Natural Hydrogen: How can Geosciences contribute to the energy transition?

Marco C. Schinelli, Petrobras

Abstract

Fossil fuels are finite resources and everyone can witness an intense technological race in the search for less polluting substitutes, not only as energy matrix, but also for the production of products that today still depend on the petrochemical chain.

In this energy transition scenario, the geosciences applied to oil industry need to adapt quickly to a new reality under construction, being able to add new knowledge and processes to those applied routinely, and with great success, to the oil sector.

On the horizon of energy substitutes, natural hydrogen emerges as a potential alternative, but there still are many knowledge gaps that pose challenges, but also opportunities, for geoscientists who work in the oil segment.

The 2031 Decennial Energy Expansion Plan (PDE 2031) prepared by the Energy Research Company (EPE) includes the possibility of exploring and producing natural hydrogen, or white hydrogen, in reserves in Brazil: "As for natural hydrogen, previously considered marginal, if not non-existent, it increasingly appears as an important option to be explored by energy companies in the near future", cites the EPE report (1).

In this work we develop a line of reasoning to justify the importance of building the scientific and technological support base necessary for the exploration of natural hydrogen, our new and promising energy substitute.

Introduction

Humankind developed, along several centuries, the scientific base that allows us the efficient exploitation and use of fossil fuels that are, and will still be for a long time, the energy vector of our society.

Fossil fuels were already known, before the Christian era, and used for different purposes, thanks to easily recognizable exudations, bringing oil to the surface (fig. 1). Such oxidized oil, also called Bitumen was used in lighting, heating, and others, and led to the suspicion of existence of larger deposits in the subsurface.

Fig 1. Naturally occurring oil seep near McKittrick, California, United States. (source Wikipedia)

In addition to environmental issues, the reduction in the amount of fossil fuels, whose availability is estimated to guarantee current consumption levels for approximately 50 years, brings an urgent need to find alternative solutions.

Hydrogen: A brief history

Hydrogen was first identified by the British scientist Henry Cavendish, who proved to the Royal Society of London in 1766 that there were two different types of air: "fixed air" or carbon dioxide – and "flammable air" or hydrogen.

In 1863, the Belgian inventor Etienne Lenoir created the 'Hippomobile'(Fig.2). Prior to other gases, the Hippomobile engine was supplied with hydrogen, generated via the electrolysis of water. Along with being a genius, it's clear that Etienne Lenoir was more than a century ahead of his time.

Practical interest in hydrogen as a fuel grew in Europe after World War I - driven in part by increased interest in energy self-sufficiency.

World War II further boosted the search for hydrogen fuel.

Growing demand for fuel and risks of supply cuts led the Australian government and others to consider using industrial hydrogen – until Allied victory made cheap oil and gasoline available once more.

US military also explored the use of hydrogen for its Air Force, Army and Navy during the war. These efforts eventually led to the use of liquid hydrogen in the United States space program.

In the 1930s, the Hindenburg, a German Zeppelin filled with hydrogen, made ten successful transatlantic flights from Germany to the United States. However, when it arrived in Lakehurst, New Jersey on 6 May 1937, it all went terribly wrong and the airship went up in flames.

The 1950s saw the development of the use of hydrogen in outer space - In the 1960s, several scientists proposed using solar energy to split water into hydrogen and oxygen (2).

The 1973 fuel crisis also boosted scientific interest in hydrogen. The shock suggested that the era of cheap oil was over – and that alternatives were needed.

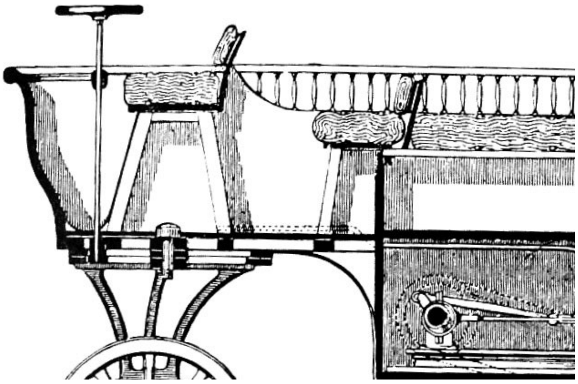

Fig 2. Etienne Lenoir's Hippomobile (1863) 1-cylinder, 2-stroke engine called the 'Hippomobile'. The oxyhydrogen (also known as 'water gas') for the engine was produced by electrolysing water (2).

White Hydrogen: Why the "favorite color"?

The different colors used to classify the hydrogen relate to how it is obtained.

Basically, one need inputs, industrial processes, and energy to produce hydrogen. The different processes have usually high production costs and often environmental impact (Fig 3). For example, to obtain gray hydrogen from coal gasification, fossil fuels are used, and high amounts of CO_2 are produced.

Natural hydrogen, also called white or golden hydrogen, emerges as the best alternative, at the lowest cost and negligible environmental impact.

There are many occurrences (exudations) of natural hydrogen found in different parts of the world (7). But unlike oil, natural gaseous fumes are much harder to find.

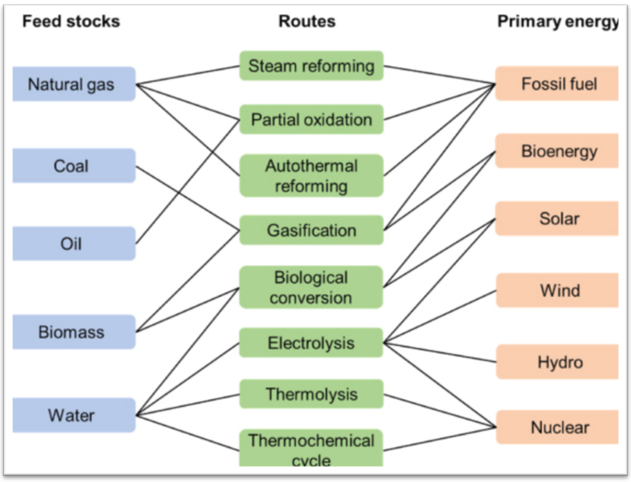

Fig 3. Primary energy sources, feed stocks and routes for hydrogen production (3).

And to make its exploration even more challenging, there is a scientific base of geosciences still incipient and under construction.

Despite some results such as a H_2 production well in Mali, Africa, which produces hydrogen at 98% concentration, or other results in the United States, Russia or Australia, the conditions for the occurrence of those deposits are still poorly understood.

In Brazil, exudations of natural hydrogen have been found and tested using surface geochemical sampling, in typical circular structures (Fig 4), which are also associated with the occurrence of H_2 in Mali, Australia and other parts of the world (4).

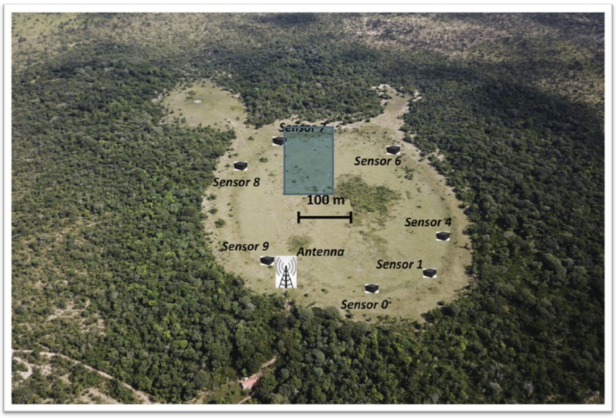

Fig 4. Location of H2 monitoring in a circular depression of the São Francisco Basin (Brazil). H2 sensors positions, and the data-transmitting antenna are shown (4).

Despite those surface' evidence about the potential of H_2 occurrence on areas associated with such circular depressions (also called "fairy circles"), there are still numerous uncertainties about the geological processes for natural H2 generation.

Initially, it was believed that the serpentinization of Olivine and alteration promoted by natural (U, Th, K) radiation of mafic rocks, in the presence of water, were the only processes responsible for the generation of hydrogen in the subsurface.

But currently, there are other different hypotheses (Fig 5 (5)), including the deep generation inside our planet, at the level of the Earth's mantle, from where, H2, could ascend to the surface, through faults, volcanic dykes and trapped in the sedimentary sequence above whenever found a seal interval on its pathway to surface.

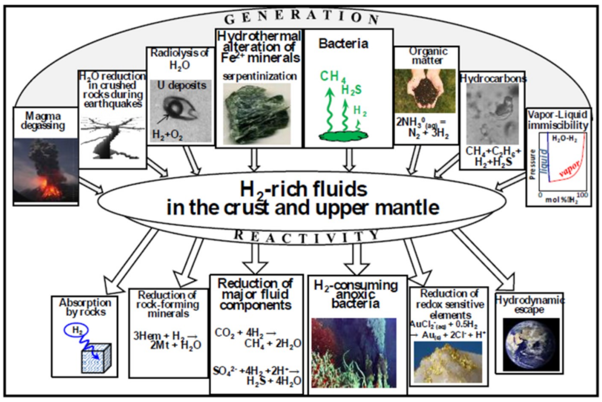

Fig 5. Main H2 sources and sinks in the crust. McCollom and Seewald 2013; Murray et al. 2020. (5).

Therefore, the scientific base that can guide the exploration of natural hydrogen is still under construction and the geoscientists need to adapt to this new challenge.

Hydrogen system vs. Petroleum system

Source and sealing rocks, synchronism, migration paths and reservoirs will remain as mandatory actors in the "hydrogen system" (as a reference to the well-known "petroleum system"). Even H2 sources are becoming better known.

Our traditional seismic method, very effective in oil prospecting, will certainly lose the first place on the podium to multiphysics methods, more appropriate for the identification of metallic mineral provinces, in direct contact with saline aquifers.

The rarely used surface geochemistry, will certainly play an important role, being challenged to identify hydrogen emanations, not only from the surface or on drilled wells, but also from space. The European Space Agency, in association with IFP Energies nouvelles (IFPEN) and other companies are working on the detection of naturally occurring hydrogen emanations (sen4H2 project) to evaluate the contribution of satellite images to the detection and qualification of natural hydrogen emanations on the Earth's surface (6).

The traditional seismic method will have to overcome itself with the characterization of the geometric behavior of volcanic and metamorphic rocks, commonly known as base reflection limits in a sedimentary sequence (8).

Even the bases of elastic properties, so well established for sedimentary rocks, will need to be adapted for volcanic and metamorphic environment.

The characterization of properties such as Poisson's coefficient, velocity anisotropy, seismic illumination at deep intervals with low impedance contrast, are among some of the challenges, which will require the geoscientific community to redirect its efforts in building the knowledge base to challenges that did not deserve our attention on oil exploration.

A look into the future

The planet is our only, and finite source of natural resources and geosciences is the instrument that guarantees society access to those resources.

Our best contribution to the energy transition will be through rapid and solid preparation to find alternative energy sources.

Natural hydrogen emerges as an excellent solution for the end of the fossil fuel era, and we need to get out of our comfort zone and prepare our science to the challenges that will be required to take advantage of this natural resource.

Acknowledgments

To Petrobras for its willingness to be a player in the energy transition process and for permission to share this work

References

(1) Potencial do hidrogênio natural merece ser investigado no Brasil, aponta PDE. Gabriel Chiappini, Janeiro 22, EPBR.

(2) Hydrogen in history - Gasuine, Netherlands. Gasunie (https://www.theworldofhydrogen.com/gasunie/history/) and Jean-François Tissot, Oct 2020, Accelteron Industries, Charge! Magazine

(3) Review and comparison of various hydrogen production methods based on costs and life cycle impact assessment indicators. Mengdi Ji,

Jianlong Wang. International Journal of Hydrogen Energy, 2021

(4) Natural hydrogen continuous emission from sedimentary basins: The example of a Brazilian H2-emitting structure. A. Prinzhofer, Isabelle Moretti, Joao Francolin, Cleuton Pacheco, A. D'Agostino e, Julien Rupin. International Journal of Hydrogen Energy. Volume 44, Issue 12, 1 March 2019, Pages 5676-5685

(5) Natural Hydrogen: Promising opportunities for Exploration & Production. McCollom and Seewald 2013; Murray et al. 2020.

(6) Detecting Naturally Occurring Hydrogen Emanations with Satellite Images - launch of the Sen4h2 project. IFP Energies nouvells, 2019.

(7) The occurrence and geoscience of natural hydrogen: A comprehensive review. Viacheslav Zgonnik. Earth-Science Review, April 2020.

(8) Improved Imaging Inside Fractured Basement Using Broadband Technology, Offshore Vietnam. Z. Zhang, J. Zhou, C.H. Chionh, J. Li & G. Bone. EAGE Conference, 2015