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Potential for Underground Hydrogen Storage in the Uruguayan Continental Shelf

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Abstract

In this work, the potential for underground hydrogen storage in porous media, offshore Uruguay, is assessed by identifying play elements and their competence. General conditions for geological storage are similar to those of hydrocarbon accumulations: a stratigraphic, structural or mixed trap, a suitable reservoir and an adequate seal to prevent fluids to escape from the trap. This analysis is restricted to shallow waters of Punta del Este and Pelotas basins, where bottom fixed or floating wind turbines could be placed for renewable energy generation. The main geological storage play identified, consists of Late Cretaceous stratigraphic pinch-out traps of the postrift sequence, composed by shoreline-shelf, estuary or delta sands, sealed by thick marine shales related to a transgressive regional event in the Paleocene. The Late Cretaceous sequence can be observed on seismic to pinch out in a shoreward direction against a basement high (Polonio). In addition, the play shows lateral closure associated with differential compaction of sediments on depocenters, located on both sides of the high, which generates gentle drape structures. Those structures appear all along the shelf, in a NE-SW direction, from 50 up to 200 meters of water depth. In terms of competence, nearby exploratory wells data evidence satisfactory properties for the potential Cretaceous reservoirs with good porosity values. Moreover, the effectiveness of the Paleocene shale seal, a key factor, is evidenced by the abrupt change in the fluid inclusions population detected in the wells, comparing Cretaceous with Cenozoic sequences.

Key words: Hydrogen, Underground Storage, Play, Uruguay, Offshore

Introduction

The offshore of Uruguay is located in the South Atlantic Ocean between 50° 00’ and 55°60’ west longitude and 33°75’ and 37°80’ south latitude. Its exclusive economic zone extends up to 200 nautical miles, covering an area of approximately 125,000 km^2 with bathymetries up to 4000 m. No hydrocarbon discoveries have been made yet, in an underexplored area with only three exploratory wells drilled over 40 years. However, the continental shelf of Uruguay, in the context of the South Atlantic Ocean, shows an interesting potential for the generation of renewable energy, taking into account the high wind speeds and capacity factors (Global Wind Atlas, 2022), currents and solar irradiance. In anticipation of a future global market for hydrogen, Uruguay, through its National Oil Company is planning to tender offshore areas for the production of green hydrogen from offshore renewable sources (Buljan, 2021). Moreover, from the perspective of a global energy transition, it is expected that oil and gas companies take advantage of their offshore skills and gradually incorporate the production of renewable and low carbon energies. On this framework, geological and geophysical data from offshore oil and gas exploration, including 40,000 km of 2D, 43,000 km^2 of 3D seismic, 130 seabed samples and metocean and environmental data, can be of value to address various challenges, including the long-term storage of hydrogen.

Geological setting

The Uruguayan continental margin comprises three sedimentary basins: Punta del Este Basin to the southwest, Pelotas Basin to the northeast and Oriental del Plata Basin, that develops in deep-waters over oceanic crust. These basins were generated during the process of fragmentation of the Gondwana supercontinent and later opening of the South Atlantic Ocean in the Late Jurassic-Early Cretaceous. Punta del Este Basin has a funnel shape with a NW-SE trend, constituting a failed arm (aulacogen) of the rifting process (Stoakes et al., 1991). The main features of this basin is the development of large half-graben structures that, in some cases, reach thicknesses of more than 4 km. Pelotas Basin extends through offshore Uruguay and southern offshore Brazil with a NE-SW trend, representing the flexural margin of the rifting process that evolved into a passive margin (Conti et al., 2017). It is characterized by thick wedges of seaward dipping reflectors (SDRs) in its central segment. Punta del Este and Pelotas basins developed over continental crust and are separated from each other in shallow waters by a basement high, the so-called Polonio High, which played an important role as sediment source area. In deep and ultra-deep waters these two basins become a unique depositional setting, called Oriental del Plata Basin (Soto et al., 2011), that overlays oceanic crust with a NE-SW orientation.

The evolution of these offshore sedimentary basins can be divided into three main tectonic phases (Soto et al., 2011): a) Prerift phase (Pre-Jurassic deposits), represented by sedimentary and igneous rocks deposited in the area previous to the breakup of Gondwana. This sequence includes Paleozoic continental to marine sediments, as well as Proterozoic and older crystalline basement rocks), b) Synrift phase (Late Jurassic-Early Cretaceous), constituted by volcanic rocks and continental sediments deposited in grabens and half-grabens structures during the Gondwana fragmentation process, and c) Postrift phase (Aptian to Present Day), corresponding to the sedimentation associated with the development of marine conditions and eustatic changes. These three phases are represented in Punta del Este and Pelotas basins while, Oriental del Plata basin infill is constituted only by Cretaceous and Cenozoic postrift marine deposits.

Due to the fact that these are passive margin basins, the sedimentary package has suffered little deformation, with most of the large faults associated to the synrift phase. For this reason, most of the hydrocarbon traps that developed in these basins are of a stratigraphic origin.

Method

General conditions for geological storage are similar to such of hydrocarbon accumulations: a stratigraphic, structural or mixed trap, a suitable reservoir and an adequate seal to prevent fluids to escape from the trap. The seismic data acquired offshore Uruguay in the last 15 years allowed the interpretation in detail of different sequences that compose the sedimentary infill of the basins and also the identification of numerous hydrocarbons plays in the prerift, synrift and postrift sequences, most of them associated with stratigraphic and mixed traps such as turbidites, submarine channels and pinch-outs. More than 40 prospects, with varying size, volume, reservoir properties, overburden, bathymetries and geological risk, have been mapped (Gristo, P. et al, 2021). By seismic-stratigraphic analysis of the 2D and 3D data, and the geological data from wells, ANCAP identified plays with specific characteristics that could potentially be used for geological storage.

The first criteria established to restrict suitable storage plays is related with bathymetry, only selecting plays located in water depths below 200 meters. This analysis is restricted to shallow waters of Punta del Este and Pelotas basins, taking into account the high wind speeds and capacity factors of these regions (Global Wind Atlas, 2022), where bottom fixed or floating wind turbines could be placed for the renewable energy generation, notwithstanding that floating technology would allow large-scale renewable energy generation in deep water settings, in the near future (DNV-GL, 2019).

The second criteria established is associated to the depth of the reservoir that should be over 1,500 m. According to Hassanpouryouzband et al. (2021), suitable offshore hydrogen storage reservoirs should be at depths over 1500 m to ensure that hydrogen densities of 10 kg·m−3 are achieved. In addition, the geological target should have good porosity and a high permeability to allow the migration of the injected gas and pressure dissipation (Sainz-García, 2017). For this reason, the storage area should not be located at very high depths that could compromise the reservoir quality. The third criteria is related to the efficiency of the seal and overall effectiveness of the trap. The reservoir must have an impervious overlaying and lateral seal to prevent the upward migration of hydrogen. Finally, the fourth criteria to select a suitable play is related to the volume of the prospect. Accordingly, the reservoir must have a large potential capacity (hundreds of Mm^3) to store the produced hydrogen during seasonal periods. Additional information (e.g., core data) is required for properly addressing some other challenges associated with underground storage of hydrogen such as the interaction between H_2 with minerals and microorganisms of the reservoir and seal (Reitenbach et al., 2015).

Results and discussion

Three different plays for geological storage of hydrogen were identified in shallow waters, associated with the prerift, synrift and postrift sequences (figure 1). The main geological storage play identified that meet the established criteria, consists of Late Cretaceous stratigraphic pinch-out traps of the postrift sequence. This play is distributed over a large area of the continental shelf (figure 1).

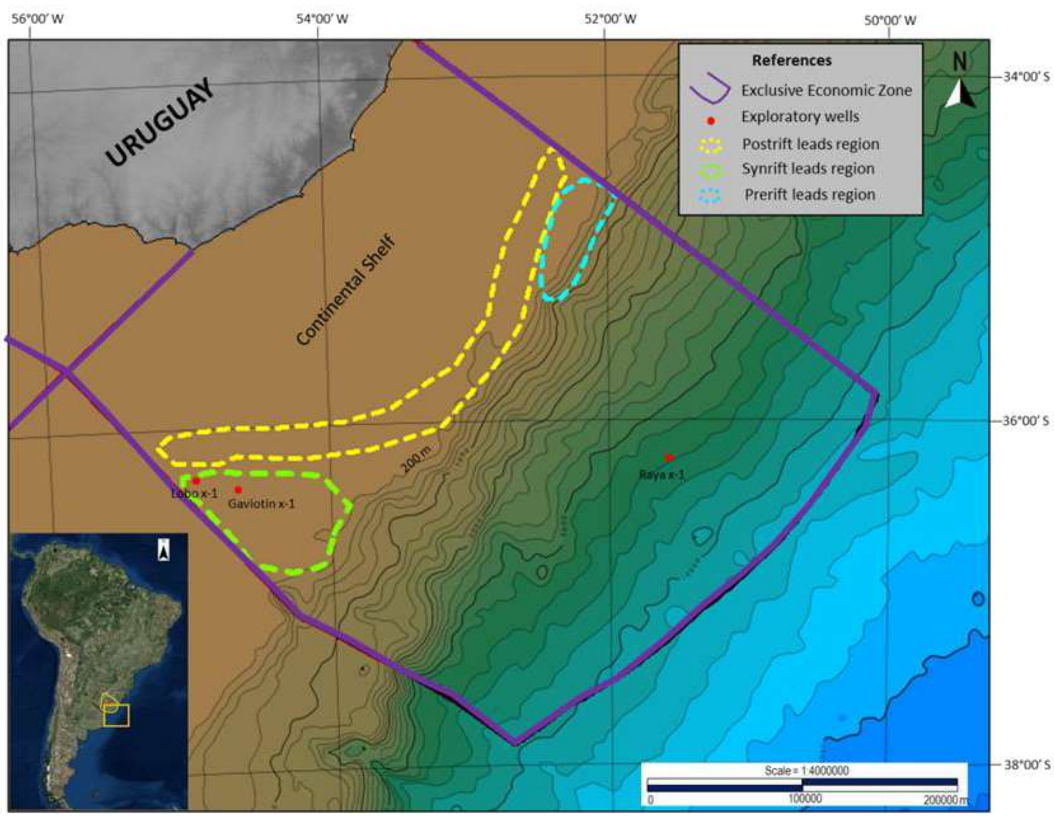

Figure 1- Distribution of potential storage plays in shallow waters, offshore Uruguay.

The reservoir is composed by shoreline-shelf, estuary or delta sands, sealed by thick marine shales related to a transgressive regional event in the Paleocene. The Late Cretaceous sequence can be observed on seismic to pinch out in a shoreward direction (figure 2) against a basement high (Polonio). In addition, the play shows lateral closure associated with differential compaction of sediments over the Punta del Este and Pelotas depocenters, located on both sides of the high, which generates gentle drape structures. This pinch-out play appear all along the shelf, in a NE-SW orientation, in bathymetries ranging from 50 up to 200 meters at sediment depths between 1800 to 2000 meters. In terms of competence, nearby exploratory wells data (Lobo X-1 and Gaviotín X-1 wells) evidence satisfactory properties for the potential Cretaceous reservoirs with good porosity values. Moreover, the effectiveness of the Paleocene shale seal, a key factor, is evidenced by the abrupt change in the fluid inclusions population of oil and gas detected in the wells, comparing Cretaceous with the Cenozoic sequences (Soto et al., 2016). Finally, the capacity of storage for some of the leads associated to this play appear to be very large (thousands of Mm^3), taking into consideration the extension and thickness of the reservoir. However, a volume estimation from a selected prospect was not made for this particular study.

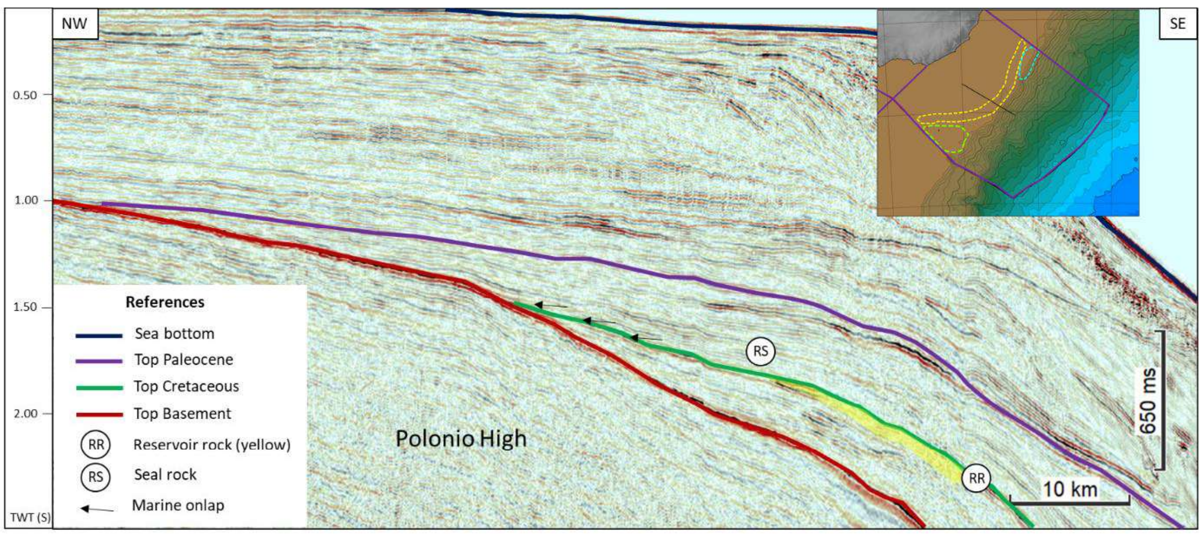

Figure 2- Seismic section showing the Late Cretaceous pinch-out play.

Conclusions

A preliminary evaluation of the potential for geological storage of hydrogen was made in the offshore basins of Uruguay, taking advantage of the knowledge and data, both geophysical and geological, generated in the last 15 years of hydrocarbon exploration.

Based on different criteria including bathymetry, sediment depth, competence and capacity of the reservoir, and trap and seal effectiveness, a candidate play was selected for potential geological storage of hydrogen. This play is represented by a Cretaceous postrift sequence composed by shoreline-shelf, estuary or delta sands located in shallow waters (below 200 m) of the continental margin of Uruguay in a SW-NE direction. The trapping mechanisms consisting of stratigraphic pinch-out sands over a basement high that develop drape structures, sealed by thick marine shales related to a transgressive regional event in the Paleocene. This study is a first approach to the subject of geological storage offshore Uruguay to identify potential play candidates. In a future work specific leads and prospects for this particular play can be characterized in detail and an estimation of storage capacity can be performed.

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