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POTENTIAL • EXPLORATION • PRODUCTION

Natural Hydrogen in Uruguay: source rock catalog, prospective exploration areas and potential H2 systems

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GENERAL OBJECTIVE

Evaluate the Natural Hydrogen (H_2) potential through the creation of a national-scale catalog of potential H_2 generating rocks, highlighting the areas with the highest occurrence favorability, and proposing systems for generation, migration, and accumulation.

GEOLOGICAL FRAMEWORK

Uruguay presents a Precambrian basement divided into two lithospheric units: a cratonic area (Río de la Plata Craton) and an orogenic belt (Dom Feliciano Belt), along with three Phanerozoic sedimentary basins (Fig. 1), the Norte Basin (Paleozoic-Mesozoic) and the Santa Lucía and Laguna Merín basins (Mesozoic). The basement rocks are composed of Precambrian rocks, which outcrop in the southern region and in the 'crystalline islands' of Rivera and Aceguá.

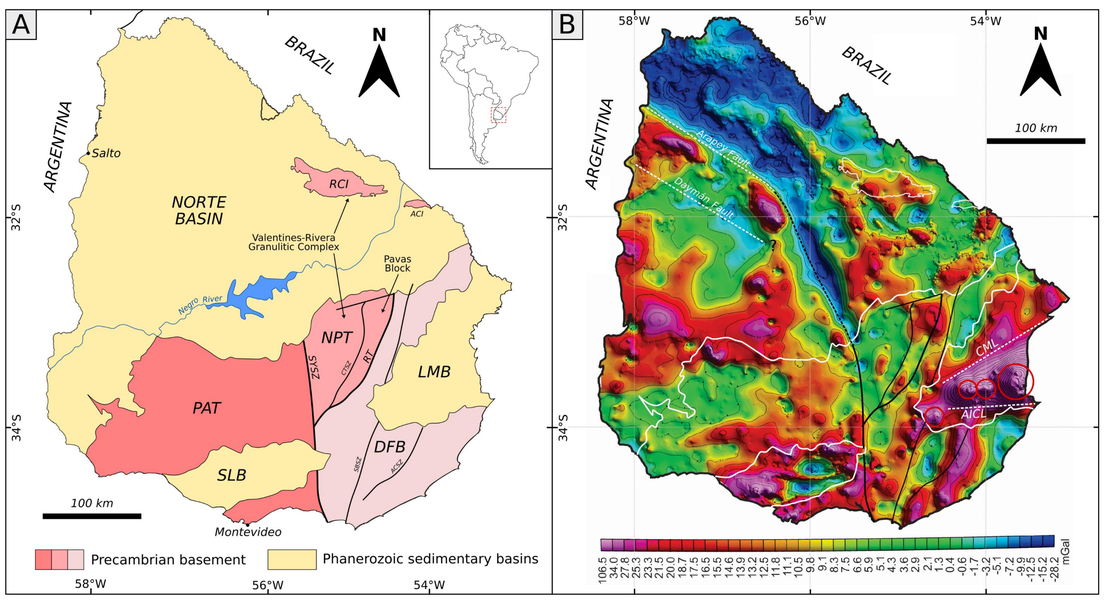

Figure 1. A: Simplified geological map of Uruguay showing the main tectonic domains of the Precambrian basement and its Phanerozoic sedimentary basins (modified from Morales et al., 2022). B: Bouguer anomaly map of Uruguay (Rodríguez et al., 2015).

METHODOLOGY

- Development of a catalog of potential H_2 generating rocks, according to the classification described by Lévy et al. (2023), which defines four types based on generation processes: basic/ultrabasic, iron-rich, radioactive and organic-rich.
- Comprehensive analysis of prospective areas and H_2 systems, defining the potential generation, accumulation, and trapping processes. The models were developed by analogy with petroleum systems previously outlined in the literature for H_2 exploration.

RESULTS

The catalog of potential H_2 generating rocks is summarized in Table 1. Its location, along with the main exploration areas, is shown in Figure 2A.

H_2_GR1	Geological unit	ID	Domain	Fe content
Serpentinites	Paso del Dragón Fm.	S1	DFB	2.55-5.17%*; 10.25-17.68%** (Fe_2O_3)
	Ojosmín Complex	S2	TPA	9.7% (Tremolite); 16.5% (Gabbro) (Fe_2O_3)
	Tapes Complex	S3	DFB	7.56%*; 15.88%** (Fe_2O_3)
	Arroyo Grande Fm.	S4	TPA	*n.d*
Gabbros	Guaycurú Complex	G1	TPA	8.0% (FeO); 3.2% (Fe_2O_3)
	Isla Mala Suite	G2	TPA	8.5±1%*; 7.71-9.84%** (Fe_2O_3) (Rospide)
	Lascano alkaline serie	G3	LMB	12.39-13.08% (Fe_2O_3)
	Coronilla	G4	LMB	11.38-15.97% (Fe_2O_3)
	Carbonera	G5	LMB	9.86-11.19% (Fe_2O_3)
Mafic Dyke Swarms	Florida	DS1	TPA	8.21-12.67%*; 7.93-13.25%** (FeO)
	Nico Pérez-Zapican	DS2	TPA/NPT/DFB	*n.d*
H_2_GR2	**Geological unit**	**ID**	**Domain**	**Fe content**
BIFs	Valentines Fm.	I1	NPT	33-46%*; 40.83-52.25%**(Fe)
	Vicahedero Fm.	I2	NPT	*n.d*
	Cebollatí/Las Tetas Complex	I3	DFB	*n.d*
	Marco de los Reyes Fm.	I4	DFB	55±6% (Fe_2O_3)
	Paso Severino Fm.	I5	PAT	*n.d*
	Manguera Azul Fm.	I6	DFB	*n.d*
	Arroyo del Soldado Group	I7	DFB	35.45-40.06% (Fe_2O_3) (Yerbal Fm.)

H_2_GR3	Geological unit	ID	Domain	Radiometric (Cps)	K (%)	Th (ppm)	U (ppm)
Granite Intrusions	Illescas batholith	R1	NPT	12,100	5.1	132	28
	Florencia (Aiguá batholith)	R2	DFB	3,900	4.4	34	7
	Los Cerrillos (Aiguá batholith)	R3	DFB	3,480	4.1	28	6
	José Ignacio	R4	DFB	2,800	4.2	21	2
	Santa Lucía batholith	R5	DFB	4,557	5.2	48	7
	Polanco	R6	DFB	4,245	4.1	36	7
	Cerro de las Cuentas	R7	NPT	4,345	4.9	38	6
	Cuchilla Dionisio batholith	R8	DFB	3,680	4.1	33	4
	Cerrezuelo	R9	NPT	3,320	4.7	27	3
Volcanic intrusions	Sierra de Ánimas Complex	R10	DFB	3,320	4.6	22	5
	Sierra de Ríos Fm.	R11	DFB	3,560	4.2	33	5

H_2_GR4	Geological unit	ID	Domain	TOC (%)
Coals	Tres Islas Fm.	O1	NB	*n.d*
Oil shales	Mangrullo Fm.	O2	NB	8.93*; 12.5**
Gas shales	Cordobés Fm.	O3	NB	3.6

Table 1: Catalog of potential H_2 generating rocks indicating unit name, location, and geochemistry.

- **Western Norte Basin (NB1, NB2)** presents potential H_2 generating rocks from the PAT and NPT respectively. Helium anomalies ranging from 50 to 97.74 $\times 10^{-8}$ He (cm^3/g) have been reported in two wells in this area (Geimener et al., 2024, preprint), based on dissolved gas analyses of GAS. Indications of neutron logging anomalies in NO8Y well (Fig. 3A) suggest the presence of a free-gas phase at the top of the Tacuarembó Fm. sandstones, trapped by basalts of the Arapey Fm.
- **Eastern Norte Basin (NB3)** presents significant potential due to the occurrence of large BIFs outcropping southern and northern of the area. Recent studies evidence H_2 generation from magnetite oxidation at shallow depths (Geymond et al., 2023). The lower sedimentary thickness of this area, along with the presence of dolerite sills (Cuaró Fm.), suggests high potential.
- **LMB** would have potential radioactive and ultramafic H_2 generating rocks (DFB). The inference of deep-seated faults and a conductive body at great depths (Morales et al., 2022) supports the proposal of a system for this basin.

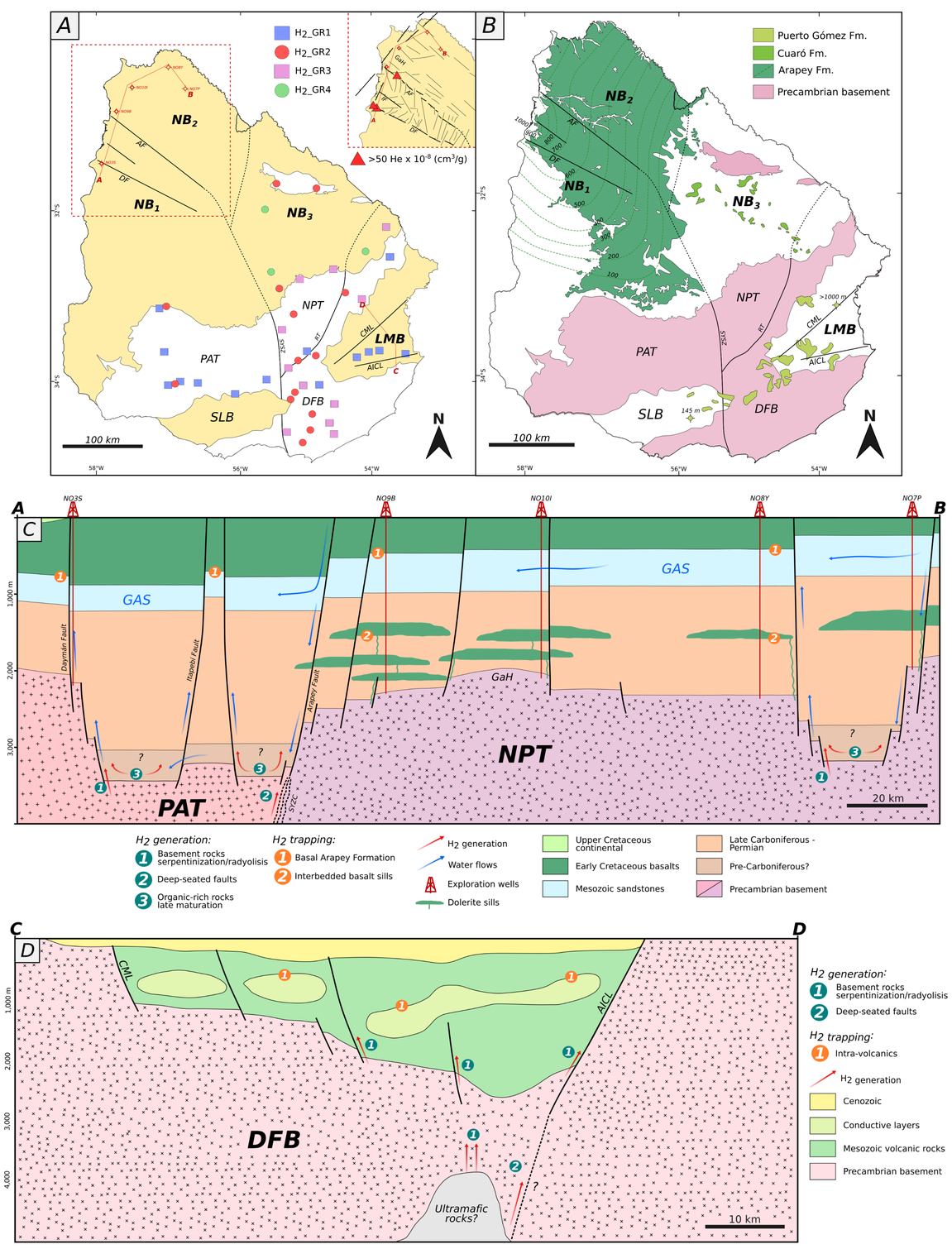

Figure 2: A: Prospective areas in onshore sedimentary basins and the location of potential H_2 generating rocks. B: Outcrop area of basaltic formations, representing the isopach map (m) of the Arapey Fm., and the maximum thickness in wells for the Puerto Gómez Fm. C: Schematic geological cross-section A-B. D: Schematic geological cross-section C-D.

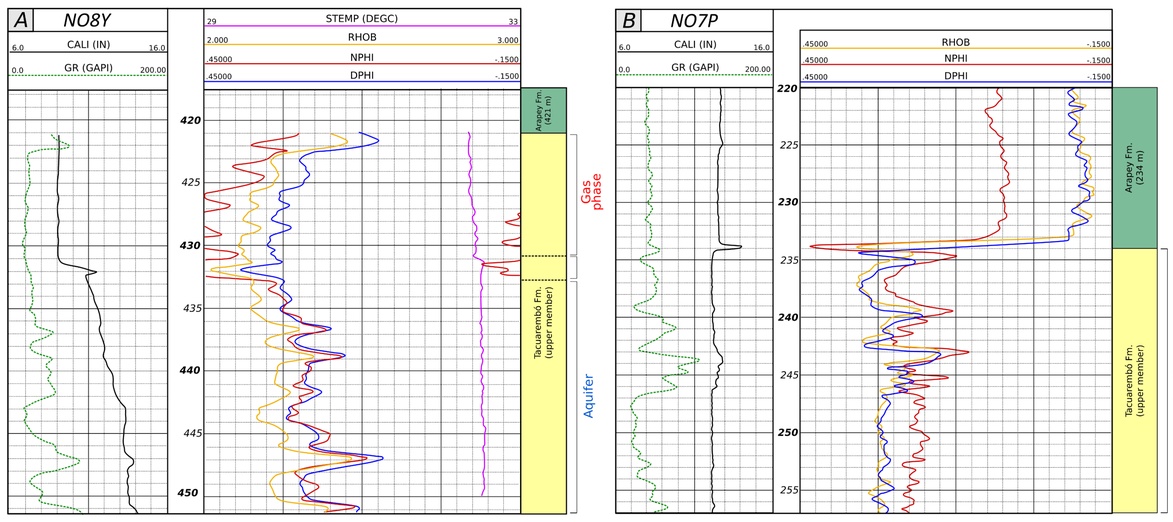

Figure 3: A: NO8Y well logging borehole data. B: NO7P well logging borehole data. CALI: caliper; GR: natural gamma-ray log; STEMP: temperature log; RHOB: bulk density log; NPHI: neutron log; DPHI: density log.

CONCLUSIONS

Uruguay exhibits significant potential for natural hydrogen generation, particularly in regions with favorable geological conditions. The western Norte Basin is identified as a key area of interest due its analogy to the Mali field geology and to the availability of relevant data. Additionally, notable potential is observed in the NB3 region, associated with the presence of BIFs, and in the LMB, due to gravimetric anomalies. Indirect evidence of H_2 presence in NB2 is observed, further supporting the prospects for natural hydrogen exploration.

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