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► To cite this version:

César Viseras Alarcón, Patricia Cabello, Luis M Yeste, Juan Alcalde, Miguel López-Blanco, et al.. Sedimentology for energy transition: SOSGAS project, an example of workflow approach to reservoir quality assessment. *Geogaceta*, 2024, 76, pp.15 - 18. 10.55407/geogaceta104487 . hal-04819434

HAL Id: hal-04819434

<https://brgm.hal.science/hal-04819434v1>

Submitted on 4 Dec 2024

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Sedimentology for energy transition: SOSGAS project, an example of workflow approach to reservoir quality assessment

Sedimentología para la transición energética: proyecto SOSGAS, un ejemplo de flujo de trabajo para la evaluación de calidad de reservorios

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RESUMEN

Se presenta el flujo de trabajo de investigación utilizado en el proyecto SOSGAS, encaminado a la Evaluación de Calidad como Reservorio de CO₂ y H₂ verde de formaciones clásticas Mesozoicas y Cenozoicas heterogéneas de origen fluvial y deltaico de la Meseta Ibérica y de las Cuencas del Ebro y de Graus-Tremp. Mediante el estudio integrado de datos de afloramiento y subsuelo (a partir de sondeos traeros a los afloramientos) se elaboran modelos conceptuales de cada ejemplo estudiado que describen las variaciones de las heterogeneidades sedimentarias y que conducen a la modelización estática de los distintos geocuerpos y de sus propiedades petrofísicas. Finalmente, la modelización dinámica basada en experimentos de simulación de inyección de gas (CO₂ e H₂) en los modelos estáticos nos permite analizar la sostenibilidad de proyectos de geo-almacenamiento de estos fluidos clave en la transición energética.

Palabras clave: sedimentología, transición energética, geo-almacenamiento, CO₂, H₂ verde.

Geogaceta, 76 (2024), 15-18

<https://doi.org/10.55407/geogaceta104487>

ISSN (versión impresa): 0213-683X

ISSN (Internet): 2173-6545

Introduction

Our society is immersed in a drastic change in the production model and this change affects, particularly in Europe, the way energy is obtained and consumed, reducing the environmental impact of the process as much as possible. The objective is to achieve this transformation without

renouncing the quality-of-life standards achieved by obtaining energy based on the exploitation of non-renewable natural resources. (BP 2021; IEA, 2022).

Thus, since the outbreak of the so-called industrial revolution, we have relied heavily on the use of fossil fuels (coal, oil and natural gas) to achieve a rapid development that has led to what is known as

ABSTRACT

The research workflow developed in the SOSGAS project is presented, aimed at the Quality Assessment as a reservoir of CO₂ and green H₂ of heterogeneous Mesozoic and Cenozoic fluvial and deltaic formations of the Iberian Meseta and the Ebro and Graus-Tremp Basins. Through the integrated study of outcrop and subsurface data (derived from boreholes drilled behind the outcrops), conceptual models are developed for each examined case, describing variations in sedimentary heterogeneities. These models contribute to the static modelling of different geobodies and their petrophysical properties. Finally, dynamic modelling, based on gas injection simulation experiments (CO₂ and H₂) into static models, enables the analysis of the sustainability of geo-storage projects for these key fluids in the energy transition.

Keywords: sedimentology, energy transition, geo-storage, CO₂, green H₂

Fecha de recepción: 09/02/2024

Fecha de revisión: 19/04/2024

Fecha de aceptación: 07/06/2024

the welfare society.

As fossil fuels are resources closely linked to sedimentary rocks, sedimentology has played a key role in their extraction, and continues to do so in the current situation where many fields under development are in production stimulation phases (Enhanced Oil Recovery, Improved Oil Recovery).

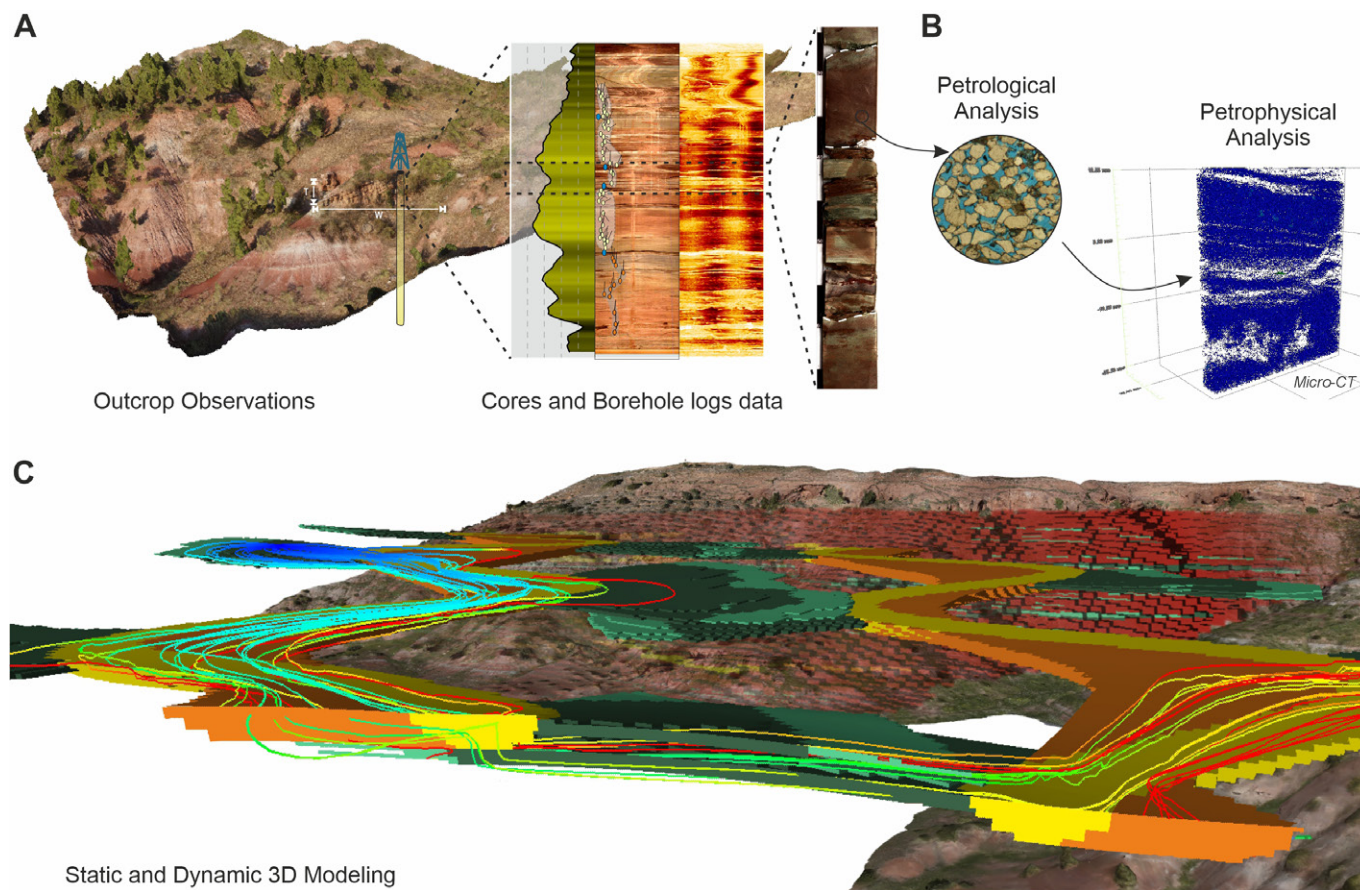


Fig. 1.- Outcrop/behind outcrop (OBO) characterization workflow for heterogeneous reservoirs. (A) Dataset derived from outcrop observation, cores and borehole logs. (B) Petrological and petrophysical analysis. (C) 3D realistic static and dynamic reservoir modelling.

Fig. 1.- Flujo de trabajo para la caracterización de afloramiento y datos de subsuelo (OBO) para reservorios heterogéneos. (A) Conjunto de datos derivados de la observación de afloramiento, testigos de roca y diagrafas de pozo. (B) Análisis petrológico y petrofísico. (C) Modelización 3D estática y dinámica de reservorios.

In the new geo-strategic energy paradigm, two fluids play a fundamental and very different role: CO₂ and green H₂, the former as one of the main industrial products whose emission into the atmosphere is to be reduced and the latter as one of the main sources of clean energy for the immediate future (Mediato *et al.*, 2015; Alcalde *et al.*, 2019, 2021). The possibility of storing both fluids in sedimentary rocks gives sedimentology a new leading role (Heinemann *et al.*, 2021).

The ALGECO2 and Pilot-Strategy projects, coordinated by the Spanish Geological and Mining Institute (IGME) and the Bureau de Recherches Géologiques e Minières (BRGM), respectively, have made an important advance in the knowledge of our subsurface for the geo-storage of CO₂ at the level of selection of favourable areas and structures (Zapatero *et al.*, 2009, Tyrologu *et al.*, 2023).

The coordinated project proposal **Impact of sedimentary heterogeneity of reservoirs on sustainable gas geo-storage (SOSGAS)** brings together the skills and complementary knowledge of two

sedimentology research groups from the universities of Barcelona and Granada. In addition, it brings together a total of 12 researchers and senior technicians from various European and American research organisations.

For this research project, a series of examples of Mesozoic and Cenozoic formations of fluvial and fluvio-deltaic origin in the Iberian Meseta and the Graus-Tremp and Ebro basins have been selected as models of clastic reservoirs of high heterogeneity in terms of reservoir and non-reservoir facies distribution

Sedimentary heterogeneity and fluid geo-storage

Low Net-to-Gross ratio sedimentary formations present heterogeneities at very different scales which, depending on the physico-chemical characteristics of the fluid in question, may represent potential baffles or permeability barriers. To simplify, we can speak of micro-, meso- and macroscale heterogeneity.

Macroscale heterogeneity is mainly

influenced by allogenic processes that control sediment supply, basin accommodation and the potential interconnectivity between reservoir facies, conditioning the distribution of sand-to-sand contacts within the formation.

At the mesoscale, the distribution of lithofacies and architectural elements within the reservoir also imprints a heterogeneity in this case of autocyclic origin, inherent to the dynamics of the sedimentary environment that gave rise to the reservoir rock (Velooso *et al.*, 2016; Varela *et al.*, 2021).

Finally, macro- and mesoscale heterogeneity is retouched at the microscale by modifications that may occur during eo-, meso- and telo-diagenesis stages (Henares *et al.*, 2014).

SOSGAS: a workflow approach to Reservoir Quality Assessment

In order to assess the reservoir quality, we first applied the OBO (Outcrop/Behind Outcrop) Characterization of reservoir analogs, (Henares *et al.*, 2016; Vi-

seras *et al.*, 2018; Yeste *et al.*, 2020) workflow to each example, which begins with the analysis of facies and architectural elements in situ supported by a Digital Outcrop Model performed by photogrammetry with Remotely Piloted Aircraft system (RPAS) for its morphometric characterization (Fig. 1A). From this study, a series of specific zones of the reservoir are selected in which drilling is carried out behind the outcrop to obtain a continuous core on which sampling is carried out for petrological and petrophysical analysis (Fig. 1B). In the shallow borehole battery, natural and spectral gamma ray logging, as well as optical and acoustic imaging logs are also taken.

The processing and integration of all the above data, obtained both from the outcrop and from the boreholes drilled in its vicinity, leads to a dense data set that will be used as input data for the

next phase of work: reservoir modelling (Fig. 1C).

Static modelling of the reservoir is achieved by producing modelling strategies that reproduces the heterogeneity distribution established in a conceptual model obtained from the outcrop study and its digital model. Using this realistic 3D static models, and considering different scenarios, the optimal number and spacing of hard data are decided in order to obtain a predictive model that matches the studied outcrop in terms of non-reservoir and reservoir facies distribution, as well as the static connectivity between the reservoir geobodies (Yeste *et al.*, 2020).

Based on the static model, a series of experiments are developed using different hypotheses of sand-to-sand connectivity between lithofacies of different petrophysical characteristics. In this way,

a pattern of wells is simulated in which some act as injectors and others as producers, obtaining different scenarios of fluid movement dynamics in the reservoir. (Cabello *et al.*, 2018, 2020; Sun *et al.*, 2023)

The application of this workflow aims to achieve an informed assessment of the quality of the reservoir, knowing details of its heterogeneity at different scales, potential baffles and permeability barriers as well as potential thief zones when recovering injected fluids (Fig.2).

In short, SOSGAS aims to provide objective and complete geological information that will allow technical decisions to be taken on the feasibility of using different types of clastic geobodies for this specific objective integrated in the energy transition.

The fine-tuning of this workflow with its application to these first examples will

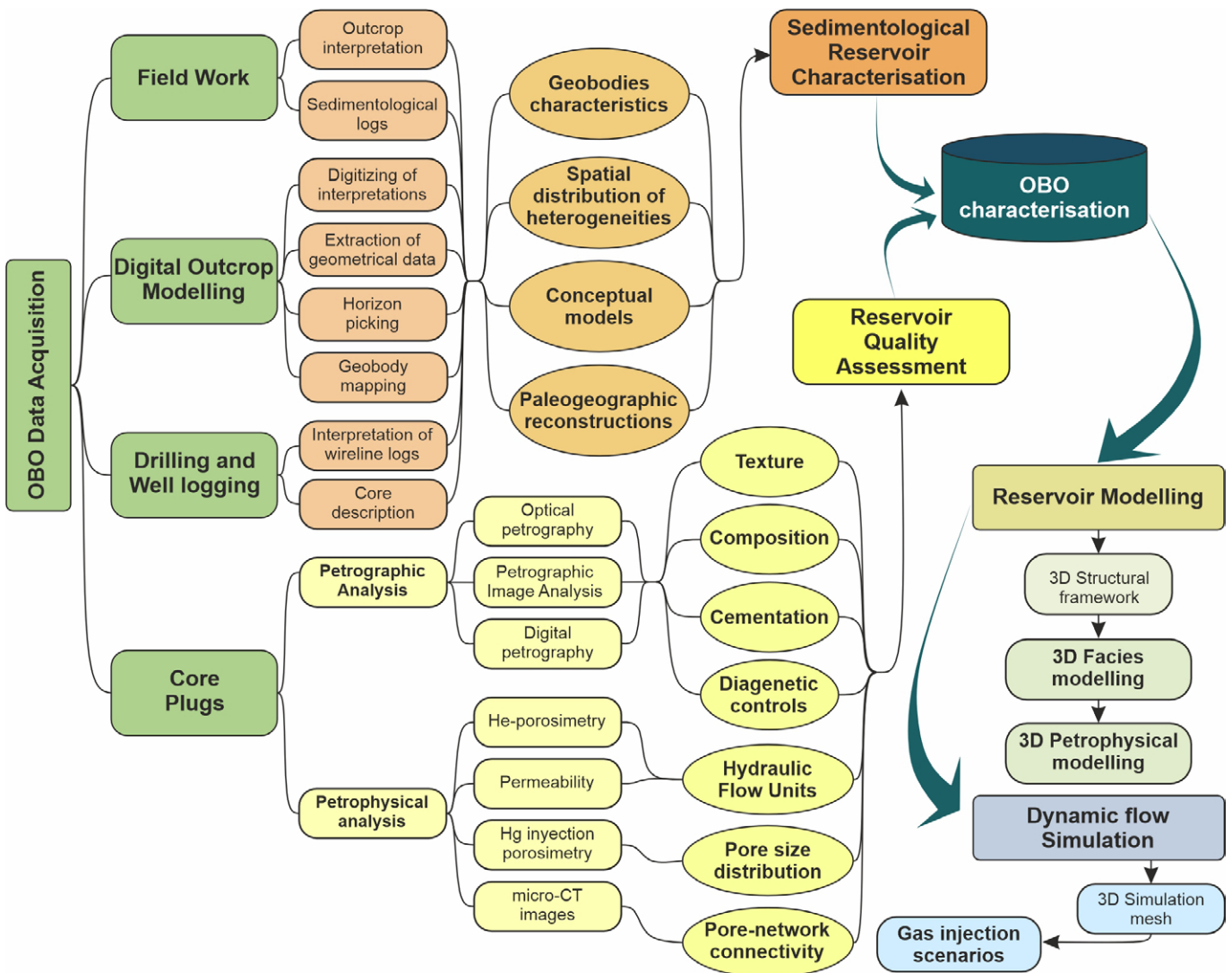


Fig. 2.- Flowchart with the Reservoir Quality Assessment procedure for gas geo-storage developed in the SOSGAS project.

Fig. 2.- Organigrama con el procedimiento de Evaluación de Calidad de Reservorios para el geo-almacenamiento de gas desarrollado en el proyecto SOSGAS.

hopefully serve as a basis for the extension of its application to rock assemblages originating from the dynamics of other sedimentary environments.

Conclusions

A sedimentological research workflow applicable to low net-to-gross ratio clastic formations is presented (Fig 2).

Using a dataset derived from the integration of outcrop observation, as well as cores and borehole logs obtained behind the outcrop, we conducted data analysis (OBO characterization). Robust static models were derived from the design of geostatistical modelling strategies aimed at reproducing the heterogeneity distribution based on the OBO characterization.

Finally, dynamic modelling allows prediction of fluid movement patterns in the reservoir.

The application of this workflow to fluvial and deltaic reservoirs is allowing the SOSGAS project to predict the sustainability of geo-storage of key fluids in the energy transition (CO₂ and green H₂), by identifying permeability barriers and baffles as well as thief zones in these highly heterogeneous reservoirs.

Author contributions

Viseras, Cabello, Yeste, structure and co-ordination, Alcalde, Heinemann, De Mesquita, Cuevas, methodology, Caracciolo, Varela, López-Blanco analysis, Falivene, Gil-Ortiz, Rúa, Jaímez, data acquisition.

Acknowledgements

Grants PID2022-140850OB-C21 and PID2022-140850OB-C22 funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe". The support of the groups RNM369 (PAI), and 2021SGR00076 (GC). Additionally, we acknowledge the support of REPSOL EP, CEPSA EP, ENAGAS, SLB and AGGEP. The

quality of the paper has been substantially improved in response to the modifications proposed by Drs J. Soria and A. Pérez (Editor) and another anonymous reviewer.

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