CO2 Geological Storage in the Czech Republic – New R&D Project

V. Hladik[1], R. Lojka[1], V. Kolejka[1], J. Francu[1], E. Francu[1], D.G. Hatzignatiou[2], F. Riis[2], F. Bratteli[2]

1. Czech Geological Survey, Praha, Brno - CZECH REPUBLIC
2. International Research Institute of Stavanger, Stavanger - NORWAY

1. Introduction

The Czech Republic belongs to countries with high level of CO_2 emissions. The emissions per GDP unit are double the value of Italy (EEA, 2006). This is one of the reasons why application of CO_2 capture and storage is very relevant for achievement of Czech national emission reduction targets. The first activities in the area of CO_2 geological storage (CGS) in the Czech Republic date back to the year 2003 when Czech Geological Survey started the first preliminary evaluation of the country's geological structures within the European CASTOR project. This work continued in the following years within several other projects, the most important of which being EU GeoCapacity – a European project with the full title 'Assessing European Capacity for Geological Storage of Carbon Dioxide' – co-financed by the European Union within the 6^{th} Framework Programme for research and technological development.

The above-mentioned activities resulted into basic maps of the CGS potential of the country, first capacity assessments of individual structures and case studies for a few selected, most prospective areas [1]. Among these areas, the Permian-Carboniferous basins situated in Central Bohemia (see Fig. 1) attracted the most attention, especially due to the fact that they are located close to the brown coal basins of Northern Bohemia with the largest coal-fired power plants. In this region the first potential CO_2 sources – new or retrofitted power blocks equipped with CO_2 capture technology – can be foreseen. New research oriented towards deeper understanding and in-detail evaluation of these prospective basins was required.

2. Project description

Using the methodology and techniques described below, the new Czech-Norwegian research project "Towards Geological Storage of CO_2 in the Czech Republic (TOGEOS)" represents an important step on the route towards implementation of geological storage of CO_2 in the Czech Republic, i.e. towards a pilot or demonstration CCS project. Focusing on subject matters such as mineralogy and geochemistry of reservoir rocks and seals or integrated modelling of basin structures, the project brings a significant increase of knowledge of potential CO_2 storage sites and improved specification of their storage capacities. Knowledge transfer of the Norwegian partner – International Research Institute of Stavanger (IRIS) - and common bilateral activities are essential for this work.

The main objective of the project is to significantly increase the level of knowledge of the most promising structures potentially suitable for geological storage of CO_2 in Czechia – i.e. the deep saline aquifers of the Permian-Carboniferous basins in Central Bohemia and to re-assess more accurately their CO_2 storage potential.

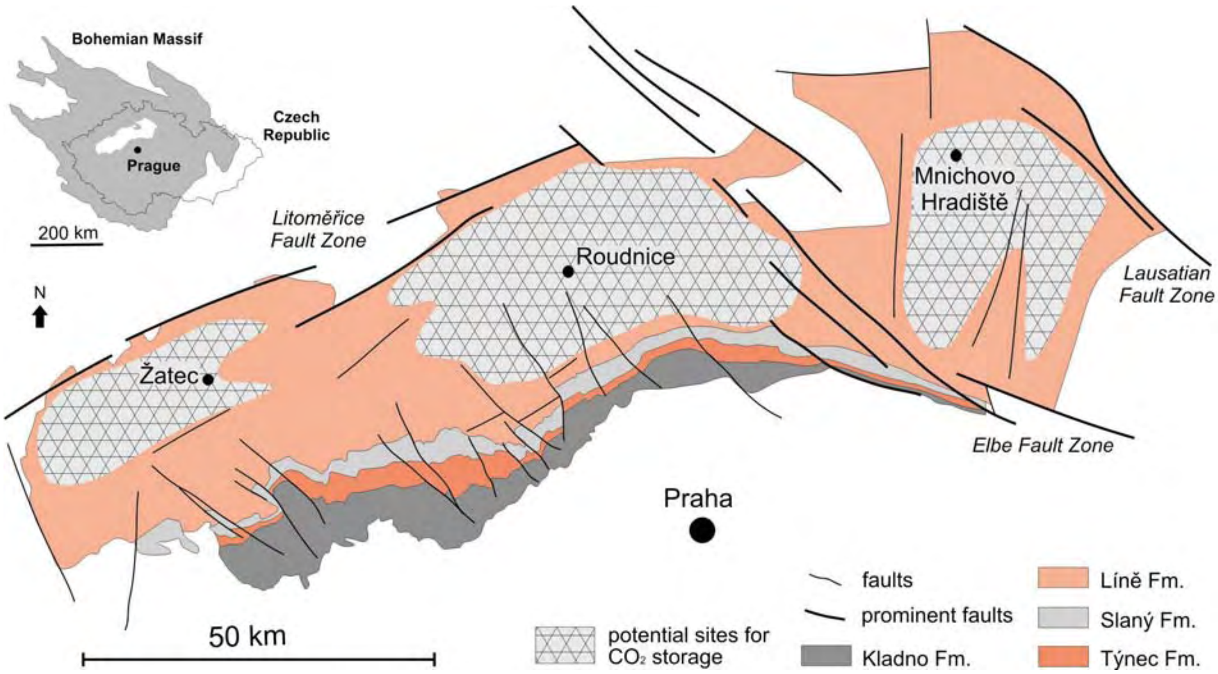

Fig. 1 Situation of the area of interest (top left) and simplified uncovered (pre-Cretaceous) geological map of the Permian-Carboniferous basins of Central Bohemia with potential CGS sites. From left to right: Zatec Basin, Central Bohemian Basin, Mnichovo Hradiste Basin.

This is to be achieved by fulfilling the partial project objectives represented by the project individual activities, sub-activities and tasks. The main project objectives are to:

- increase the knowledge of petrophysical, lithological and geo-mechanical properties of both reservoir and seal rocks by laboratory analyses; knowledge of these properties is essential for storage capacity assessments and storage formation modeling;
- perform a multi-criterial analysis of three partial Permian-Carboniferous basins (Zatec, Central Bohemian Basin - CBB and Mnichovo Hradiste) and select the most promising one where further research will be focused on;
- update the initial volumetric model of the selected basin into a real basin model by introducing newly measured data, sequence-stratigraphic analysis, etc.;
- build an initial reservoir model of the selected storage site and perform the very first simulation of potential CO2 injection and storage;
- disseminate the results of the project by presentations at international scientific events, by publications in scientific journals and by organising an open workshop at the end of the project.

3. Site selection

For the site selection, geological & other site selection criteria developed within the EU GeoCapacity project were used [2]:

- sufficient depth of reservoir to ensure that CO_2 reach its supercritical dense phase but not so deep that permeability and porosity is too low;
- integrity of seal to hinder CO_2 escape;
- sufficient CO_2 storage capacity to hold the CO_2 expected to be released from the source;
- effective petrophysical reservoir properties to ensure CO_2 injectivity to be economically viable and that sufficient CO_2 can be obtained.

In the assessment of site suitability for CO_2 storage (site screening) it is important to decide or at least estimate if the basic criteria listed above and their associated geological and physical parameters are fulfilled. The goal with the screening process is to identify predictable, laterally continuous, suitable permeable reservoir rocks overlain by potentially good quality caprocks at a suitable depth based on existing data. By the screening an overview is obtained of those sites which are best described and best fulfil the storage criteria on the basis of existing data. The screening therefore narrows the search at an early stage so that costly and time-consuming supplementary investigations such as deep drilling or colleting and interpreting seismic data is confined to potentially prospective areas only. Tab. 1 shows application of the basic site selection criteria to the three basins depicted in Fig. 1.

Basin name	Zatec	Central Bohemian (CBB)	Mnichovo Hradiste
Reservoir properties			
Capacity (Mt CO2)	94	233	109
Depth)Max, relative.)(m)	1400	1100	1850
Porosity (%)	15	15	15
Permeability (mD)	80	30	Up to 70
Pressure (max) Mpa	14.0?	15.5?	18.5?
Temperature (°C)	34-44	44 - 54	?
Sealing properties			
Thickness (m)	200-300	20-30	10-20
Permeability	low	very low	3mD
Location			
Distance to big emission sources	up to 40 km	up to 70 km	more than 70 km
Availability of data			
No of wells	6	105	26
Well-logging	GR, resistivity	GR, resistivity	GR, resistivity
Geophysical data	VES	Seismic, VES, DC-resistivity	Seismic, VES

Tab. 1 Application of site selection criteria to the three pre-selected basins

As a result, the CBB was selected as the most prospective storage site. Then, a similar procedure was used for the selection of most suitable aquifer bodies (strata) inside the selected basin. Here the two deepest aquifer bodies in the Nyrany Member of the Kladno Formation (see Chapter 4 for description) were selected as most prospective CGS structures.

4 Stratigraphy and lithology

The Kladno Formation (Carboniferous-Westphalian age) forms the deepest part of the sedimentary filling of the CBB. The Nyrany Member (Wesphalian D) with the selected aquifer bodies forms the upper part of the Kladno Formation.

Within the Nyrany Member, up to seven fining-upward alluvial-lacustrine sequences (cycles) can be defined, with thickness varying between 50 and 70 m [3]. Each cycle consists of a lower, so-called erosive part and an upper, so-called accumulation part. The erosive part comprises coarse-grained sandstones and conglomerates of fluvial origin with frequent erosional and reactivation surfaces. The accumulation part consists of fine-grained, probably lacustrine sandstones to siltstones, laminated claystones and coal seams at the top. The relative proportion between the erosion and accumulation parts of the cycle varies vertically and laterally due to changing climate and morphology. In general, the cycles at the lower part of the Nyrany Member have well-developed erosion parts, i.e. the potential aquifer bodies. Two prospective structures for CGS were selected from this lower part of the Nyrany Member. Vice versa, the sealing rocks of accumulation parts become thicker in the upward direction, which is favourable for the permanency of CGS.

5 Petrophysical properties

Knowledge of petrophysical properties of reservoir and sealing rocks is crucial for the assessment of the suitability of the selected structure for CGS. Rock porosity, permeability, sand and clay content (for sandstones) as well as properties of the reservoir fluids are the most important parameters to be investigated.

In the particular case of the TOGEOS project, acquisition of the above-mentioned data was limited by the project size and budget. No deep drilling into the storage structure itself could be performed and data collection was limited to information available in the archives and databases and to a shallow analogue site where a new well of ca 60 m depth was drilled. This well was situated in an area where the main reservoir strata of the CBB come close to the surface. New cores were obtained, sampled and analysed, and the information was used – after application of depth correction coefficients - as one of the input sources for the construction of the initial reservoir model.

In addition to the above, petrophysical data were collected from the national geophysical database and from archive reports. New measurements of porosity and permeability, as well as mineralogical and geochemical analyses, were performed on archive core samples from deep boreholes stored in the core repository of Czech Geological Survey – Geofond. Additional information on porosity, lithology and clay content were derived from new interpretation of archive well logs.

In general, the collected and newly acquired data show significant heterogeneity of the reservoir: Open porosity values vary between 4 and 21 %, permeability between 0,003 and 123 mD and groundwater mineralization ranges from 7,4 to 55,5 g/l. This ranks the CBB close to the limit of a suitable CO_2 storage site and clearly shows the necessity of further, much detailed site investigation, including deep drilling and 3D seismic, in order to reliably identify and delineate the most permeable horizons and obtain more petrophysical data, especially on rock permeability.

6. Modelling

The first initial geometric model of the CBB and its individual aquifer layers was constructed within the EU GeoCapacity project in the ArcGIS environment [4]. This model served as the basic input in the initial reservoir model that is now close to finalisation by IRIS researchers, using the Petrel reservoir modelling SW (example shown in Fig. 2). The initial model was significantly improved and adjusted within TOGEOS: Stratigraphy and layering of the basin were re-evaluated, based on new analyses of borehole core descriptions and archive well-logging data. Archive 2D seismic lines were re-evaluated and re-interpreted. New analysis of faults was performed to better fit with the seismic and gravity data.

After this enhancement of the geometric part of model, petrophysical properties (see Chapter 5) were introduced, preparing field for the first preliminary theoretical simulation of CO_2 injection into the reservoir. This simulation is expected to be finalised until September 2010 and to bring first preliminary information about viability of CO_2 injection into the aquifers of the CBB.

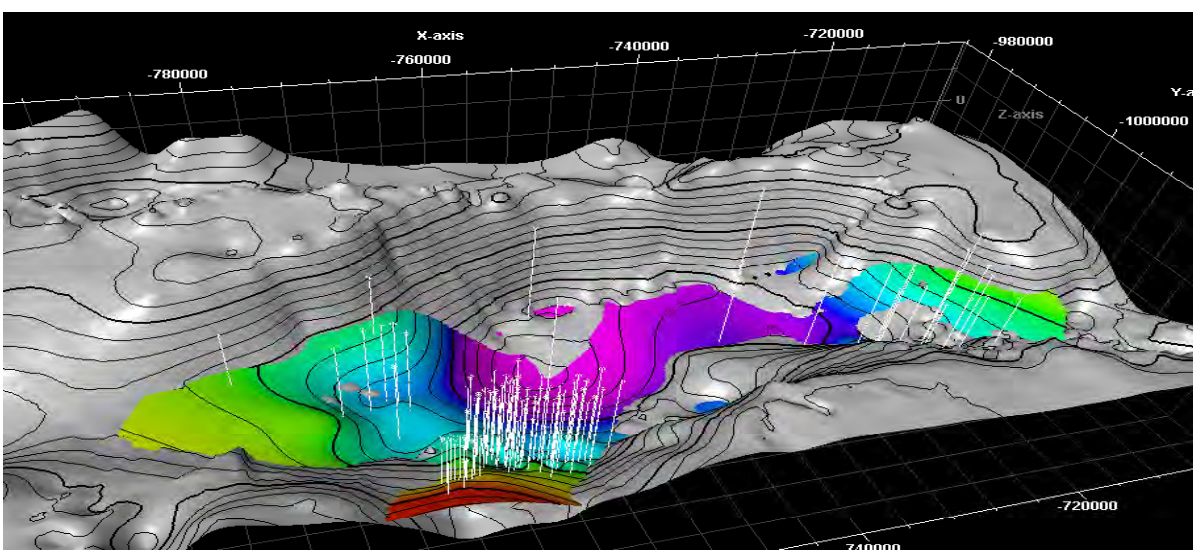

Fig. 2 3D model of the CBB – crystalline basement (grey) and top of the deepest aquifer body (coloured) in Petrel environment.

7. Conclusion

The preliminary results of the project show that the selected basin is close to the limit of a suitable CO_2 storage site, especially regarding the rock permeabilities. The new laboratory measurements show, in some cases, a disproportion between newly measured data and old archive data used for site screening and selection, which will require further laboratory testing of further core samples that are, unfortunately, not available at present. The number of newly measured samples is, however, very low and, due to limited number of cores available, by far not representative. Most probably, the newly measured samples did not include the most permeable layers of the basin. On the other hand, the modelling results indicate good structural setting of the basin from the CGS point of view. The project is still ongoing and final results are expected in September 2010. Already now it is quite clear that further site investigation, including new data acquisition, will be needed in future to finally decide upon the suitability of the Central Bohemian Basin for CGS.

8. Acknowledgements

The TOGEOS project is co-funded by a grant from Iceland, Liechtenstein and Norway through the EEA Financial Mechanism and the Norwegian Financial Mechanism as well as by a contribution from the Czech Ministry of Education, Youth and Sport. Presentation of this paper is supported by the CO2NET EAST project, sponsored by Statoil, Schlumberger, Enel, Technology Initiatives and CEZ Group.

9. References

1. Hladík, V., Kolejka, V., Lojka, R., Fott, P., Vácha, D.: *Slovak Geological Magazine*, 2008, pp.29-41 (2009).
2. Vosgerau, H., Kirk K.L., von Dalwigk, I., Vangkilde-Pedersen, T. [*EU Geocapacity – D23 - Site Selection criteria*]. Copenhagen (Denmark): EU GeoCapacity project; c2009 [cited 2010 May 31]. Available from: http://www.gelogy.cz/geocapacity/workingarea/deliverables.
3. Kautský, J., Spudil, J.: *Nové poznatky ze severozápadní části ložiska Slaný. X. exkurze uhelně-geologického semináře*, pp 73-87 (1988).
4. Vangkilde-Pedersen, T. et al. [*EU GeoCapacity – D14 – Case study scenarios*]. Copenhagen (Denmark): EU GeoCapacity project; c2009 [cited 2010 May 31]. Available from: http://www.geology.cz/geocapacity/workingarea/deliverables.