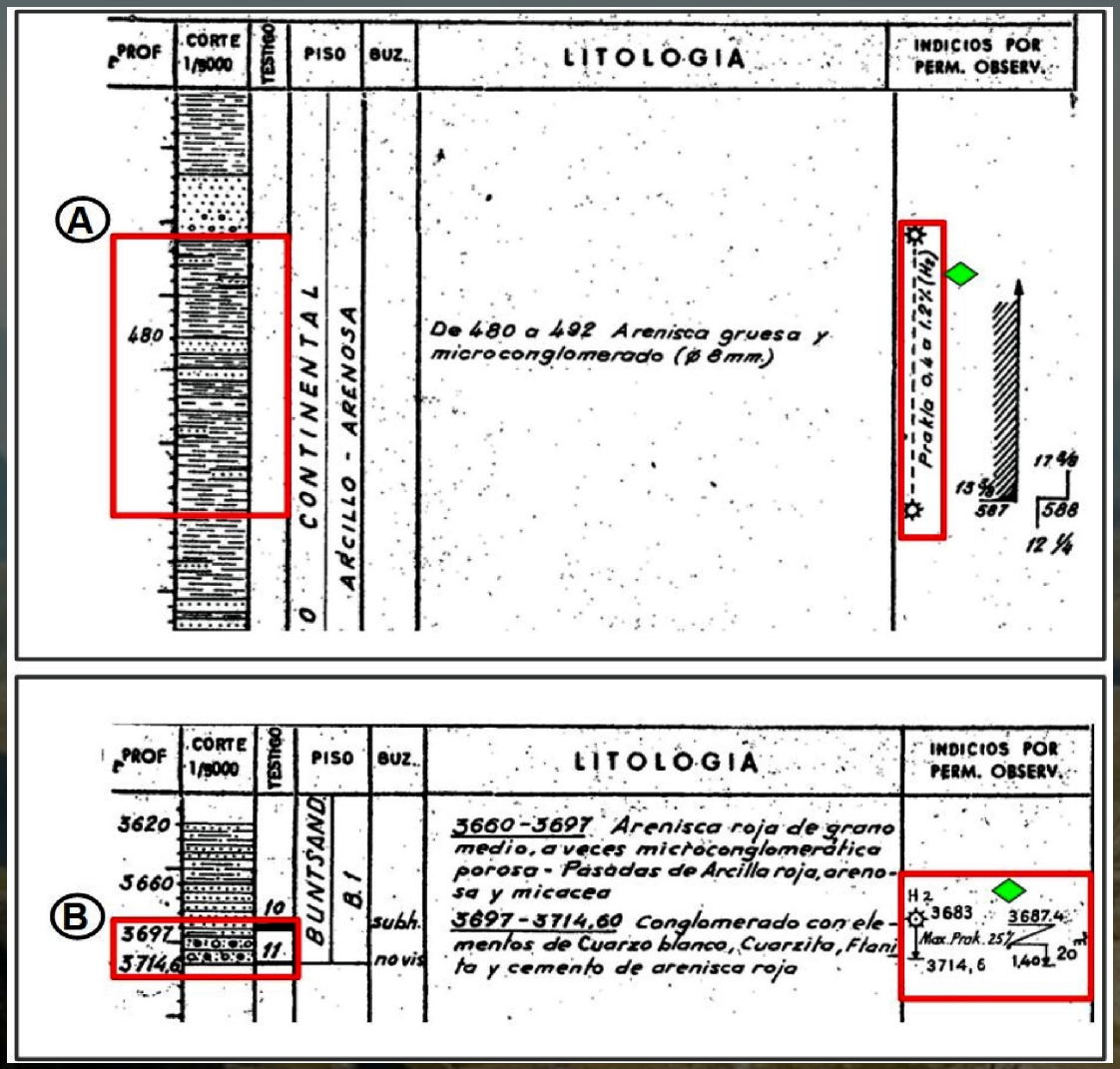
Bunter Sandstone 55m thick

Overlain by:

Lithology	Depth (m)
Evaporite bearing Bunter Shale	185
Röt Halite	60
Muschelkalk & Keuper halite & evaporite bearing shales	533
Tertiary aged halite and evaporite bearing shales	1,000+
Total	**~1,780**

VERTICAL TOTAL of 1780m of excellent sealing lithologies above the Bunter Sandstone

Natural Hydrogen in the Monzón-1 Well

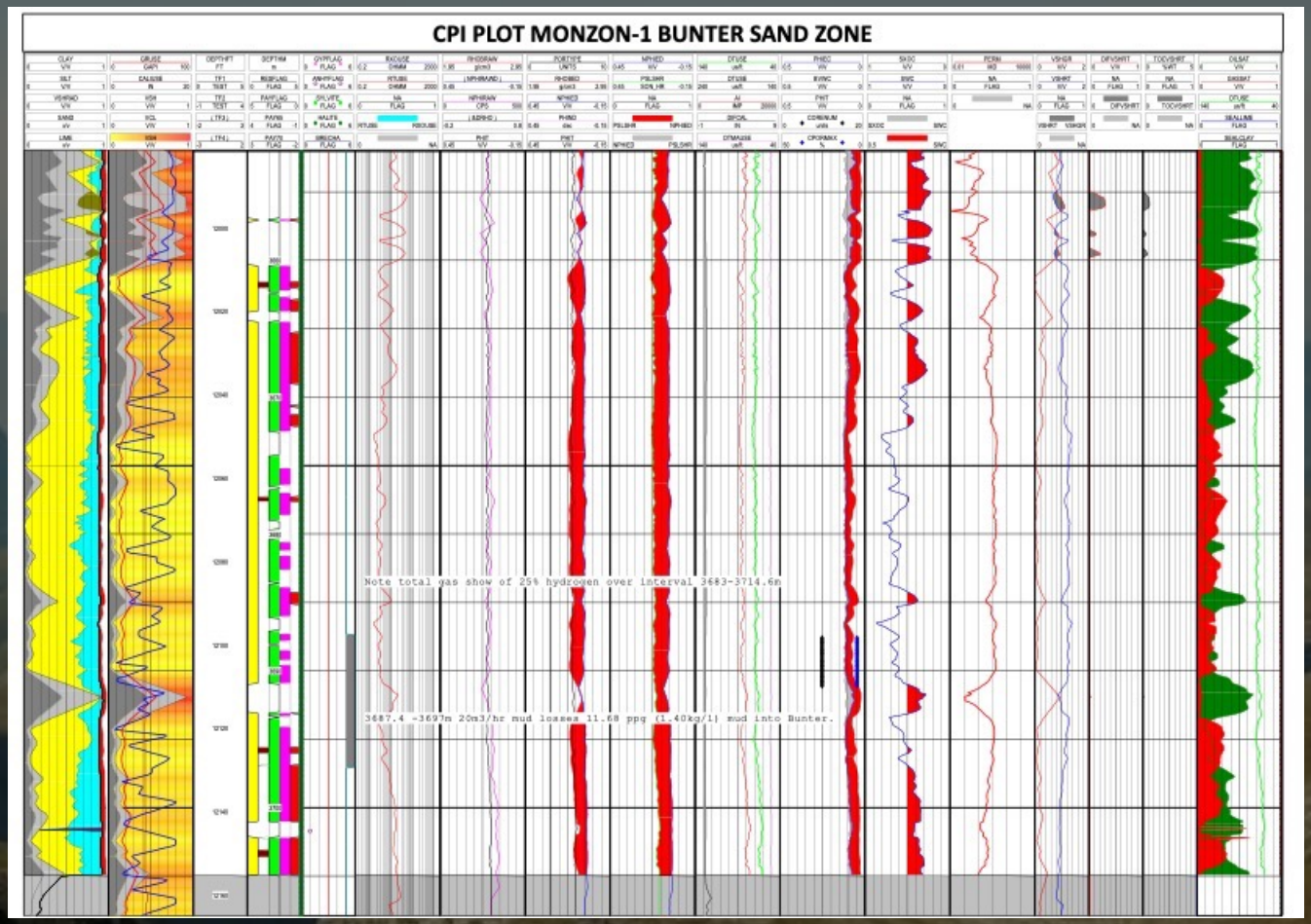


410-587m Tertiary. 0.4%-1.2% total gas shows determined by "Prakla"to be **pure** hydrogen

3,683-3,714.6m Bunter Sandstone. >25% total gas shows determined by "Prakla"to be pure hydrogen.

Fig 8. Detail of hydrogen gas shows in Monzón-1 well

Monzón-1 Bunter Reservoir Properties



- *Net Reservoir: ~ 55 meters*
- *Net Pay: ~ 30 meters*
- *Average Porosity in Pay: 9.5%*
- *Average Water Saturation in Pay: 36.4% (Gas Saturation: 63.6%)*
- *Average Shale Volume in Reservoir: 10.3%*

Fig 9. Petrophysical analysis of Bunter reservoir, Monzon- 1 well

Petrophysical analysis by HAPL confirms presence of **reservoir quality** in the Bunter Sandstones and indicates a substantial zone of **high gas saturation** from 3,660m to TD.

Monzón-1 Bunter Shale Seal

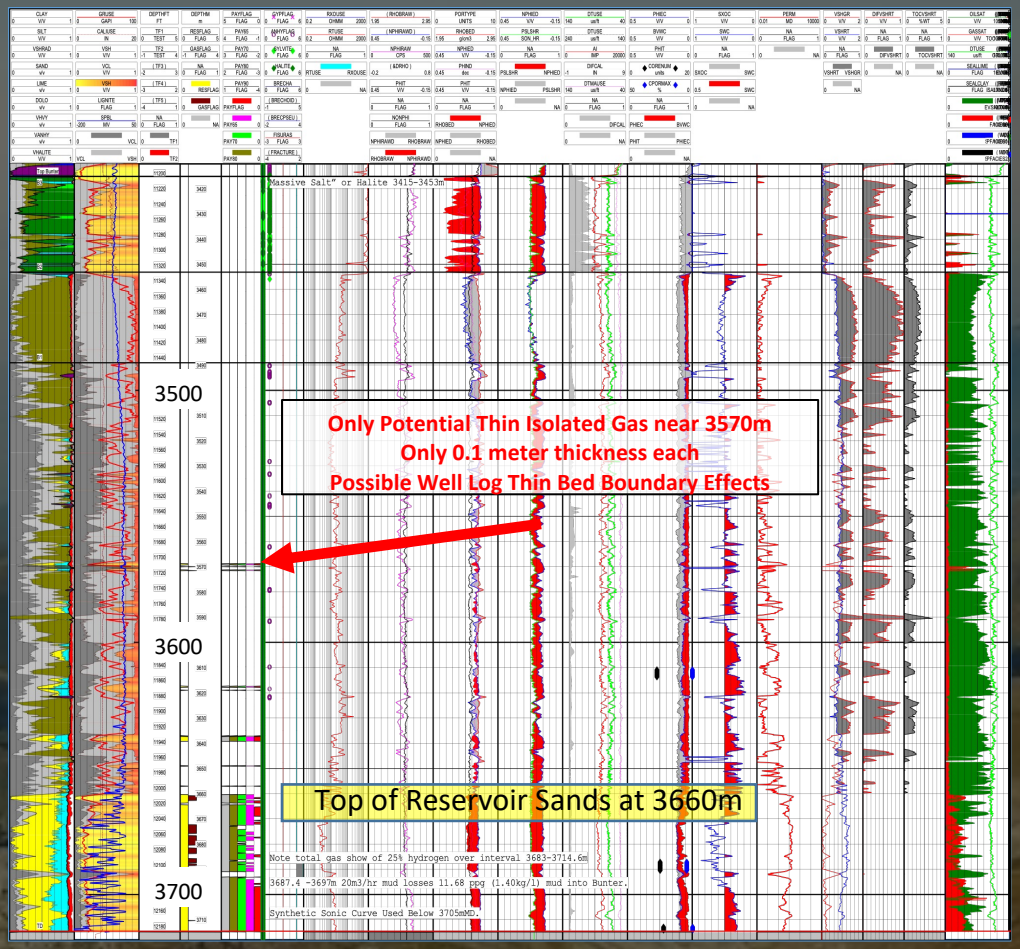


Fig 10. Petrophysical analysis of Bunter Shale seal, Monzón- 1 well

Bunter reservoir overlain by a thick seal interval of shale and interbedded evaporites ("Bunter Shale"). Monzón- 1 is interpreted by Helios Aragon to be an untested gas discovery

Soil Gas Geochemical Survey 2022

Steel sampling probe, samples collected by syringe 1.2-1.5 m depth

Sample Collection

Two samples collected.
One analysed immediately,
One returned later to lab.

Mass Spectrometry Analysis

Fig 11. HAPL field sampling techniques

Results Soil Gas Geochemical Survey 2022

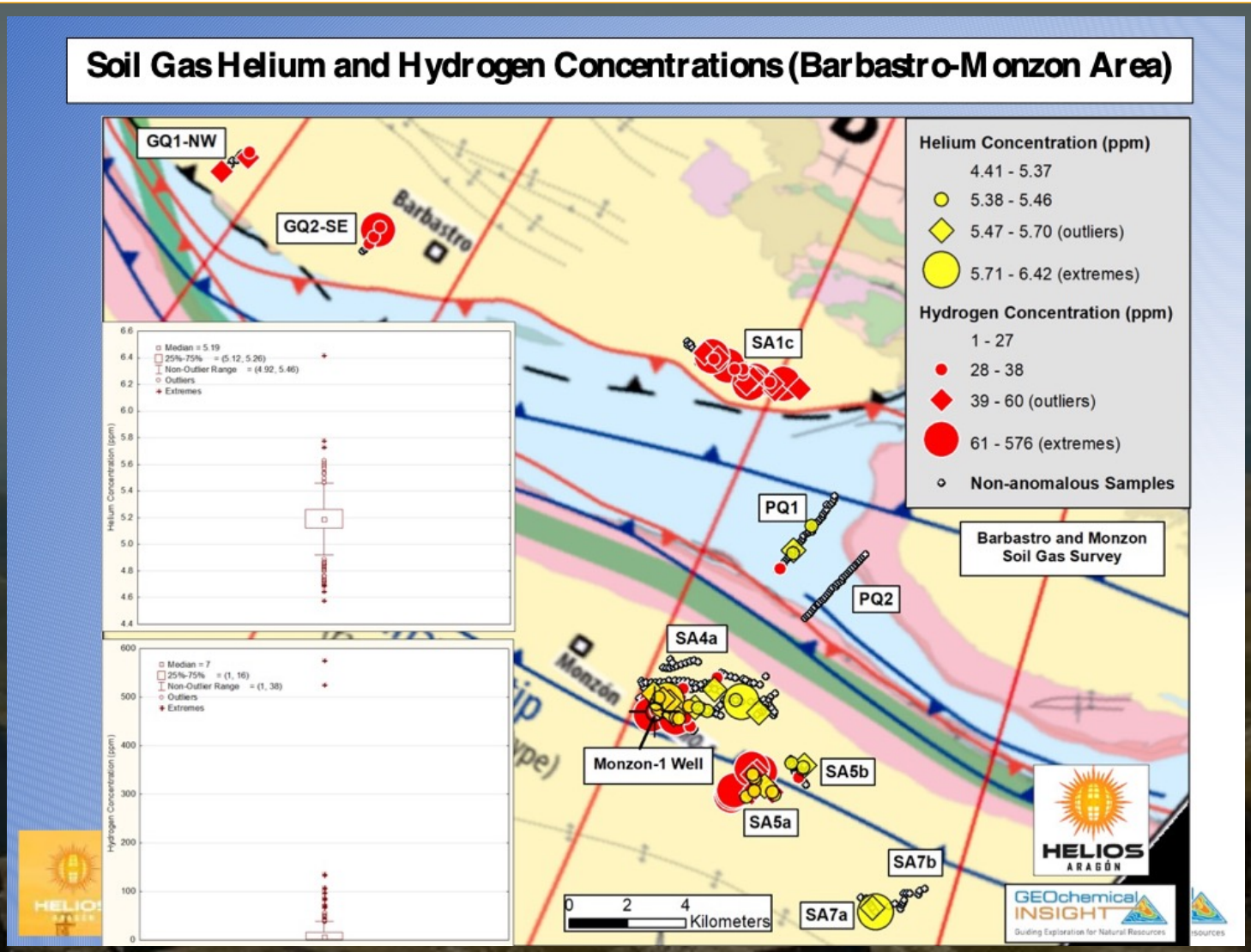


Fig 12. HAPL 2022 Soil & Gas Geochemical Sampling Results

The Monzón-1 Natural Hydrogen Discovery

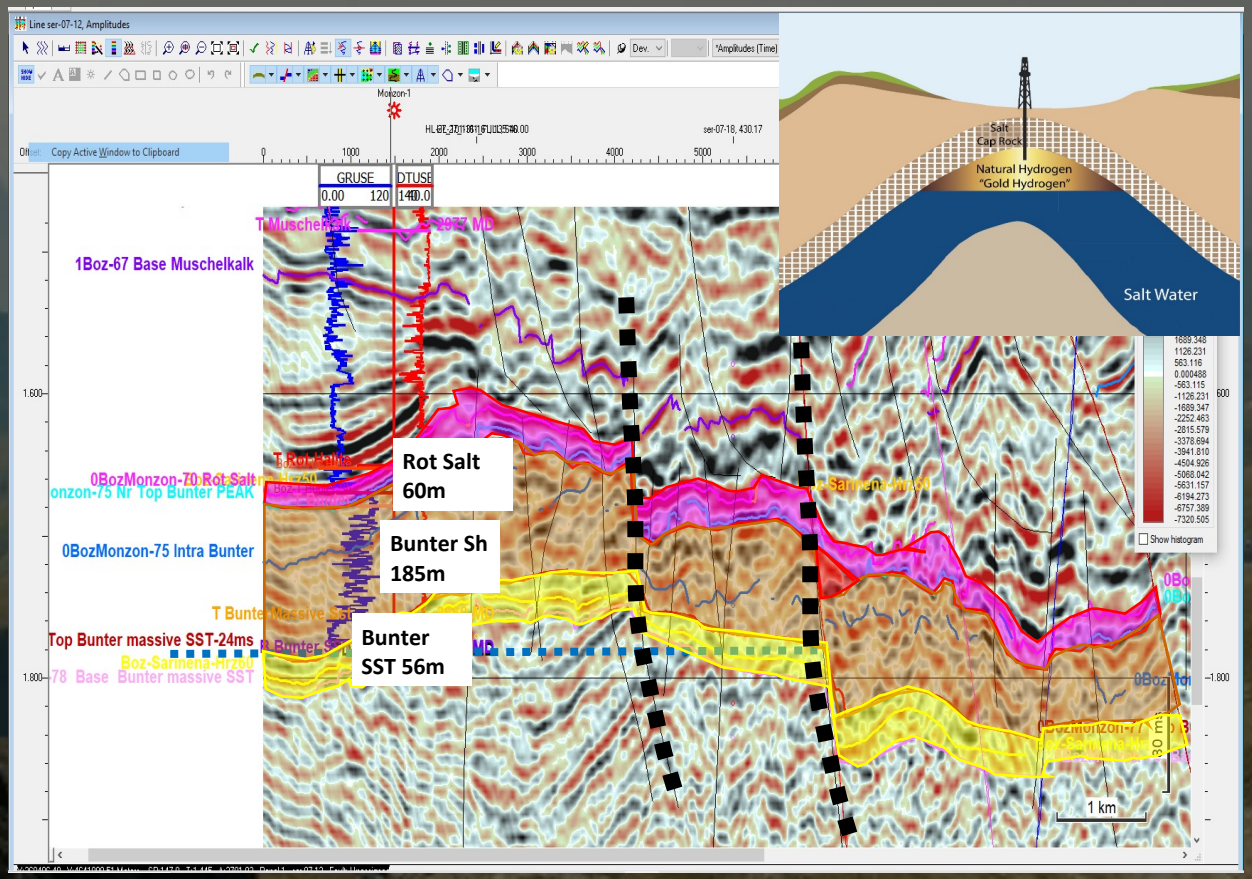


Fig 13.Summary of the natural hydrogen discovery at Monzon – 1 well

- **Source** is from mineralogical alterations in the deep crust/upper mantle.
- Migration via deep seated basement inversion faults which define the Monzón structure (black dashes).
- The Bunter Sandstone (yellow) provides a good and proven **reservoir** rock
- The Bunter Shale (orange), Röt Halite (pink) and halite/evaporitic shales in the overlying Muschelkalk, Keuper and Tertiary provide an excellent **impermeable seal**
- Reservoir depth >3000m provides for an **absence of oxygen**

Conclusions

- Natural, Gold or White Hydrogen exists and occurs extensively throughout the World!
- Favourable geological conditions should lead to trapping in the sub-surface
- Existing hydrocarbon exploration techniques will help locate those traps
- The Monzón-1 well (1963) records a “discovery” of natural hydrogen.
- It’s Helios Aragon’s contention this “dry hole” could be a key component in the largest energy transition the world has ever seen.
- The Helios forward plan is to re-drill and test the Monzón structure with the aim of defining a commercially viable natural hydrogen resource.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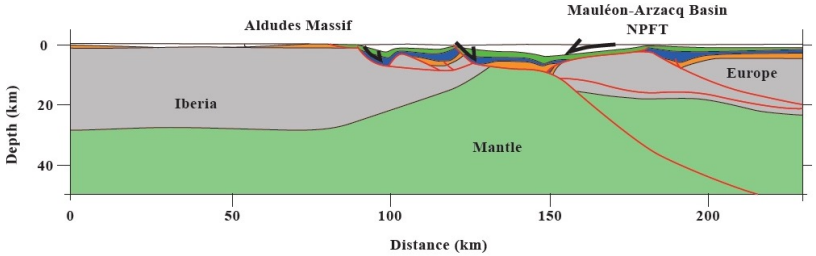
Gold H2 Existence – Why the Pyrenees?

From Lefeuvre et al, 2021

3. Geological setting

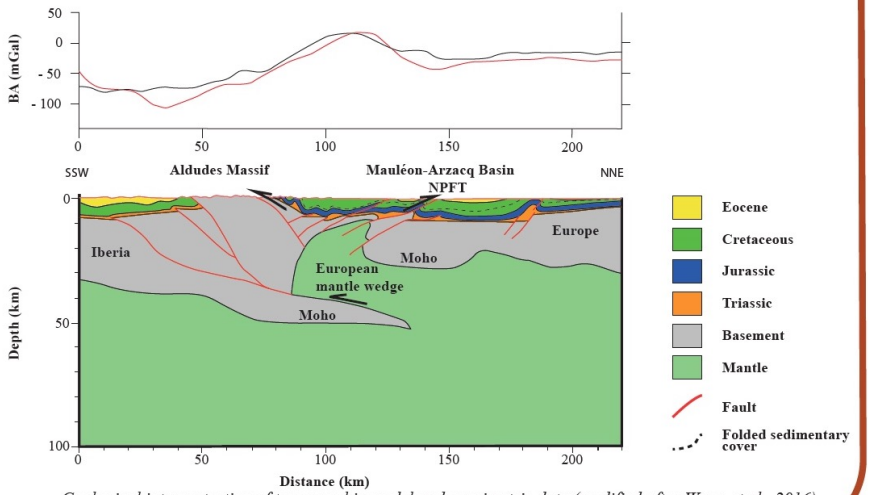
- **The Pyrenees is located in Southwest Europe,** form an intracontinental orogen that result from the **tectonic inversion of a rifted margin system (Early Cretaceous)** between the Iberian and European plates (Wang et al., 2016).



Cretaceous Hyper-extended rifting (after Gomez-Romeu et al 2019)

- **Mantle bodies were higlighted by geophysic data (Seismic, Gravimetric, Magnetic) at shallow depth**:
  - Bodies of exhumed mantle **inherited from the pre-collisional hyper-extended rift system.**
  - Mantle is **connected to the surface by two deep rooted faults** North Pyrenean Frontal Thrust (NPFT) to the north and North Pyrenean Thrust (NPF) to the south (Wang et al., 2016; Gomez-Romeu et al., 2019).

- Major fault can have two behavior
(1) **drain water to the depth** (Taillefer et al., 2017; 2018)
(2) **fluid migration pathway to the surface**. **Water at depth will serpentinize mantle rocks**

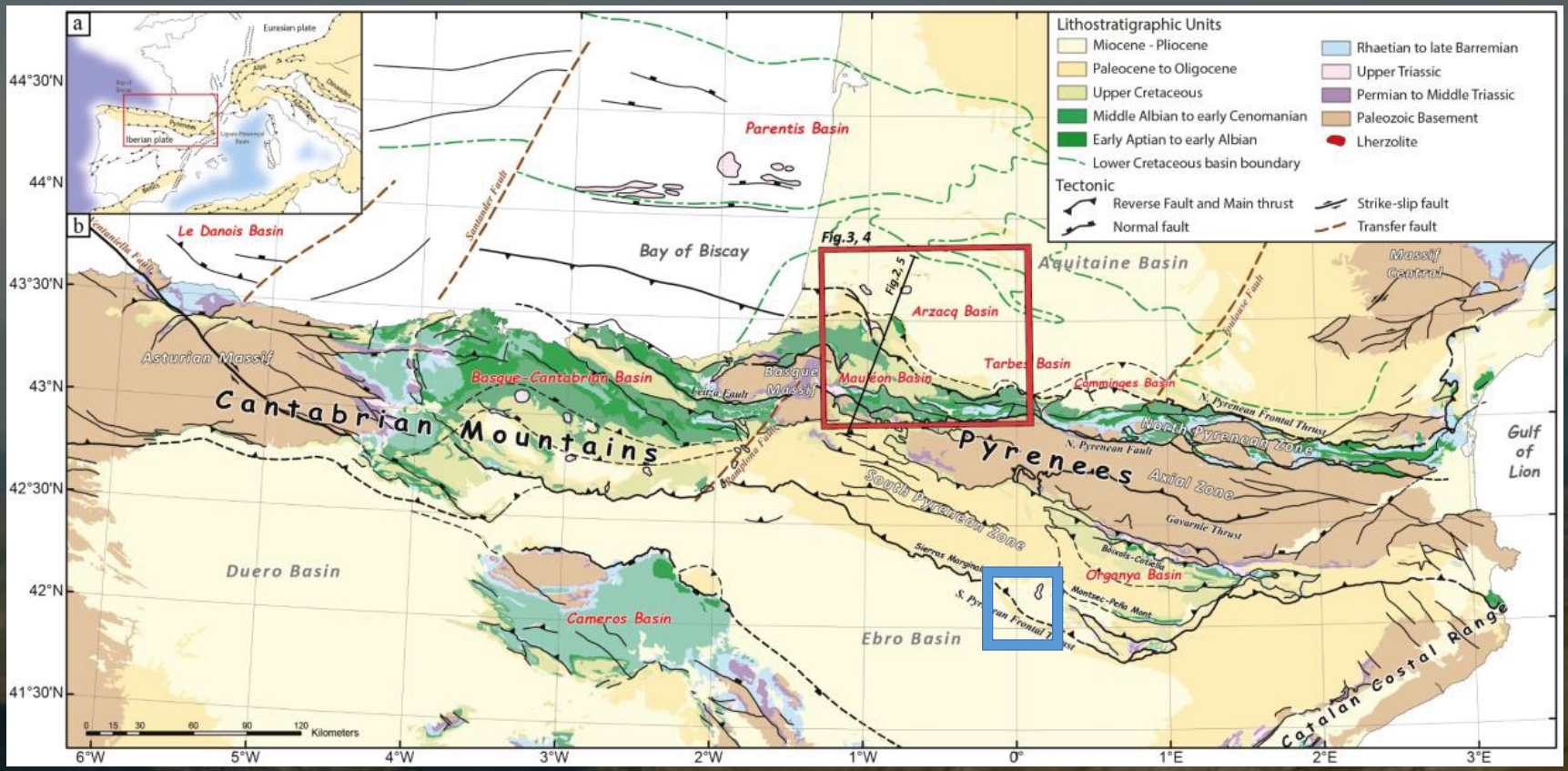


Geological interpretration of tomographic model and gravimetric data (modified after Wang et al., 2016)

H2 emanations in the north Pyrenees relate to the alteration of near surface iron rich mantle rocks and obducted and uplifted oceanic crust.

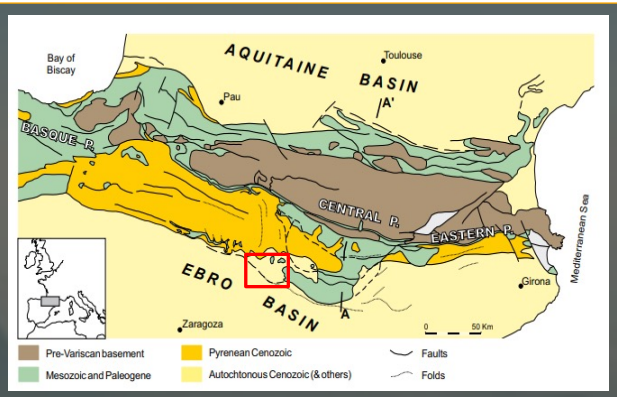
Trapping and sealing mechanisms are largely absent on the northern flanks of the Pyrenees and H2 easily escapes.

Gold H2 Existence – North Pyrenean Fault Zone



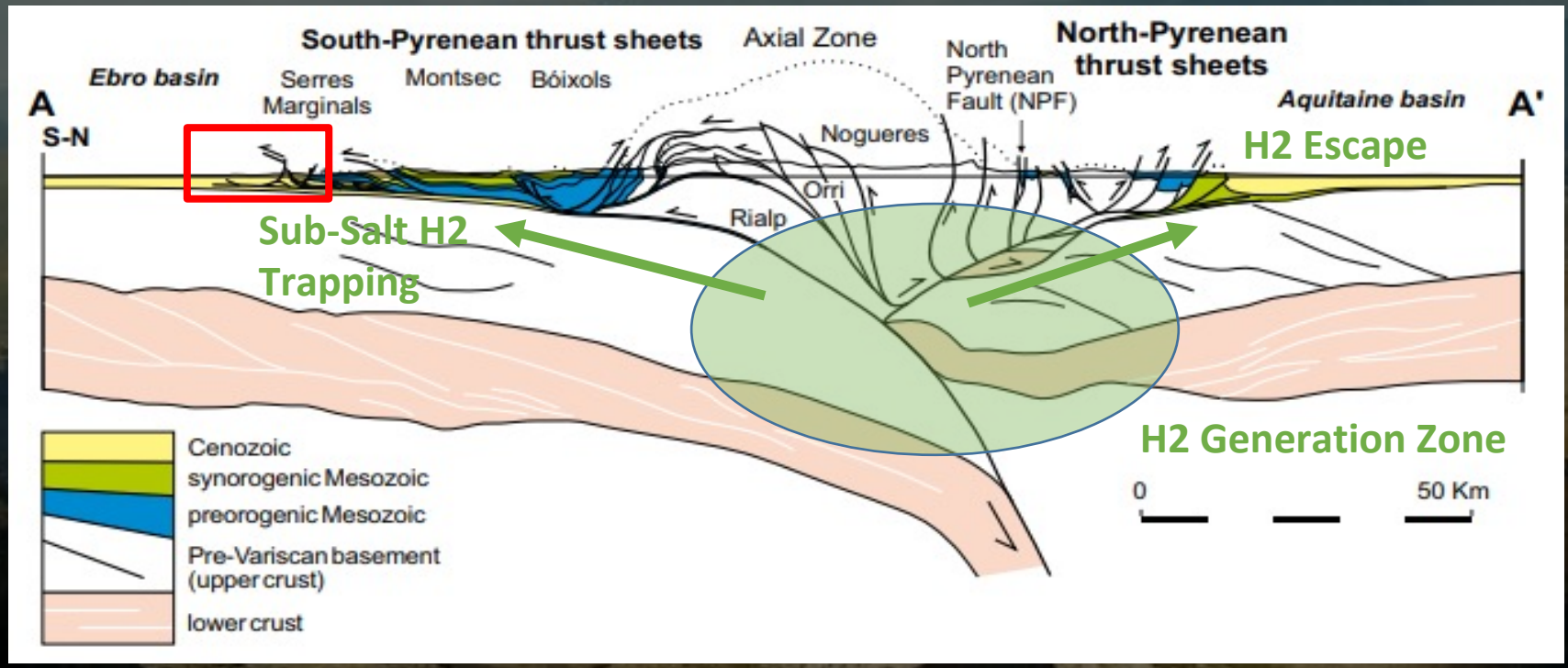
Lefeuvre et al (2021) illustrated importance of natural H2 seepage along the North Pyrenean Fault zone at southern edge of Aquitaine Basin (red). Note the symmetry of location of the Permit area (blue) on the northern edge of the Ebro Basin in the South Pyrenees.

Gold H2 Trapping in South Pyrenees



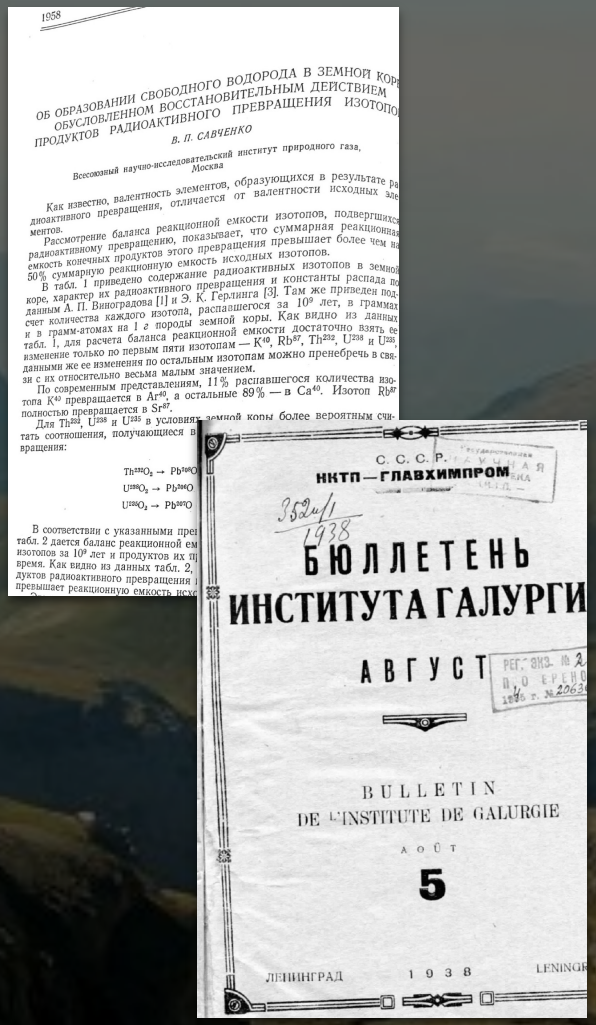
The Permit area (red) is located in the South Central Pyrenees between the southernmost Pyrenean thrust sheets and the autochthonous deposits of the Ebro foreland basin.

Presence of thick Mesozoic/Tertiary cover sediments in the South Pyrenees favours H2 trapping compared to the North Pyrenees where this cover is largely missing.



Geological cross-section of the Central Pyrenees. From Muñoz et al 2018

Why the Eastern Bias?



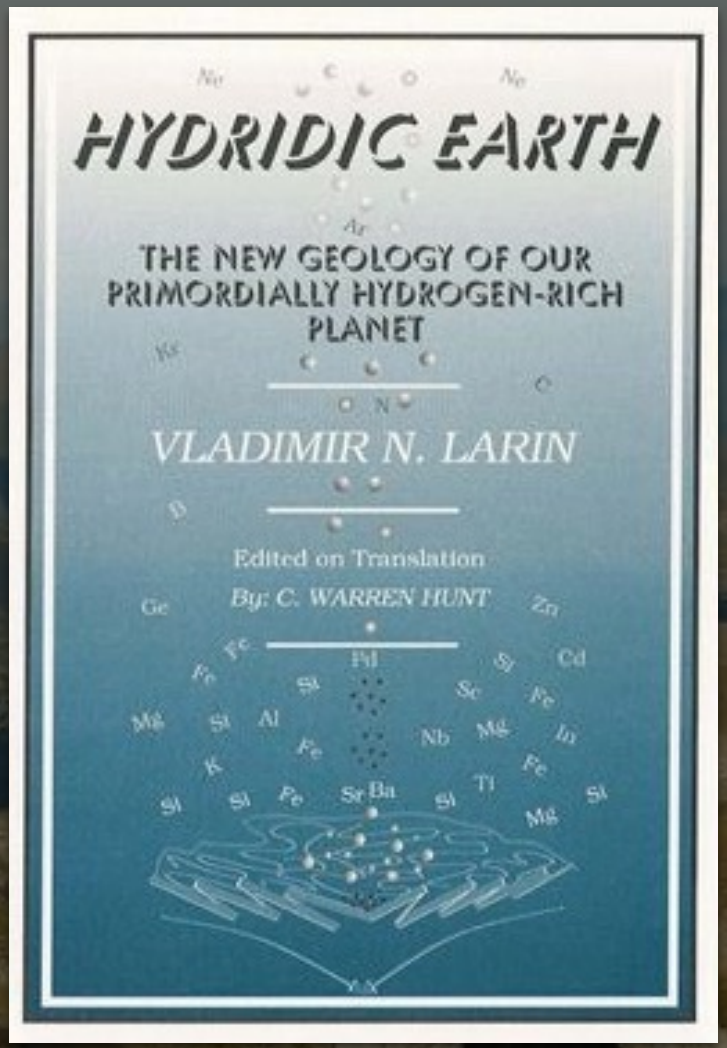


Fig 14. Russian publications on natural hydrogen

A "parallel universe" view of the origin, evolution and structure of the Earth