Advancing CO2 Storage: Development of Robust Conformance Assessment and Risk-Based Monitoring Strategies for Secure Project Execution

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ABSTRACT

The **RamonCO** project aims to streamline the permitting phase of CO_2 storage projects while ensuring safe containment throughout execution. It achieves this by developing a comprehensive, multi-dimensional conformance assessment methodology and advancing risk-based monitoring strategies. This paper presents methodologies and tools for conformance assessment at an industrial scale, integrating real-time operational data. A key advancement is the development of a multi-physics inversion framework that processes seismic, gravity, and deformation data, enhancing the accuracy of CO_2 saturation, reservoir pressure, and stress field estimations.

The project also addresses the importance of European perspectives in risk assessments, contributing to the development of optimal monitoring systems. The Romanian team plays a critical role by focusing on the unique local conditions, particularly those arising from the numerous boreholes drilled over the past 150 years in Romania's sedimentary basins. These boreholes pose challenges in monitoring selected CO_2 storage sites. The project's outcomes offer valuable insights into modeling CO_2 storage sites, particularly in depleted gas fields, and are expected to boost societal acceptance of CO_2 storage solutions.

Keywords: *Permitting phase, Secure containment, Conformance assessment, Risk-based monitoring, Romanian sedimentary basins, CO_2 storage, Multi-physics inversion framework*.

METHODOLOGY

1. Conformance Assessment

A robust conformance assessment ensures that the injected CO_2 behaves as predicted by the storage site model, ensuring that containment remains secure. The **RamonCO** project advances this through:

- **Real-time data integration:** Collecting and processing operational data, including seismic, gravity, and ground deformation measurements, allows for continuous monitoring and immediate adaptation of strategies.
- **Multi-physics inversion framework:** This innovative approach combines various physical models (seismic, gravity, deformation) to estimate key storage parameters such as CO_2 saturation, reservoir pressure, and stress fields. This increases the accuracy of the storage site's performance and helps detect early signs of containment risks.

2.Risk-Based Monitoring

Risk-based monitoring is essential for maintaining the integrity of CO_2 storage sites. The **RamonCO** project develops monitoring protocols that integrate European regulatory standards with localized assessments to:

- **Identify and prioritize risks** using geophysical and geomechanical models.
- **Tailor monitoring systems** based on the specific risks associated with the geology and operational conditions of each storage site.

A particular focus is placed on the Romanian context, where a vast number of boreholes drilled for oil and gas exploration in the last century complicate the monitoring of subsurface CO_2 movements.

RESULTS

Multi-Physics Inversion Framework

The multi-physics inversion framework allows for more precise predictions regarding CO_2 behavior in storage reservoirs. By processing seismic, gravity, and deformation data simultaneously, the framework delivers improved estimations of CO_2 saturation levels, reservoir pressure, and stress distribution. These advancements enable operators to make more informed decisions, reducing the likelihood of containment failure.

Monitoring Systems for Romanian Boreholes

The Romanian sedimentary basins present unique challenges due to the presence of numerous boreholes. The **RamonCO** project integrates borehole integrity assessments into its conformance and monitoring strategies. Borehole mapping and subsurface integrity analysis have shown that many old wells require additional monitoring attention, particularly in depleted gas fields where CO_2 injection is planned.

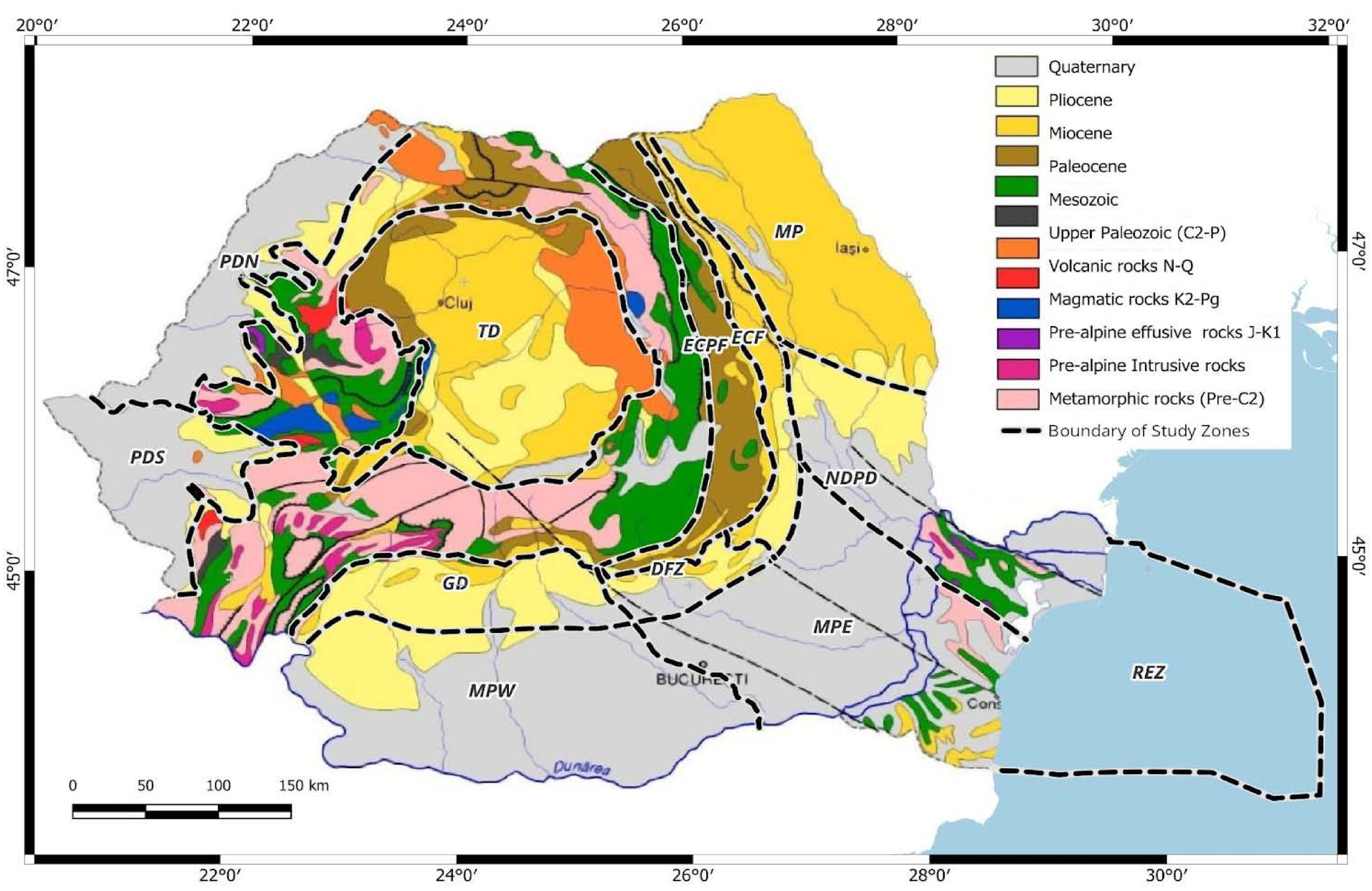
DISCUSSIONS

The findings from the **RamonCO** project underscore the importance of a multi-disciplinary approach in CO_2 storage projects. The integration of seismic, gravity, and deformation data provides a more comprehensive view of subsurface conditions, allowing for proactive management of potential risks. Furthermore, the project's focus on the Romanian context highlights the necessity of site-specific strategies, especially in areas with extensive borehole networks.

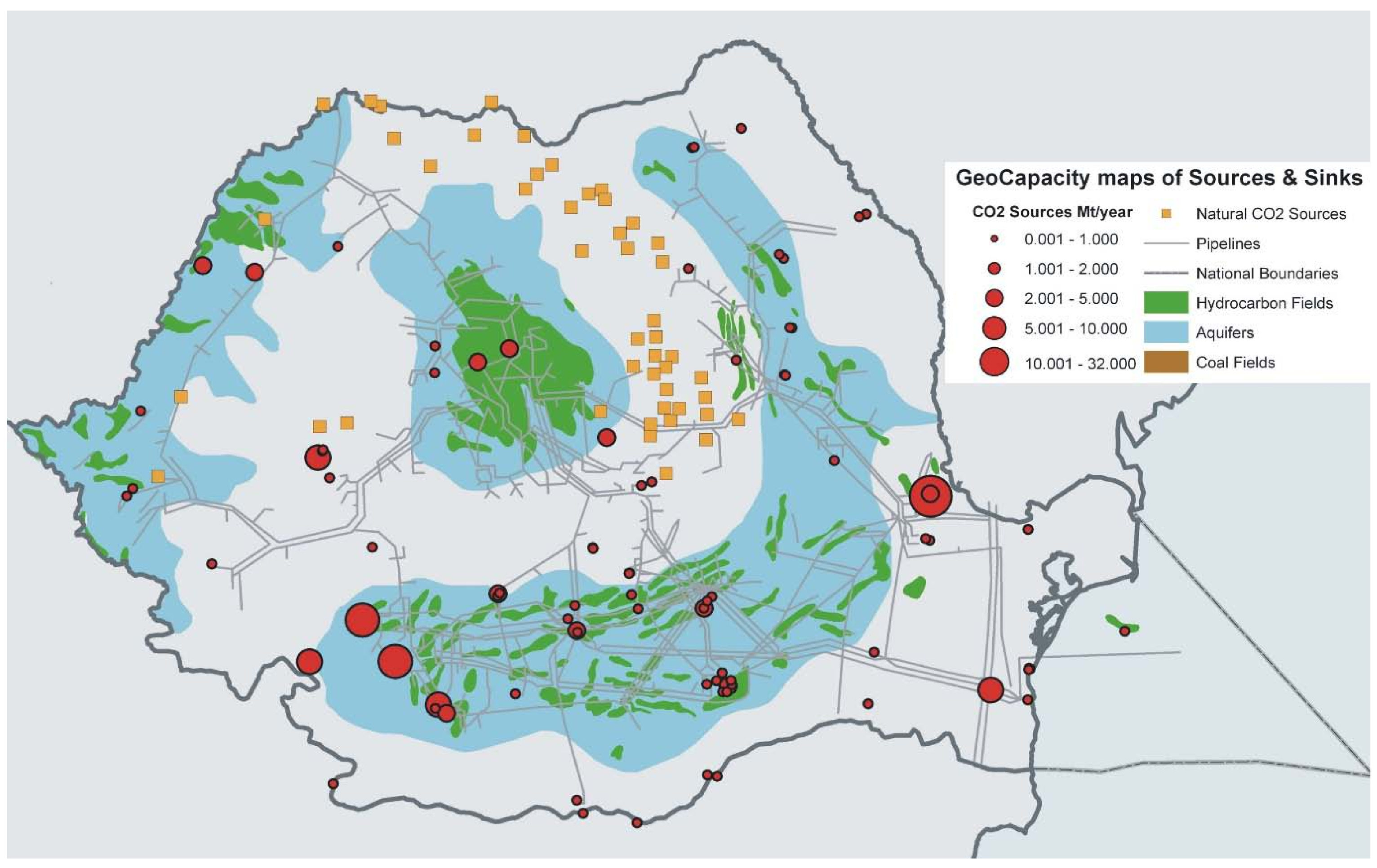
The territory of Romania, including the Romanian Economic Zone of the Black Sea, is intricately intertwined with the broader geological framework of Central and Southeast Europe. It forms a part of the Alpidic pericratonic belt, which encompasses the Carpathian Mountains, the Balkans, Rhodopes, and Pontides.

The major structural units of interest for CO_2 geological storage on the Romanian territory (**On shore**) are: Pannonian Depresion (PD) - Pannonian Depression North (PDN) and Pannonian Depression South (PDS), Moesian Platform (MP) - Moesian Platform West (MPW) and Moesian Platform East (MPE), Transylvanian Depression (TD), East Carpathians Paleogene Flysh (ECPF), Carpathians Foredeep (CF) - East Carpathians Foredeep (ECF), Diapir Fold Zone (DFZ) and Getic Depresssion (GD), Moldavian Platform (MP), North Dobrogea & Predobrogean Depression (NDPD).

The major structural units of interest for CO_2 geological storage on the Romanian Economic Zone of the Black Sea (REZ) (**Off shore**) are: North Dobrogea & Predobrogean Depression (NDPD), Moesian Platform - Moesian Platform East (MPE).



Map of the major structural units of interest for CO_2 geological storage on the Romanian territory



Synthetic Map of CO_2 emissions, infrastructure and storage capacity in Romania

The outcomes of this project are likely to have far-reaching implications for CO_2 storage in Europe, particularly in enhancing public confidence in the safety and reliability of such projects.

CONCLUSIONS

The **RamonCO** project presents a significant advancement in the field of CO_2 storage by developing a comprehensive conformance assessment methodology and risk-based monitoring strategies. The project's focus on integrating real-time operational data with a multi-physics inversion framework has resulted in more accurate estimations of key storage parameters, enhancing the safety and efficiency of CO_2 containment. Additionally, the emphasis on local conditions, particularly in Romania, provides critical insights for the successful implementation of CO_2 storage projects in diverse geological settings.

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