CO2-SPICER – CZECH-NORWEGIAN PROJECT TO PREPARE A CO_2 STORAGE PILOT IN A CARBONATE RESERVOIR

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Abstract

Carbon capture and storage (CCS) is one of key technologies to decarbonise the emission-intensive industries in the Czech Republic and reach the 2050 carbon-neutral economy target. An important step on the road to the deployment of the technology is to prepare and realise a CO_2 storage pilot project in the country. The newly launched CO2-SPICER project has been designed to make significant progress in this direction. It is the first project in Europe, targeting an onshore hydrocarbon field situated in carbonates as a pilot CO_2 storage site. Achieving the main project objective - to reach the implementation-ready stage of site development - would allow direct follow-up to project activities, using main project results as ready-made input. The target Zar-3 site is a hydrocarbon field located in the SE part of the Czech Republic. It is situated in an erosional relict of fractured carbonates of Jurassic age on the SE slopes of the Bohemian Massif, covered by Paleogene deposits and Carpathian flysch nappes. The field was discovered in 2001 and is now nearly depleted. This relatively "young age" of the field, together with active participation of field operator in the consortium and ongoing hydrocarbon production provide many advantages, such as direct access of the reservoir, availability of field monitoring data, generally good condition of wells, well-preserved core material and detailed reservoir description. However, the geology of naturally fractured carbonates brings specific research challenges. This paper provides a brief overview of the storage site and the project, its objectives, planned activities and expected outcomes.

Keywords: *CO_2 geological storage, pilot project, Czech Republic, hydrocarbon field, fractured carbonates*

1. Introduction

Up to now, storage of captured CO_2 in geological formations in the Czech Republic has only been developed on research level. The Technology Readiness Level for CO_2 geological storage in Czechia is between 4 (technology validated in lab) and 5 (technology validated in relevant environment).

In the case of underground CO_2 storage, TRL5 means its validation by realisation of a pilot project in geological conditions similar to future industrial-scale projects. The first steps for rising CO_2 geological storage in the Czech Republic towards TRL5 were made in the REPP-CO2 project [1] led by CGS, supported by IRIS (now NORCE), VSB - Technical University of Ostrava and a few other Czech entities, and focused on the depleted LBr-1 hydrocarbon field in SE Moravia as a possible pilot CO_2 storage site.

During discussions on possible further steps in the effort to prepare a CO_2 storage pilot in the Czech Republic, a dialogue was established with MND, the leading Czech oil and gas E&P company. This opened up the opportunity to consider active hydrocarbon fields as storage candidates. Among them, the Zar-3 field, a depleting oil and gas field in SE Czech Republic (Fig. 1) was identified as the most promising candidate for a CO_2 storage pilot.

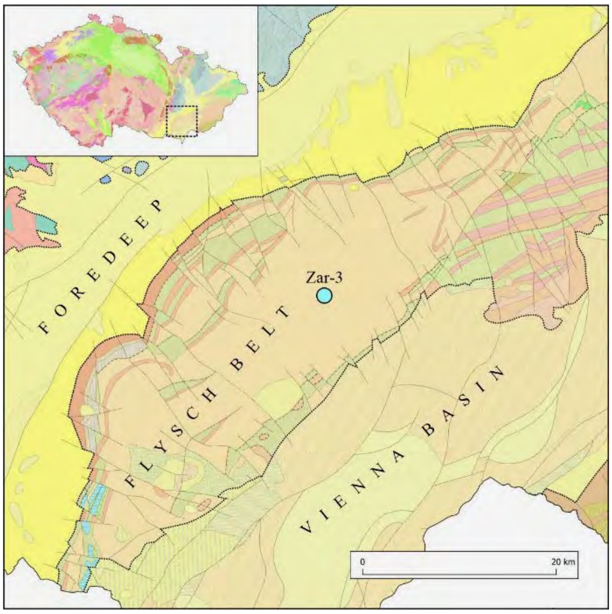

Figure 1: Position of Zar-3 site displayed on geological map of the Czech Republic [2]

CO2-SPICER (CO_2 **S**torage **P**ilot **I**n a **C**arbonat**E** **R**eservoir) is the next logical step in a series of projects and activities performed by CGS and its project partners on the road to realise a CO_2 storage pilot project in the country. The project is the first of its kind in Europe targeting an onshore hydrocarbon field situated in fractured carbonates.

2. Overview of geology and the site

2.1 Brief overview of regional geology

The Zar-3 structure is located at the contact zone between the European foreland plate, represented by the Bohemian Massif and the Western Carpathian thrust belt (Fig. 1). Rock complexes in this region belong to three main structural levels, the Cadomian, Variscan and Mesozoic. All are buried below the overthrust flysch complexes of the Western Carpathians [3][4].

The Cadomian level is represented by the Brunovistulian unit, composed of Precambrian metamorphic rocks, granitoids to quartz diorites and rare ultrabasic rocks.

The lower part of the Variscan rock complex is composed of prevailingly red-coloured, coarse-grained Cambrian to Middle Devonian lithofacies. Overlying Upper Devonian to Lower Carboniferous rocks are represented mainly by facies of carbonate platforms and basins. The carbonate deposition was replaced in the Early Carboniferous by flysch (Culm) facies, followed in the Late Carboniferous by the molasse deposition of mostly sandstones containing coal seams (Namurian-A).

After a Permian hiatus, the Mesozoic sequence began in the area by deposition of the Middle Jurassic mostly terrigenous and shallow marine clastic deposits. They are followed by the Upper Jurassic facies, characterised by deposition of platform carbonates in the shallow marginal and uplifted zones and by sedimentation of marine marly shales in deeper basinal environment.

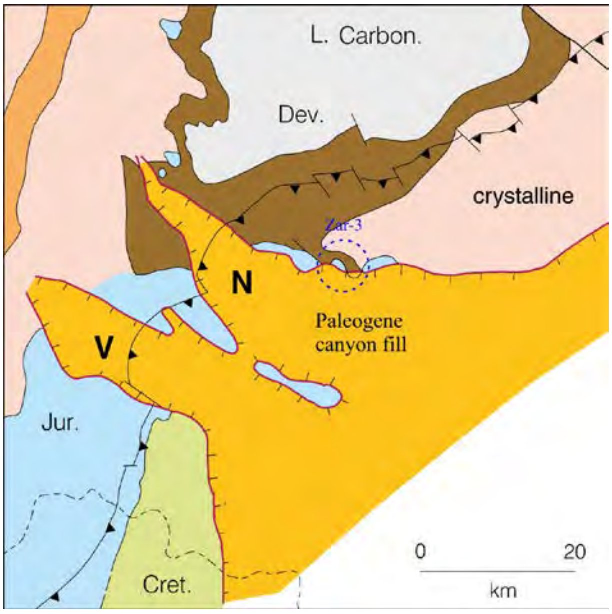

Figure 2: Pre-Neogene subcrop map showing the Nesvacilka (N) and Vranovice (V) paleovalleys [5]

During the Late Cretaceous to Early Paleogene the terrain was deeply eroded by rivers in the tectonically predisposed Nesvacilka and Vranovice depressions (Fig. 2) that turned into more than 1500 m deep submarine canyons. In both depressions most of the Mesozoic sediments were removed. The heavily eroded pre-Tertiary basement in both depressions was gradually filled by the Upper Cretaceous to Paleogene detrital deposits, mainly by flysch sediments of deep-water gravity flows.

During the Late Paleogene and Early Miocene, the flysch sequences were deformed and thrusted over the European foreland due to the late phases of the Alpine orogeny. The Carpathian thrust belt in Moravia is composed of Upper Jurassic to Lower Miocene sequences of the flysch belt, with several rootless tectonostratigraphical units, including the marginal Pouzdrany, the Zdanice-Subsilesian, the Silesian, and the Magura units [3][4][6].

2.2 Zar-3 structure

The Zar-3 structure (Fig. 3) comprising an oil field with a gas cap and an active aquifer is located in an erosional relict of Jurassic rocks on the north-eastern slope of the Nesvacilka depression (Fig. 2). The field was discovered in 2001 by the ZA3 well in the depth interval of 1565 – 1872 m (Fig. 3). The reservoir is represented by the Jurassic Vranovice carbonates, formed mostly by dolomites with some limestones and sandstones. Sealing of the reservoir is provided by a combination of the Paleogene side valley fill, the Jurassic Mikulov marls and, due to its complex tectonic settings, partially also by the Lower Carboniferous deposits.

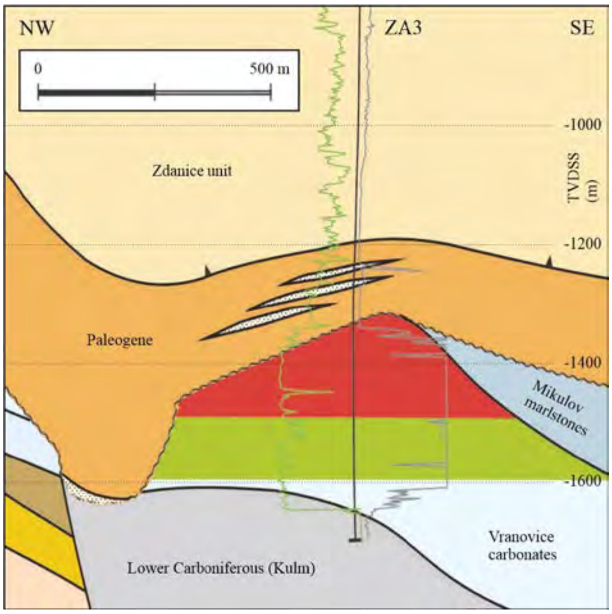

Figure 3: Schematic geological cross-section of NW – SE direction through the Zar-3 structure [6]

The porosity of the reservoir varies significantly, depending on the position within the structure and the resulting lithology (dolomitization degree, clastic and carbonate components content) and the distribution of fracture network (secondary porosity). This results in a considerable range of reservoir porosities from 2 to 20 %, based on well-log data [7]. The porosity determined from the cores shows an approximate average value of 12 %. Based on hydrodynamic tests [7], the reservoir permeability was estimated to 190 – 630 mD.

The gas cap reaches thickness up to 150 m, the original oil zone was ca. 105 m thick. Hydrocarbon reserves were estimated to 1.2 million cubic meters of original oil in place, 77 million cubic meters of solution gas and 100 million cubic meters of original gas in place in the gas cap.

The geological settings of the Zar-3 structure are relatively well known on the basis of deep drilling results and 3D seismic data covering the whole structure. The area of Zar-3 reservoir (and surrounding) comprises a total of 26 deep wells (14 in the reservoir itself) with well logging data available for about 20 wells. Check-shot surveys have been registered in 3 wells.

Even though a significant level of knowledge has been developed during the exploration and production phases of the Zar-3 field, a certain extent of geological uncertainty still exits. The main uncertainty is related to heterogeneity of the storage reservoir, in particular, the spatial distribution of rock properties and complexity of the geological settings.

3. CO2-SPICER project

The CO2-SPICER project is part of a broader long-term concept to realise a pilot project on geological storage of CO_2 in the Czech Republic. The project benefits from knowledge and experience gathered during previous pilot project preparation activities at the LBr-1 site [2][8] in previous REPP-CO2 and ENOS projects, even though the geology differs and some special investigation approaches are required to qualify the Zar-3 field for injection. The Zar-3 site has many advantages compared to LBr-1:

- ongoing oil and gas production and existence of operating injection and observation wells, enabling access to the reservoir and wells for logging, testing and sampling;
- better condition of the wells penetrating the reservoir due to later discovery of the field;
- availability of well-preserved archive cores;
- significantly more information on the reservoir, including advanced well monitoring during production history;
- reduced probability of conflicts of interest, in particular no trans-boundary issues;
- active participation of the field operator (MND) in the consortium, enabling significant speed-up of developing the project towards CO_2 injection.

The geology of carbonates brings, however, specific research challenges to the project in comparison with the clastic sediments that were investigated in previous projects. These include, in particular, fluid flow in naturally fractured rocks and chemical reactivity of carbonates with CO_2, which may cause changes in mineral composition and reservoir (porosity, permeability) and geomechanical properties. These challenges must be identified and evaluated, and possible mitigation actions must be taken in the specific site design and monitoring system.

3.1 Project objectives and approach

The main objective of CO2-SPICER is to prepare implementation of a CO_2 geological storage pilot project at the mature Zar-3 oil and gas field in the SE part of the Czech Republic. To achieve this, the following set of sub-objectives has been set:

- build a 3D geological model of the storage complex;
- evaluate geomechanical and geochemical properties of the storage complex and identify if the injected CO_2 could affect reservoir integrity;
- simulate various CO_2 injection scenarios;
- assess risks related to CO_2 storage on the pilot site;
- prepare a site monitoring plan;
- evaluate scenarios for future site development, including design of CO_2 injection facilities.

Research methods will include collection and quality control of data from archives, core sampling, collection of fluid samples from the reservoir, laboratory experiments, field data acquisition both on the surface and in wells, data processing and interpretation, geological modelling, reservoir simulations and synthesis of results. The work will be carried out in close cooperation of all project partners - CGS, MND, NORCE, VSB - Technical University of Ostrava and Institute of Geophysics of the Czech Academy of Sciences.

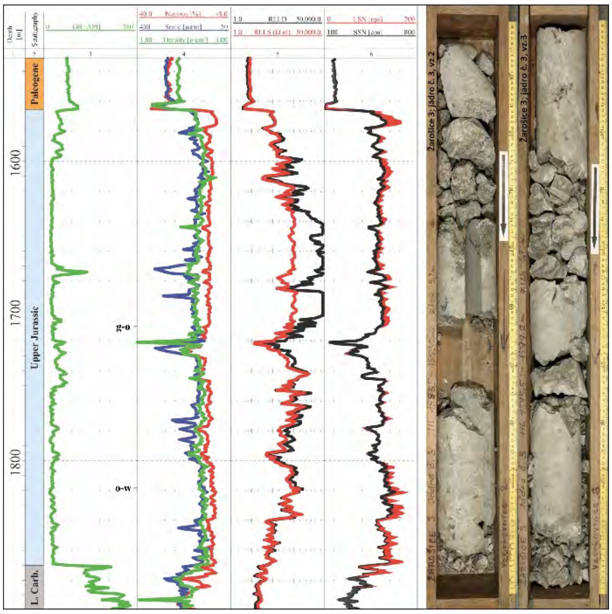

Figure 4: Well-logs of the reservoir (on the left, [6]) and core samples from the upper part of the reservoir (on the right, photos from MND core repository)

The field operator and project partner MND will provide 3D seismic data for the site (Fig. 5). The data cube will cover the whole site area, allowing the project team to prepare a detailed fault and structural plan of the net storage and the whole storage complex. The data and its interpretation will be prepared for input to the 3D geological model.

The 3D geological model of the storage complex is one of the most important outcomes of the project. Individual steps of 3D model construction will include definition of covered spatial area, import of data, spatial well-log correlation and seismic interpretation, construction of layer boundaries (bases and surfaces), interpretation of tectonics, modelling of distribution of petrophysical parameters and distribution of fluids. The model will serve as an input into other parts of the project, especially the reservoir simulations of CO_2 injection, assessment of risks and possible CO_2 leakage pathways and setting up the site monitoring plan.

Another important outcome of the project will be the results of reservoir simulations of CO_2 injection focusing on various injection scenarios. These will serve as an input into risk assessment and preparation of a monitoring plan. Moreover, they will be directly used in all future stages of site development: applying for storage permit, carrying out the storage pilot and subsequent full-field CO_2 injection and storage.

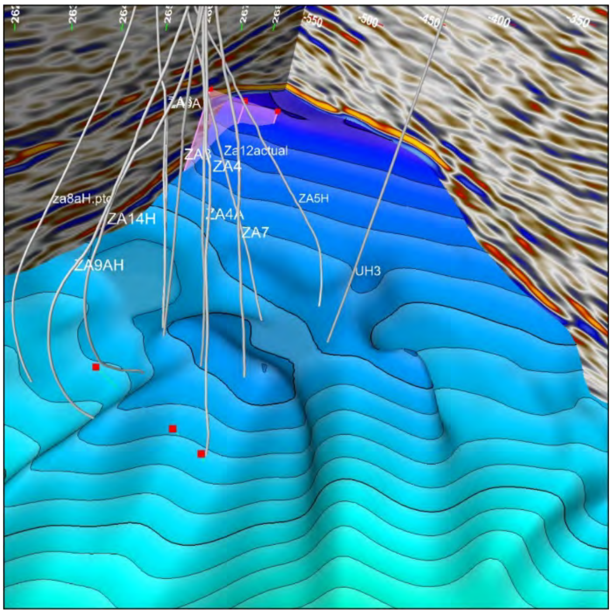

Figure 5: 3D view of the Zar-3 structure on 3D seismic data with interpreted reservoir top (MND data and interpretation)

Many novel approaches and methods will be used in the project, including handling of geological uncertainty through multiple geological realisations, evaluation and modelling of dynamic fracture behaviour, assessment of modern monitoring techniques such as time-lapse pressure transient analysis and seismic monitoring, as well as evaluation of the possibility to combine CO_2 storage with in-situ bacterial methanogenesis.

A comprehensive work programme consisting of ten work packages, spreading over 3.5 years (11/2020 – 04/2024), has been prepared to achieve the project objectives.

3.2 Expected outcomes

CO2-SPICER project results will include a 3D geological model of the whole storage complex, containing the reservoir itself as well as its over- and under-burden. The model will comprise a set of derived structural geological maps and cross-sections illustrating distribution of reservoir parameters at defined stages of future reservoir development, using various CO_2 injection scenarios. The studied parameters will include CO_2 and other reservoir fluid saturations, pressure distribution, all in dynamics according to simulated scenarios, which will range from a basic CO_2 storage pilot up to full field-scale storage.c

Project results will be prepared to enable their immediate application in practice by the industry partner MND for future development and implementation of the CO_2 storage pilot at the Zar-3 field. Many outcomes, e.g. the CO_2 injection scenarios, may be implemented very soon after the project completion, provided that parallel efforts to prepare a full-chain CCS pilot project involving a suitable industrial source of captured CO_2 in combination with the Zar-3 field as the storage site are successful.

The main precondition for the implementation of the pilot project is the availability of a suitable source of captured CO_2. This will require liaison with a company interested in reducing CO_2 emissions by means of CCS technology. Relatively large amounts of emissions are produced by industrial facilities in the Czech Republic, amounting to about 16.4 mil. tonnes annually (Tab. 1). Opportunities of cooperation have been investigated during the project preparation and some of the potential partners have expressed their intent to join the project End-User Club.

Table 1: Overview of CO_2 emissions in industrial sectors in the Czech Republic (data from the year 2018). Source: https://portal.cenia.cz/irz/unikyPrenosy.jsp

Industrial sector	CO_2 emission (t / year)
Iron and steel	5 564 686
Refinery	4 089 807
Cement plants	2 997 169
Pulp and paper mill, millwork	1 116 245
Chemical plants	1 109 317
Lime works	1 071 379
Glass factory	285 022
Cooking plant	119 847
Total all sectors	**16 353 472**

4. Summary

The CO2-SPICER project aims for preparation of a CO_2 storage pilot in the Czech Republic to the implementation-ready stage, where project results would feed in directly as a design concept. By this, CO2-SPICER will significantly increase the Technology Readiness Level of CO_2 geological storage in the Czech Republic and make an important step towards practical deployment of the CCS technology in the country, as well as in Central & Eastern Europe.

Addressing an operational hydrocarbon field located in naturally fractured carbonates as potential storage site makes this project a unique showcase for CCS deployment in onshore Europe, having large application potential for brown and abandoned carbonate fields. The close collaboration with the field operator is crucial for achieving the project objectives.

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