Carbon storage in dolomite reservoir: rock-fluid-CO_2 interactions

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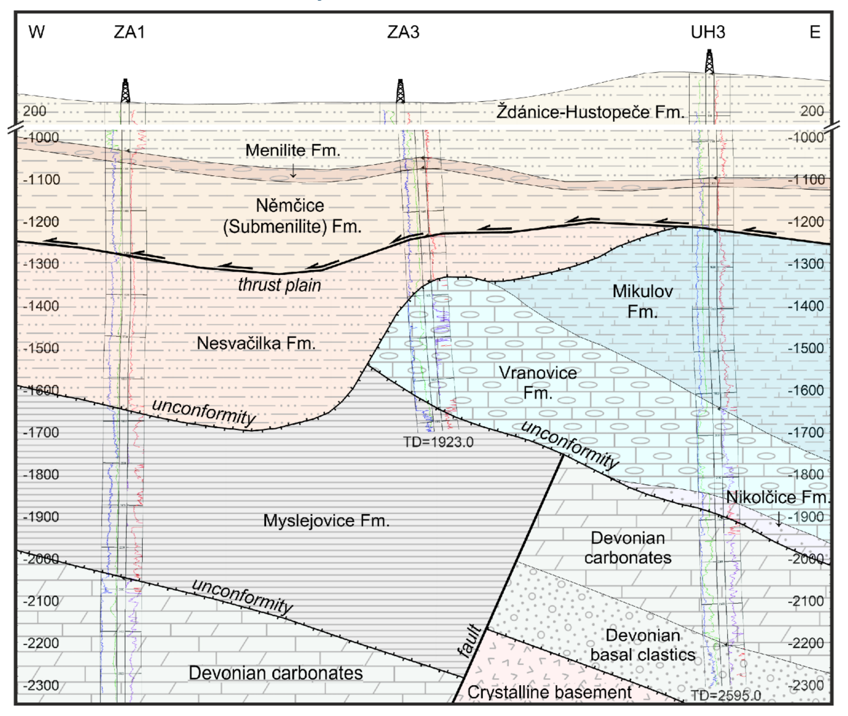
Introduction and objectives

- knowledge on geological settings in future CO_2 storage reservoir is crucial to understand upcoming CO_2-fluid-rock interactions
- pilot Zar-3 CO_2 storage research on depleted oil and gas field Žarošice, SE Czech Republic
- Jurassic carbonates on SE margin of Bohemian Massif, overthrusted by Carpathian Flysch Belt
- tilted and heavily eroded slab



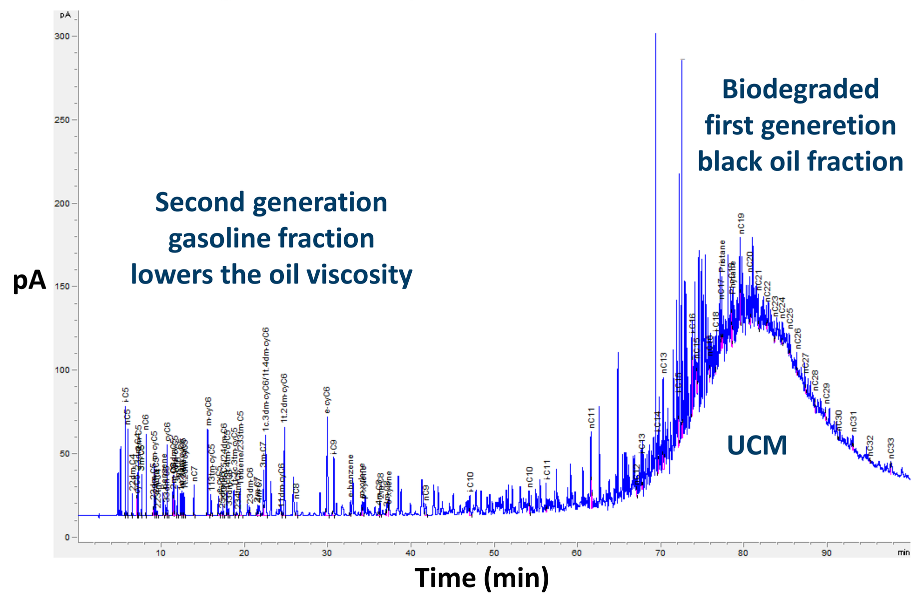
Cross section through the reservoir (Pereszlényi et al. 2022).

Methodology and samples

- core, oil, gas and water samples from Zar-3
- optical, fluorescence and electron microscopy
- electron microprobe analysis (WDS) and pXRD
- optical porosimetry on blue-dyed thin sections
- gas chromatography of petroleum and gas
- reaction chamber with formation water
- 53˚C and 15 MPa CO_2 (injection conditions)

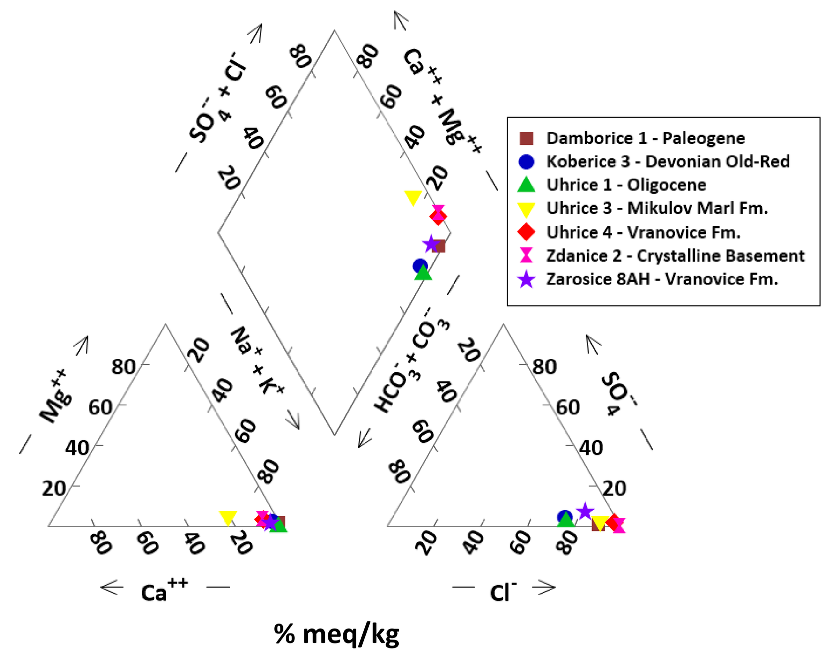
Reservoir fluids

- medium sweet crude oil (0.150 $\%_{wt}$ S)
- API gravity 23–24°
- TAN 0.60–0.70 mg KOH/g
- oil biodegradation (level ≥ 6 on PM scale)



Whole oil GC analysis shows mixture of biodegraded black oil and fresh gasoline.

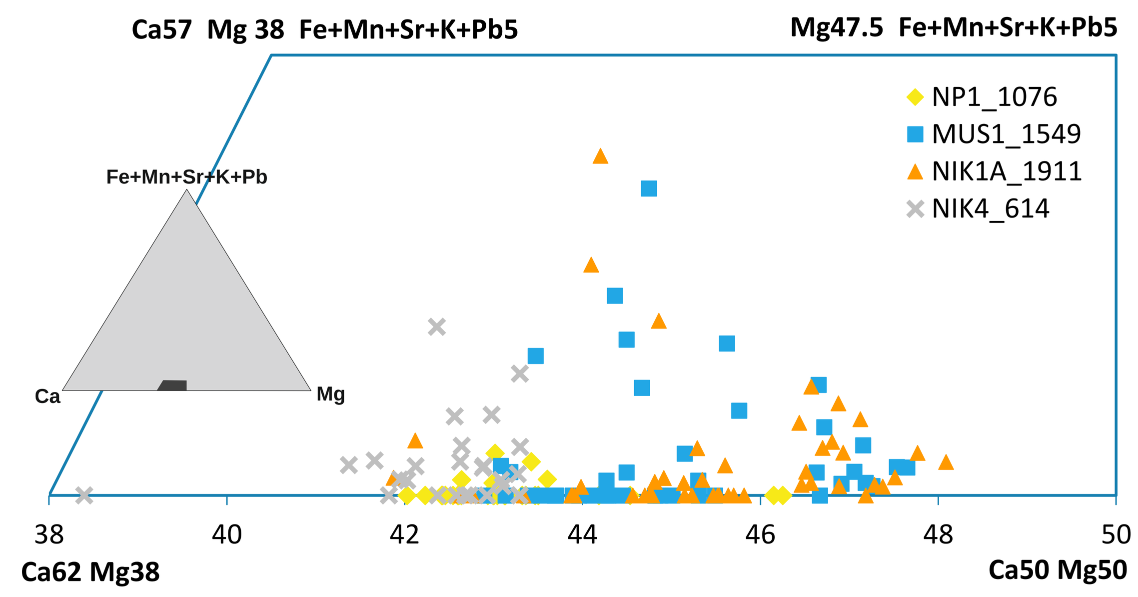
- natural gas with 84–90 $\%_{mol}$ CH_4
- C2–C7 higher gaseous hydrocarbons 5–8 $\%_{mol}$
- high CO_2 (5–8 $\%_{mol}$), different concentrations in dissolved gas and gas cap
- reservoir brine – NaCl type (TDS ca 26 g/l), elevated SO_4^{2-} concentration (up to 1500 mg/l)



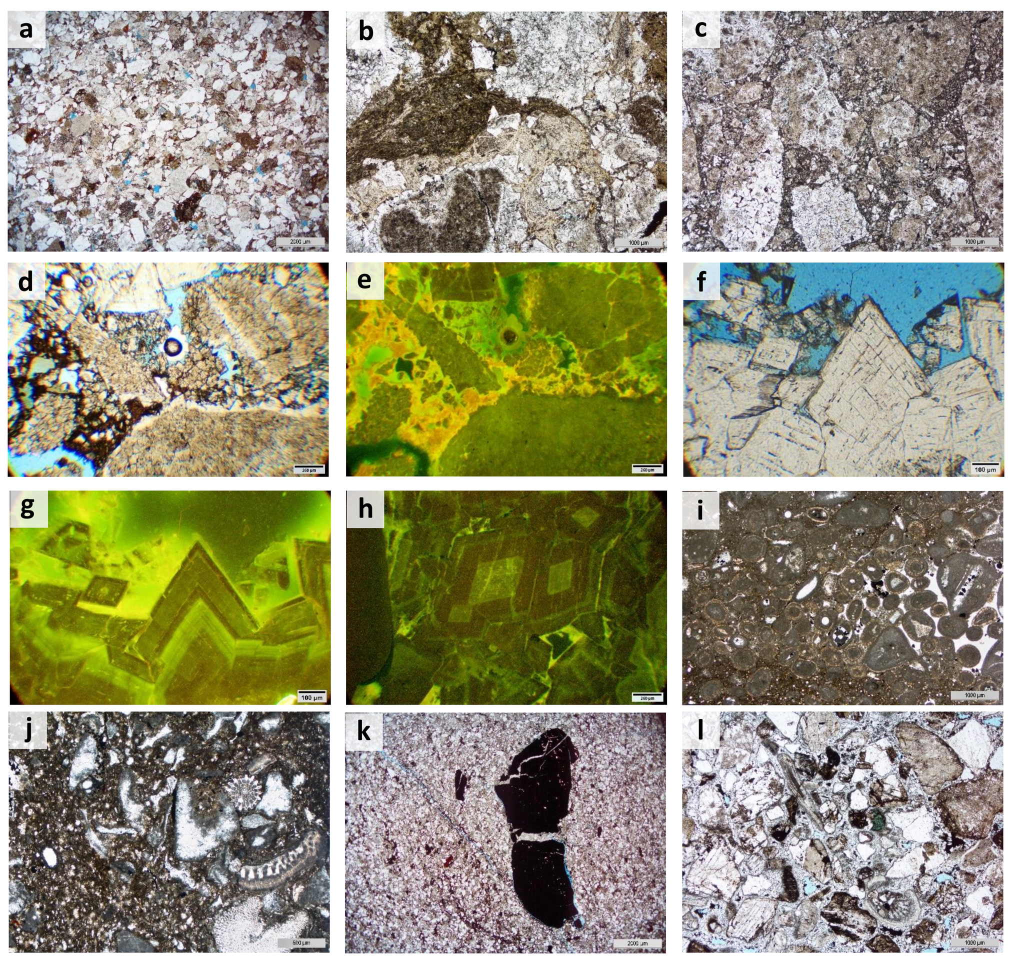
Piper diagram of the formation waters in Zar-3.

Petrological characteristics

- upper seals – marls, silty sandstones and wackestones of Mikulov Fm. (Jurassic) and calcite cemented siltstones to sandstones of Nesvačilka Fm. (Paleogene) with coal
- main reservoir (Jurassic) – brecciated and cavernous dolostones and oolitic packstones of Vranovice Fm.
- bottom of reservoir (Jurassic) – sandy dolostones to dolostones of Nikolčice Fm.
- bottom seal – underlying silty sandstones to siltstones of Myslejovice Fm. (Carboniferous)

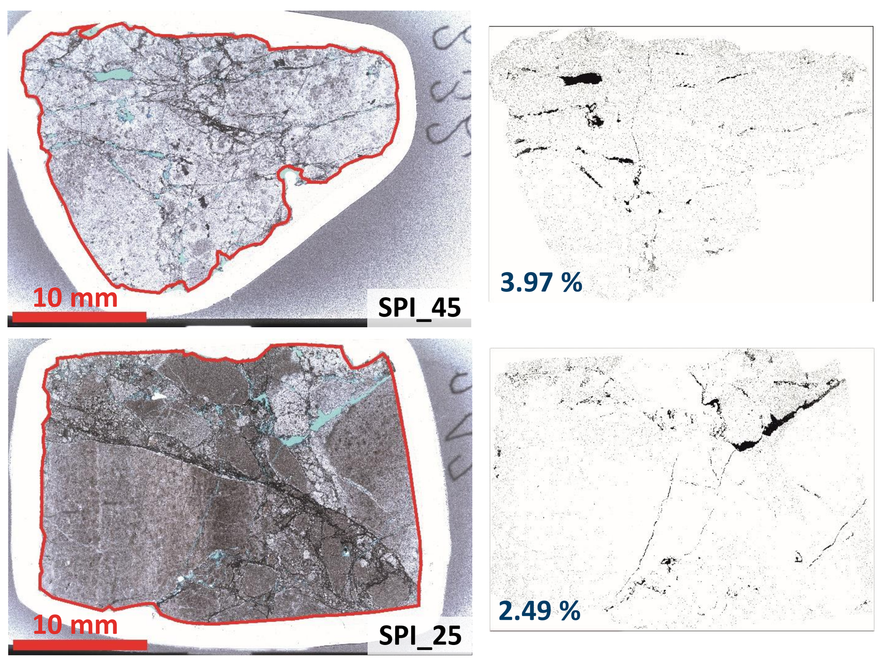


Chemical composition of dolomites from Vranovice Fm. varies only slightly.

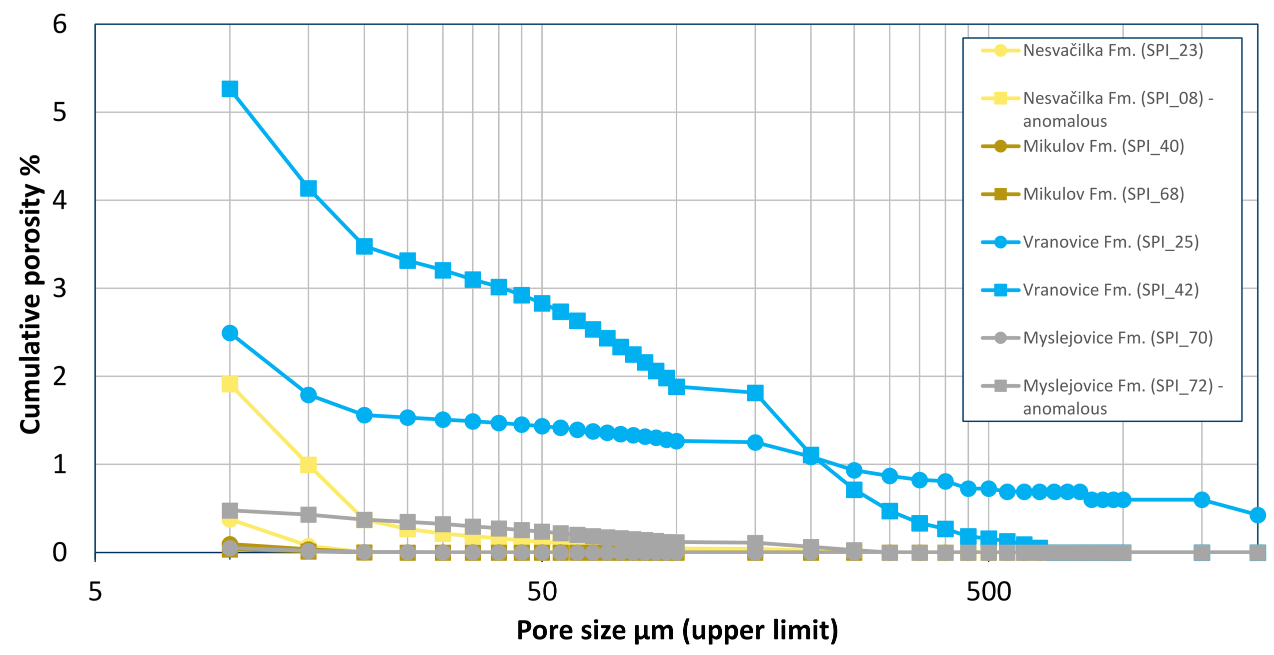


Silty sandstone to arkose, rarely with dissolved feldspars, Myslejovice Fm. (PPL, a), sandy, brecciated, dolomitized limestone with clay, Nikolčice Fm. (PPL, b), intensely brecciated dolostone, Vranovice Fm. (PPL, c), brecciated, dolomitized, higly-porous micritic limestone (PPL, d), with bright orange oil remains in pores, Vranovice Fm. (RL fluorescence, e), large zonal dolomite crystals grow into vuggs created by multi-stage karstification of Vranovice Fm. dolostones (PPL, f and RL fluorescence, g), and sometimes fill the pores completely (RL fluorescence, h), oolitic packstone from shelf lagoon facies, Vranovice Fm. (PPL, i), silty carbonatic fossiliferous sandstone, Mikulov Fm. (PPL, j), silty sandstone with coal, Nesvačilka Fm. (PPL, k), and dolomitic sandstone to arkose with isopachous calcite cement sealing high interparticle porosity, Nesvačilka Fm. (PPL; l).

- cavernous porosity in Jurassic dolostones up to 4.5 %
- seal porosity very low, rarely up to 0.4 % interparticle porosity, but not effective due to cementation



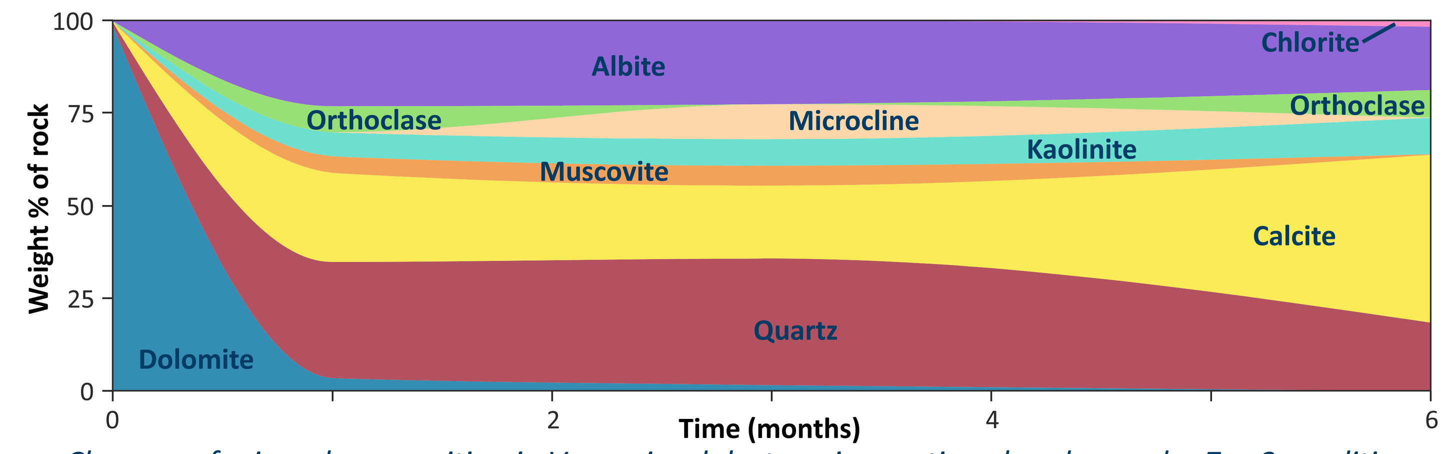
Optical (macro)porosity evaluations of Vranovice Fm. rocks.



Cumulative pore size (macroporosity) of different rock types in the Žarošice reservoir.

Reaction chamber experiment

- rapid and complete dissolution of rock-forming dolomite
- precipitation of silicates (feldspars, phyllosilicates) and quartz, later slow dissolution
- significant precipitation of calcite
- only short-term changes



Changes of mineral composition in Vranovice dolostone in reaction chamber under Zar-3 conditions.

Discussion

- limestone dolomitization during periodical sea level drops in shallow marine environment
- carbonates emerge from sea, multi-stage karst processes form porosity (Zhang et al. 2020)
- repeated massif destabilization, collapse and dolomite brecciation
- well logs suggest higher fracture porosities, but it is not possible to extract such porous cores intact for analysis

Conclusions

- types of reservoir and seal rocks are defined more in detail using microscopy and geochemistry
- black oil accumulation underwent considerable biodegradation and was later mixed with more fresh light oil
- reservoir rock is cavernous brecciated dolostone with calcite cement, dolomite is chemically uniform
- reaction chamber experiment reveals changes in reservoir rock composition under CO_2 injection conditions in time

Literature

Pereszlényi et al. (2022): Revised geological setting of Zar-3. – MS, unpublished report from project CO2-Spicer. CGS.

Zhang Y., Luo B., Chen C., Li M., Jin Z., Zhang S. and Shen Y. (2020): Genesis and characteristics of the dolomite reservoirs in Middle Devonian Guanwushan Formation, Northwest Sichuan Basin, SW china. – Petroleum, 6, 138–148.

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