Basin modeling of a pilot CO2- storage in a dolomite reservoir Bohemian Massif, Czech Republic

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Zar-3 pilot CO_2- storage

Outline

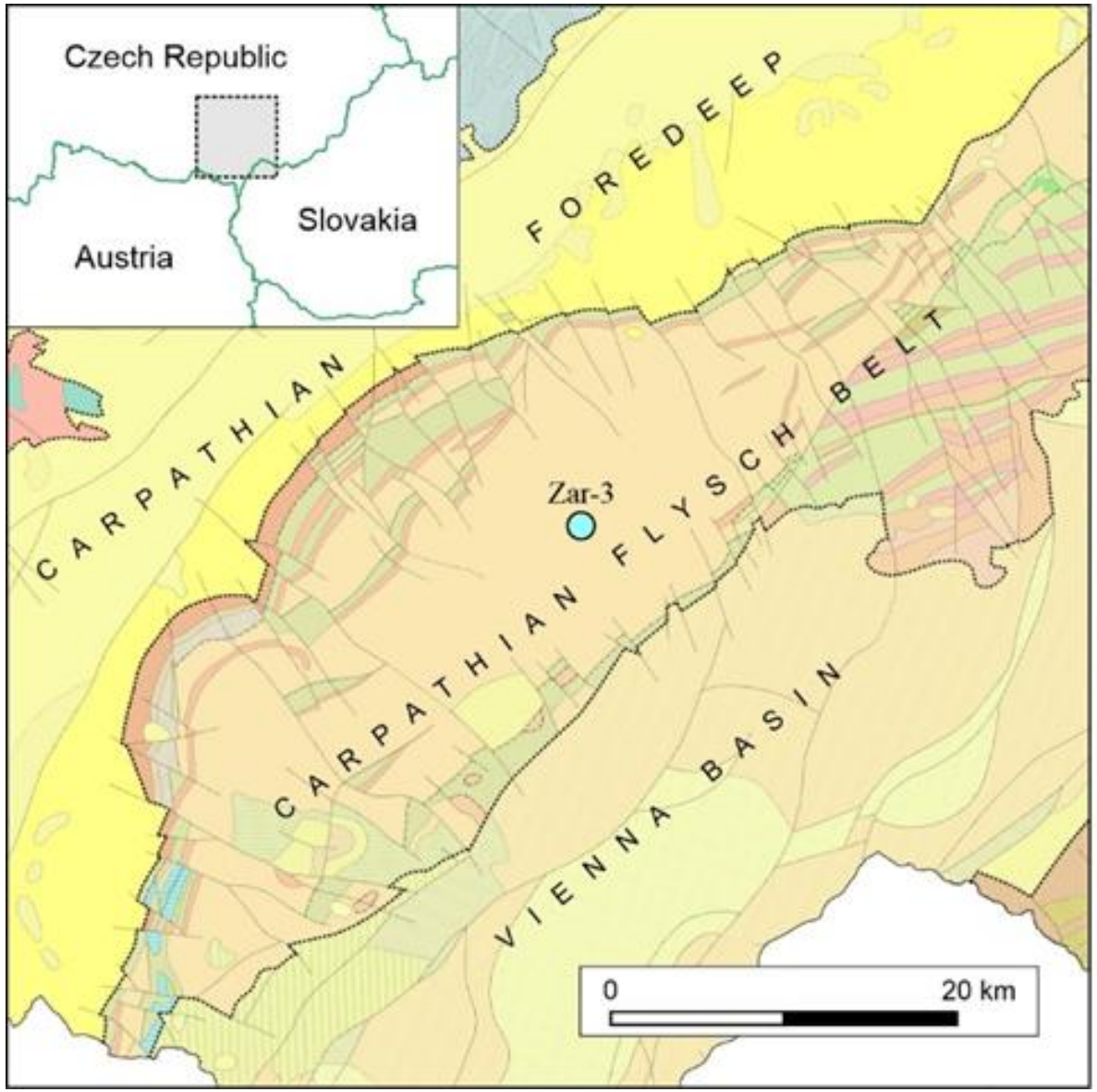
- Building a geological Petrel (Slb) model
- Reservoir and cap rocks geochemical properties
- Depositional settings in Jurassic and Paleogene
- Formation water geochemistery
- Burial and thermal history model
- CO2–water–rock interactions

Norway grants

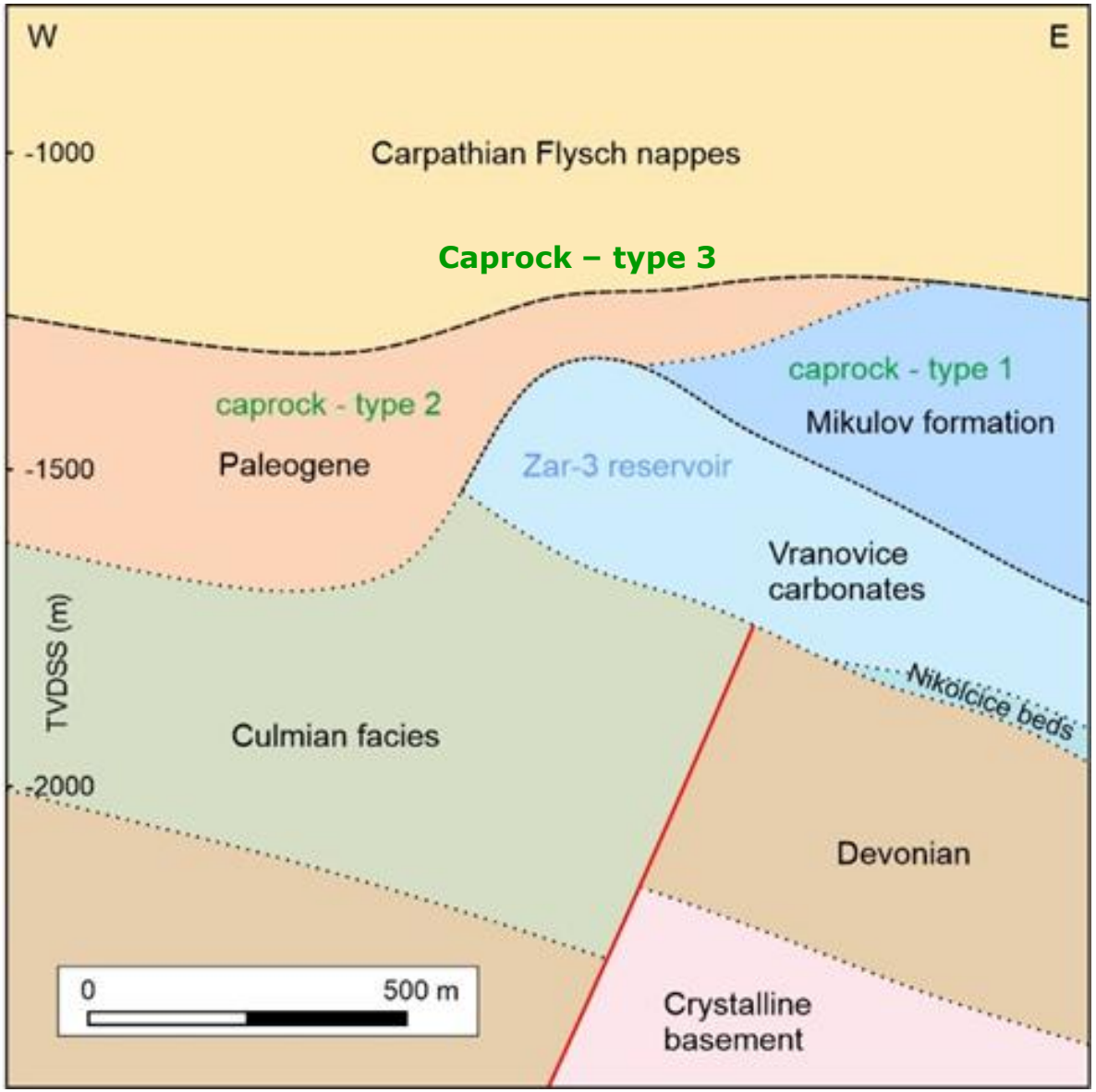
Programme Kappa

T A
Č R

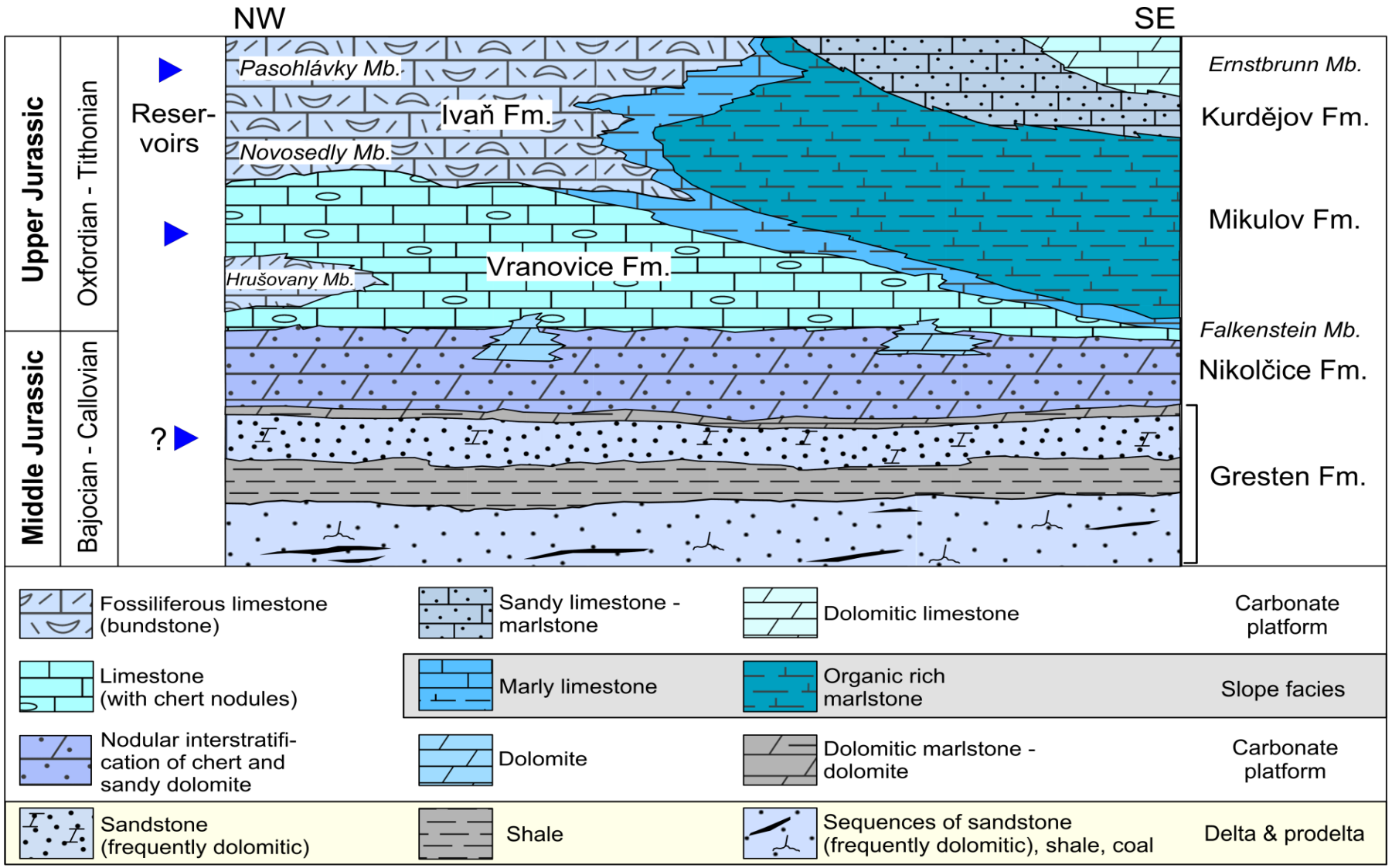
Surface geological map



W – E Cross section

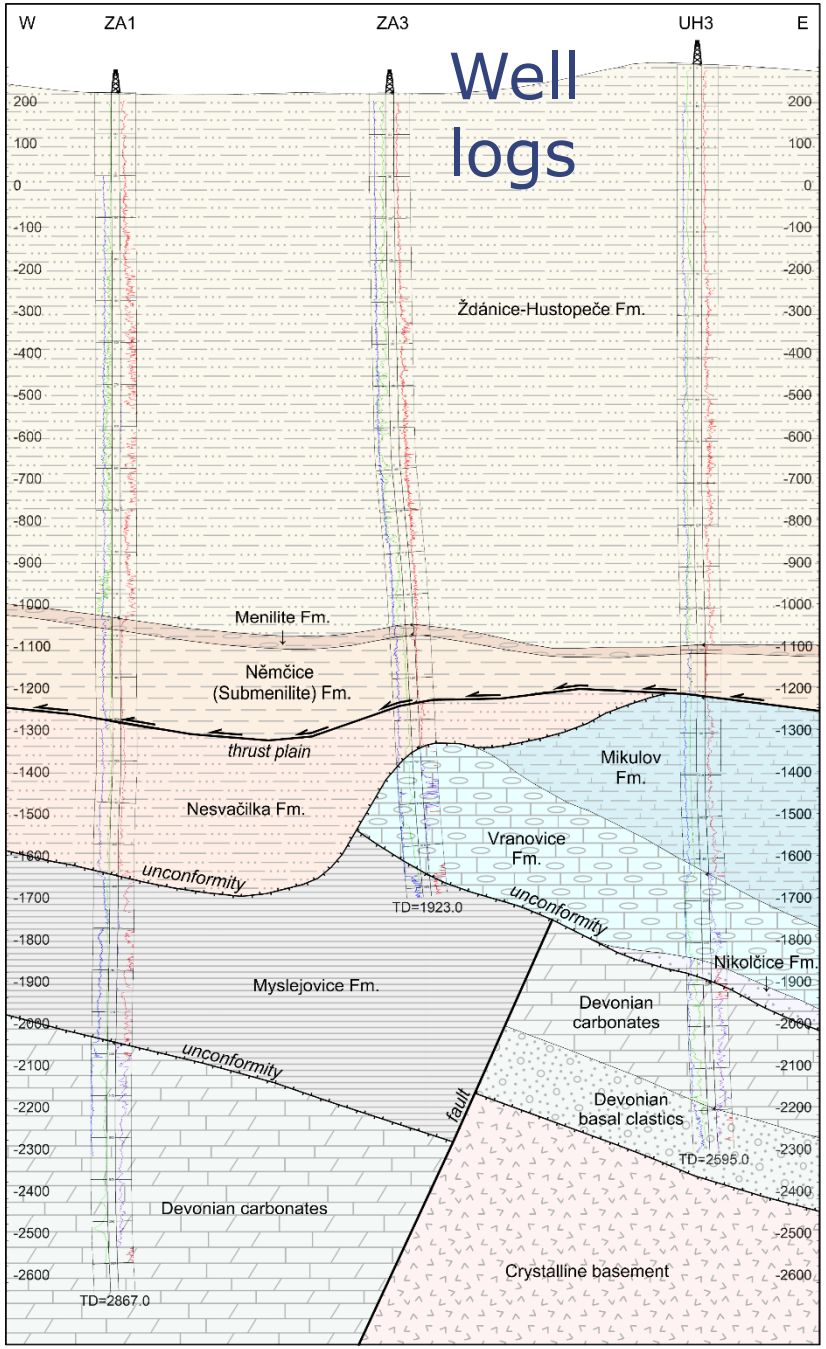


Lithofacial model of the Jurassic in Zar-3

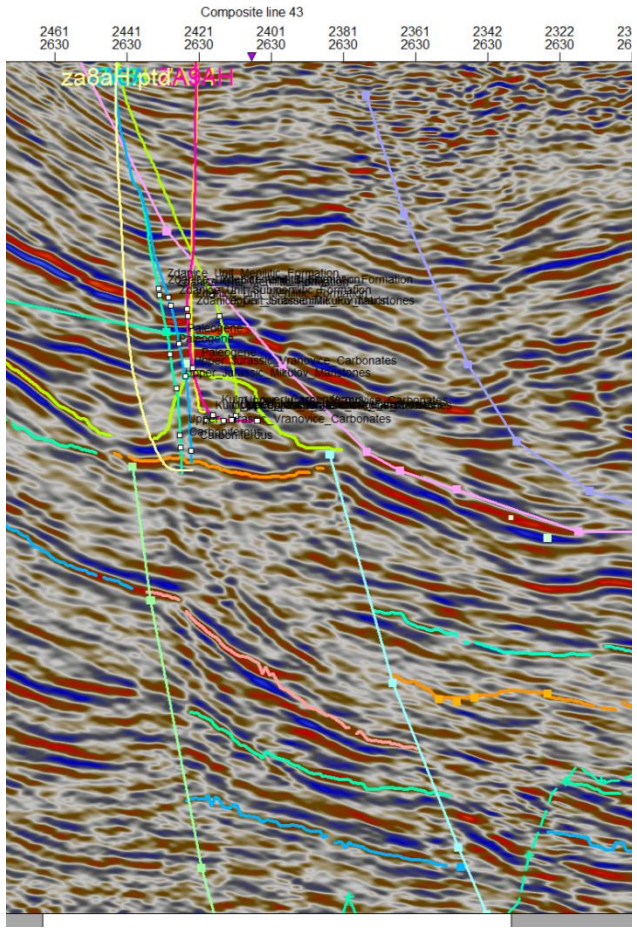


Lithofacies and lithostratigraphy of the Jurassic of the SE margin of the Bohemian Massif (modified from Ladwein 1988; Eliáš & Wessely 1990; Adámek 2005)

Building the 3D static model of the storage site

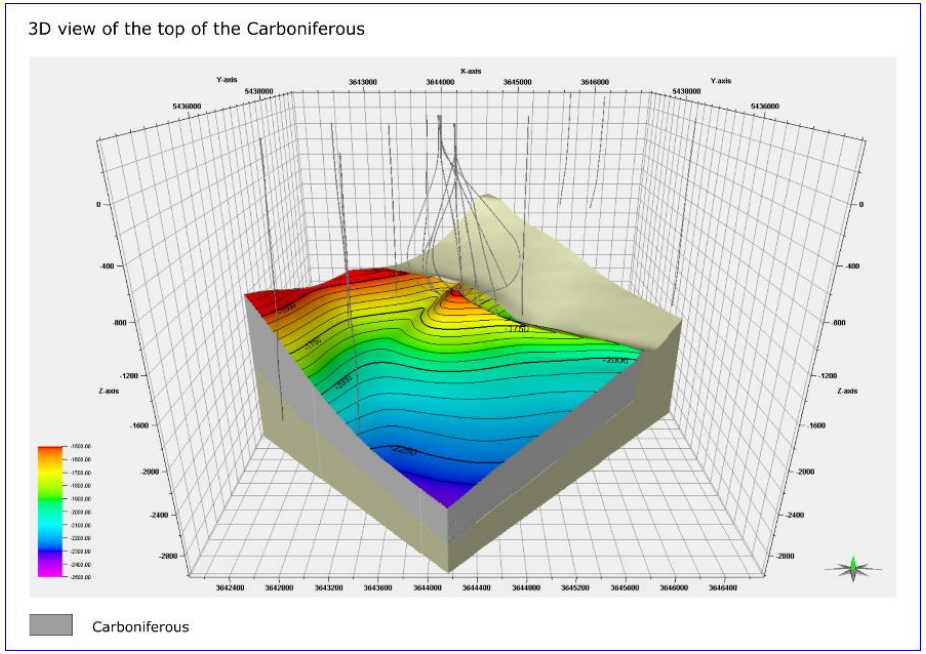


Seismic 3D cube

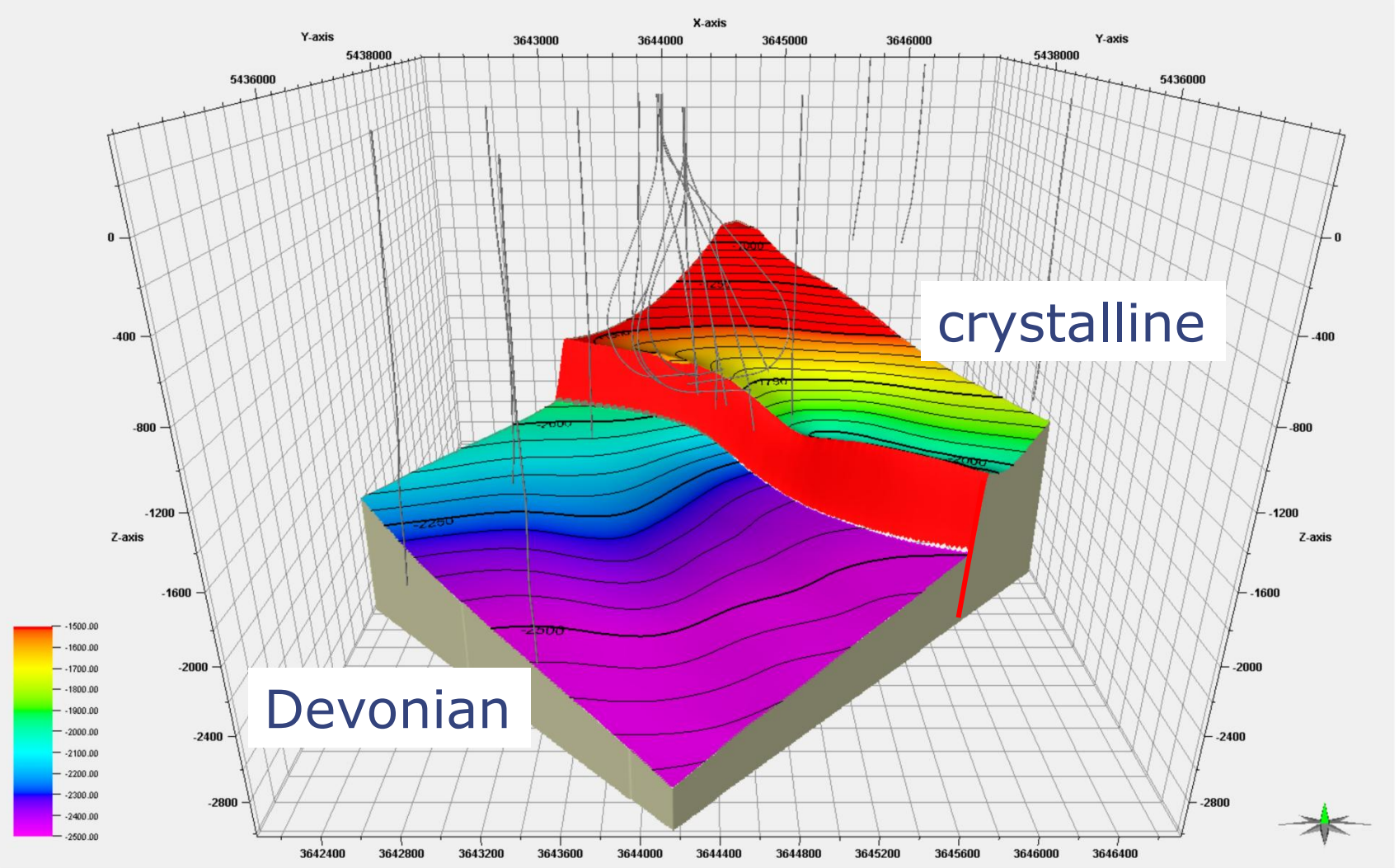


3D geological model

+ sedimentology + stratigraphy
+ tectonics + rock properties

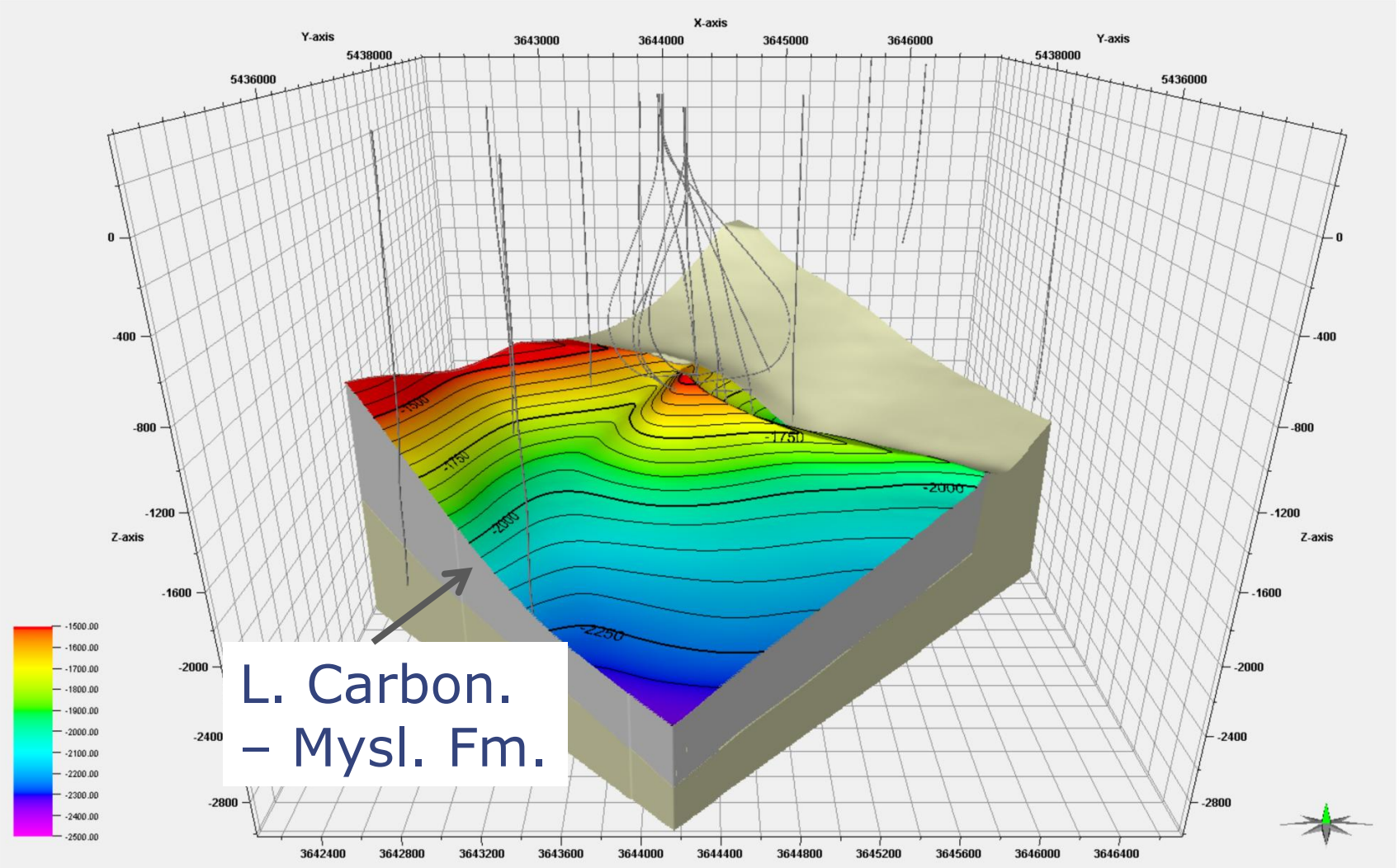


3D view of the top of pre-Carboniferous (on the left) and pre-Jurassic (on the right) basement



3D view of the top of the Carboniferous

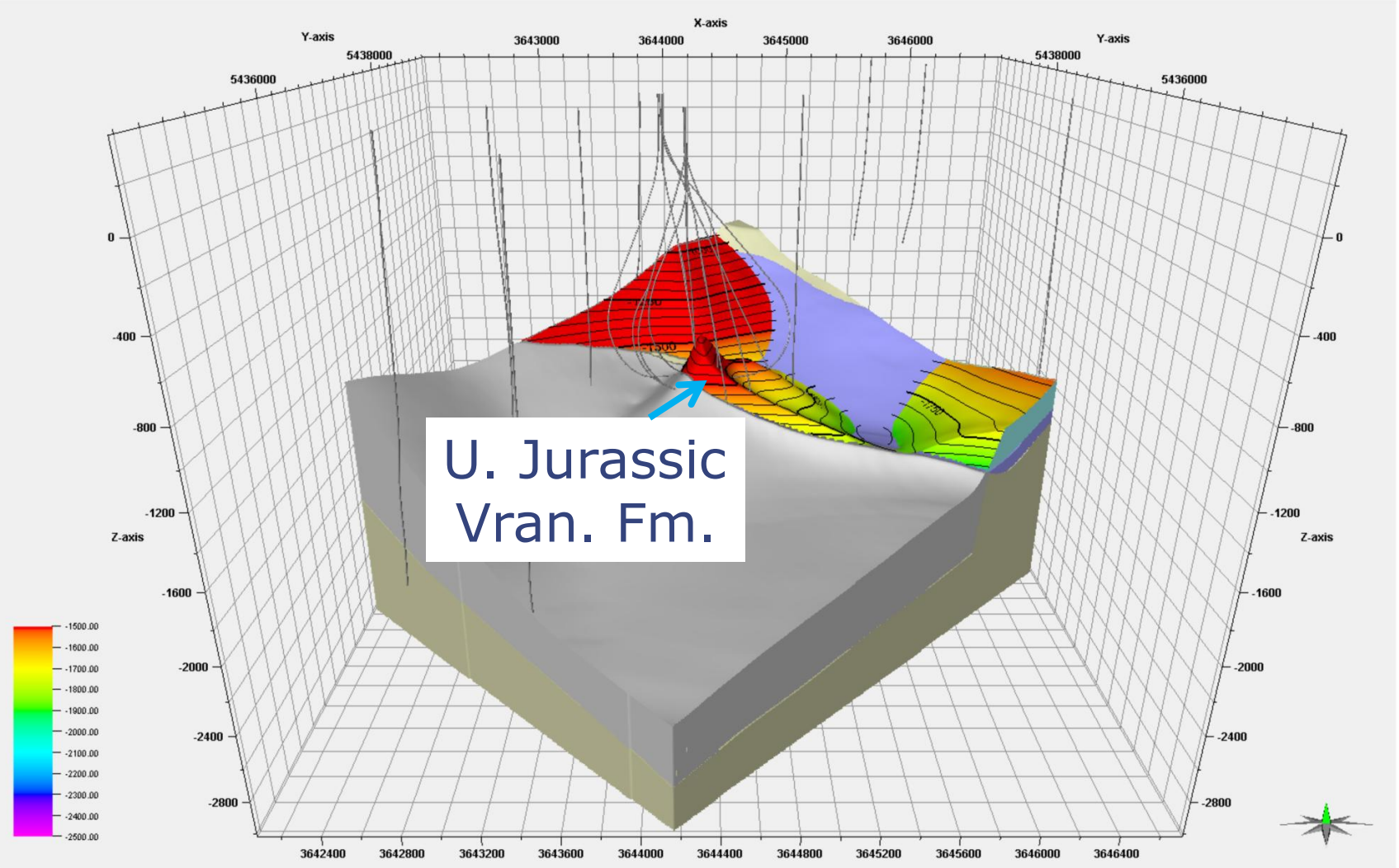
Bottom Seal



Carboniferous

3D view of the top of the Jurassic Vranovice formation

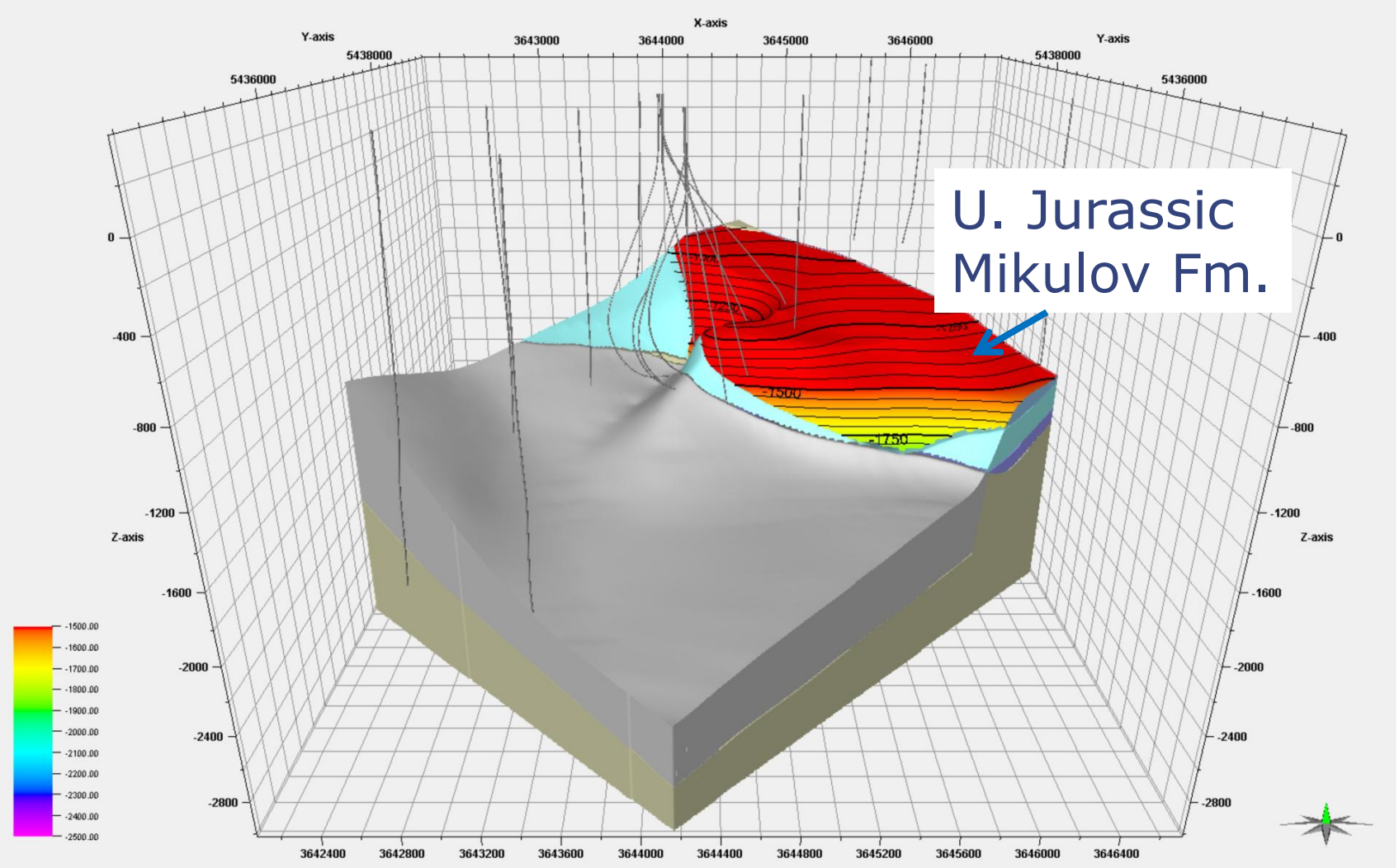
Principal Reservoir



Vranovice fm.

3D view of the top of the Jurassic Mikulov formation

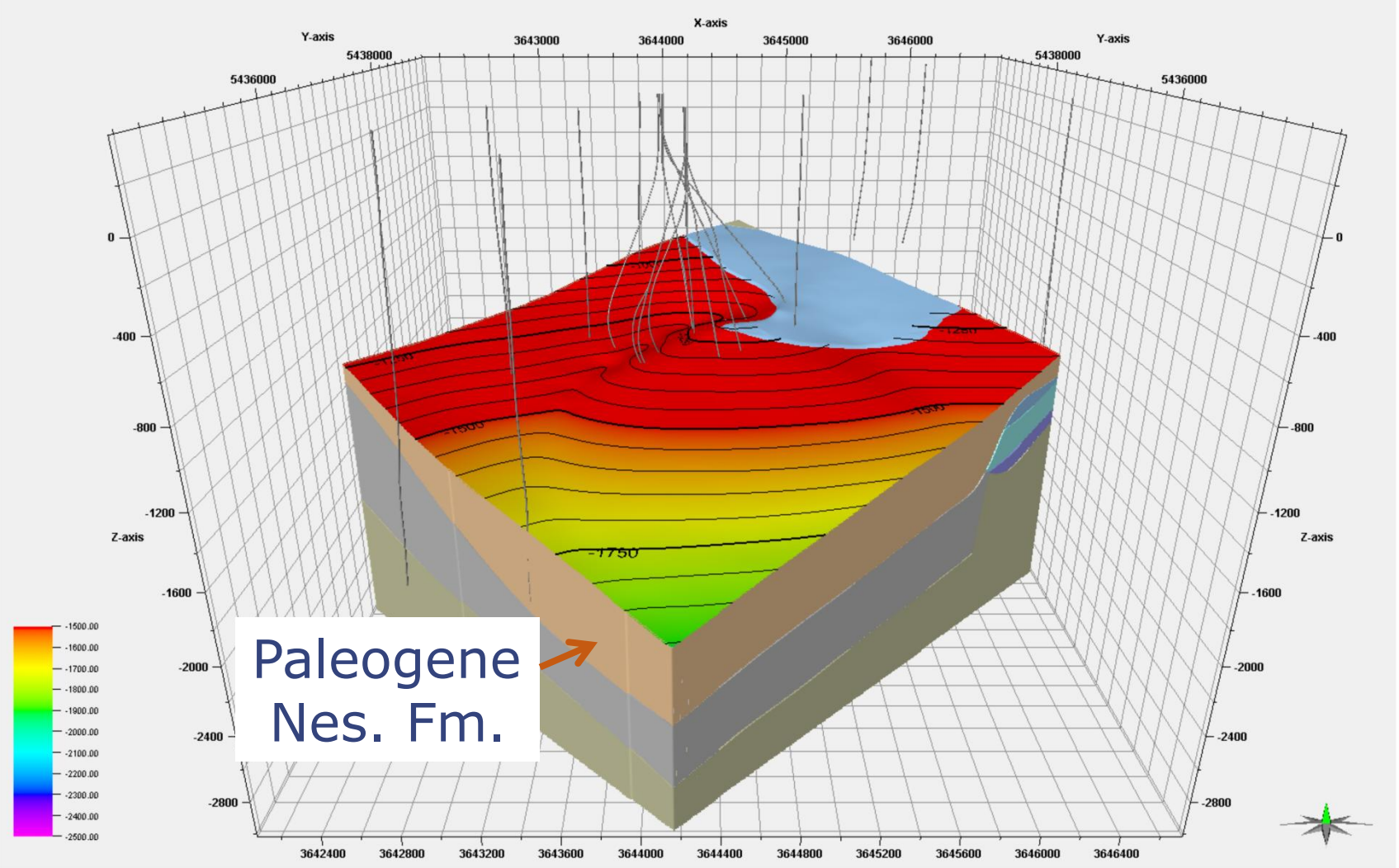
Primary Seal 1



Mikulov fm.

3D view of the top of the Paleogene

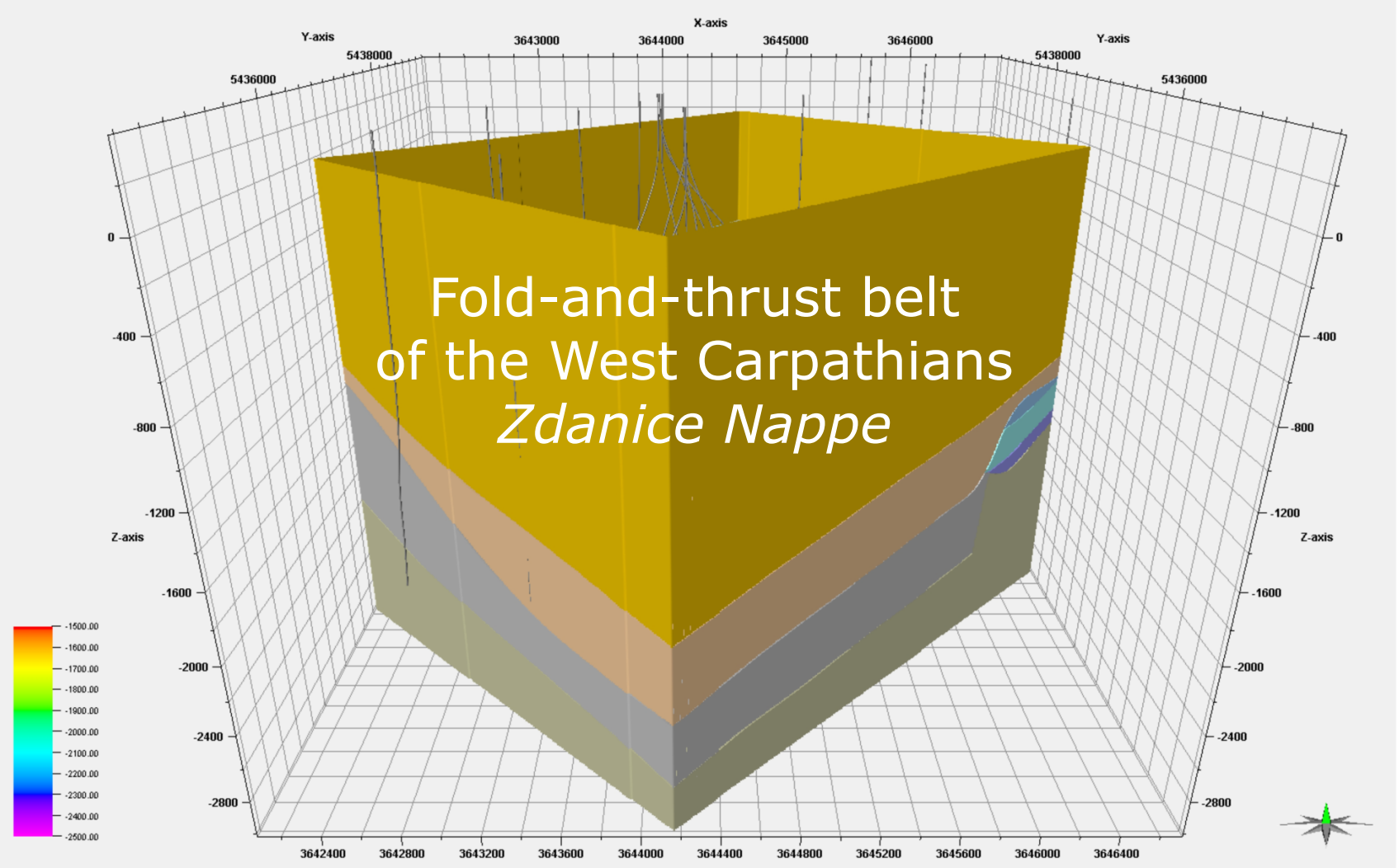
Primary Seal 2



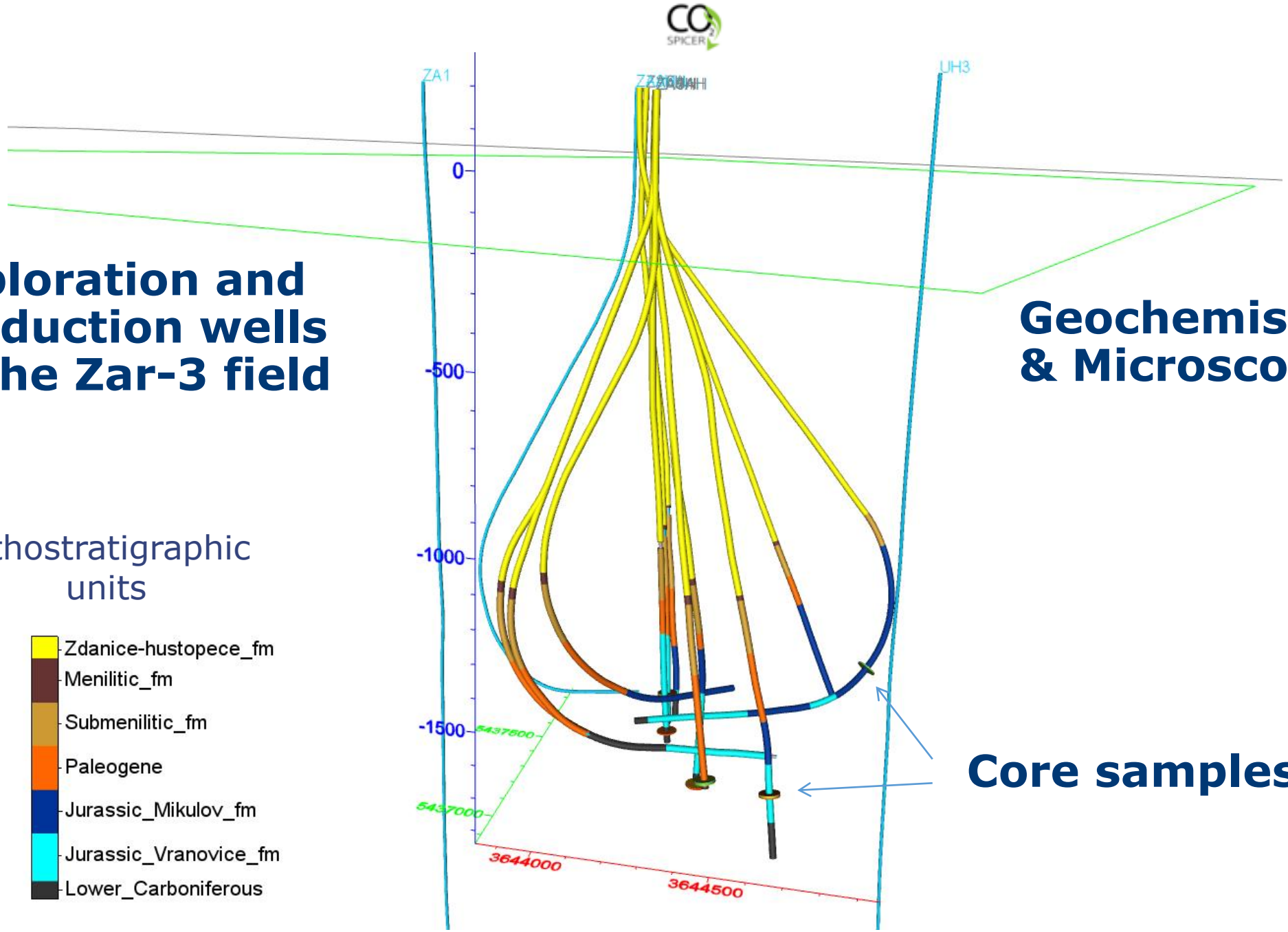
Paleogene

3D view of the stratigraphic succession at the Zar-3 site

Secondary Seal 1



Exploration and production wells in the Zar-3 field



Lithostratigraphic units

- Zdanice-hustopece_fm
- Menilitic_fm
- Submenilitic_fm
- Paleogene
- Jurassic_Mikulov_fm
- Jurassic_Vranovice_fm
- Lower_Carboniferous

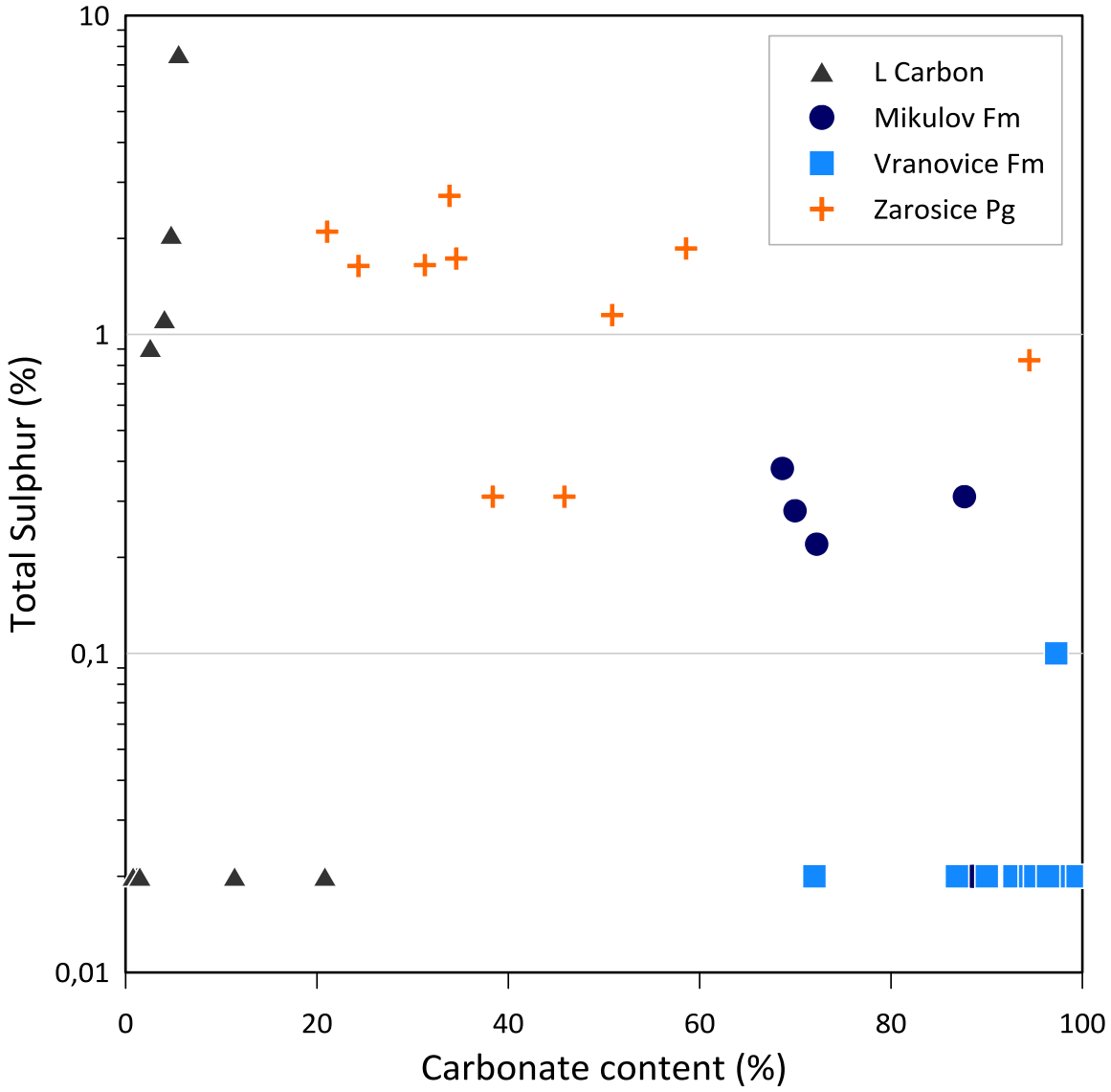
Geochemistry & Microscopy

Core samples

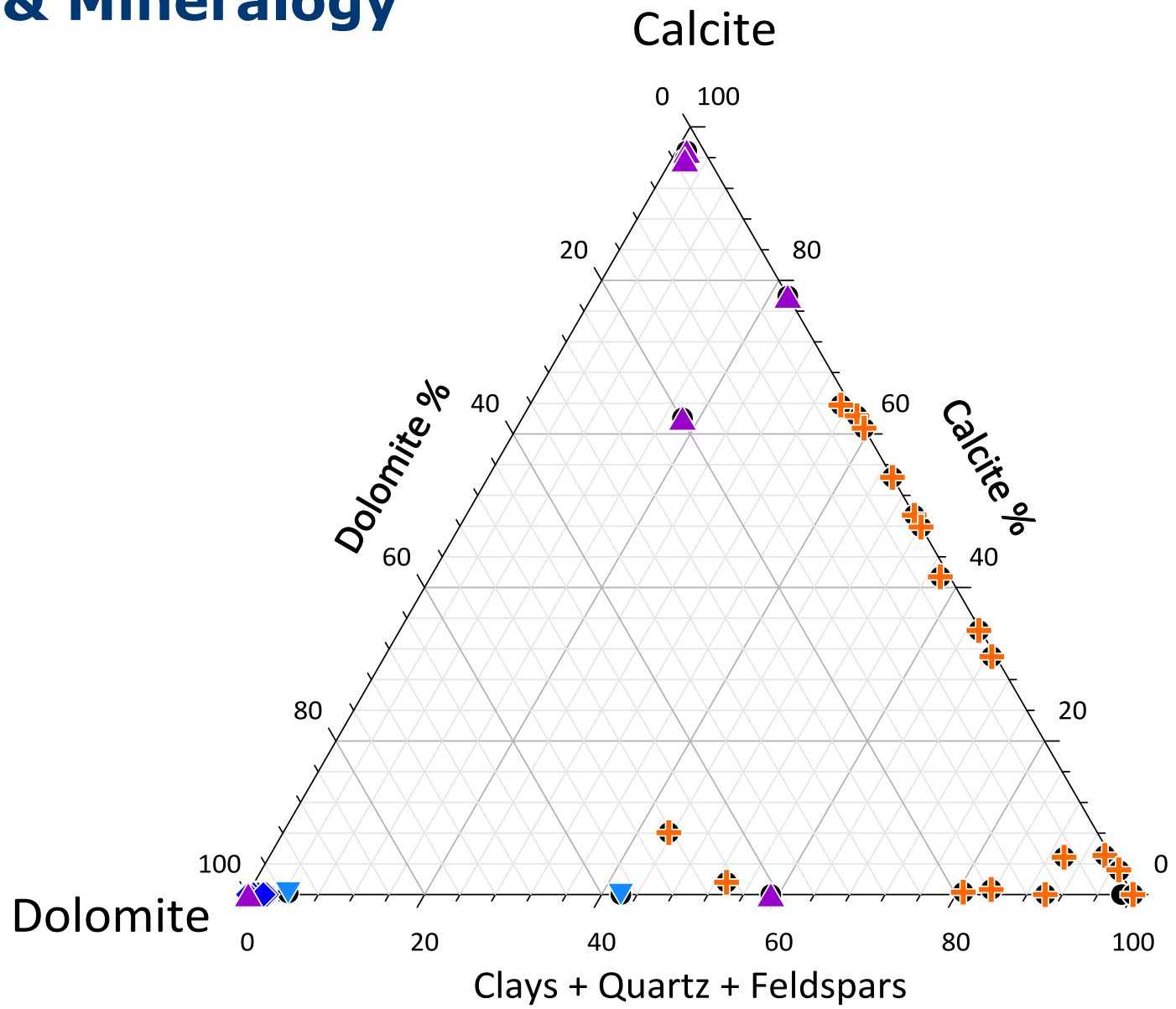
Geochemistry – Elemental analysis of rock samples

Paleogene – seal Žarošice Mb.
tectonic / erosional
Jurassic – seal Mikulov Fm.
conformal
Jurassic – reservoir Vranovice Fm.
tectonic / erosional
Carboniferous – seal Myslejovice Fm.

Reservoir and caprocks form specific geochemical types



WP5 – Geochemistry & Mineralogy

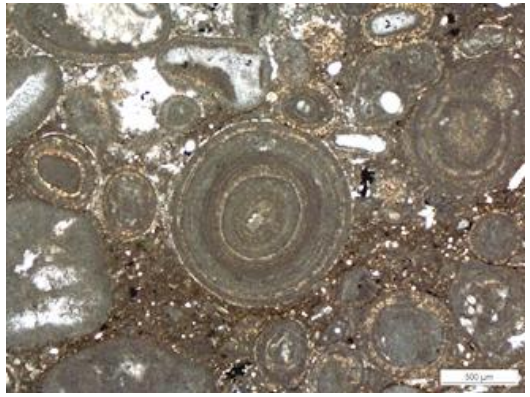


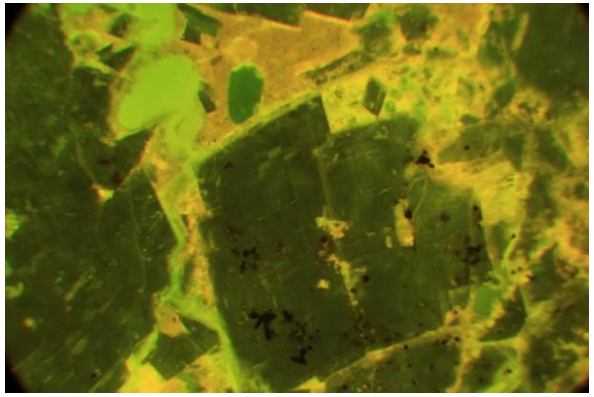
X-ray Diffraction Analysis (XRD)

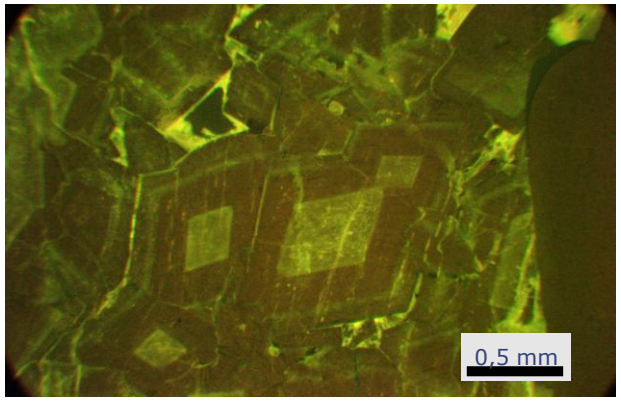
Formation	
+ Pg Zarosice	seal
▲ J3 Mikulov	seal
◆ J3 Vranovice	**reservoir**
▼ J3 Vran-Nikol	**reservoir**
● C1 Myslejovice	seal

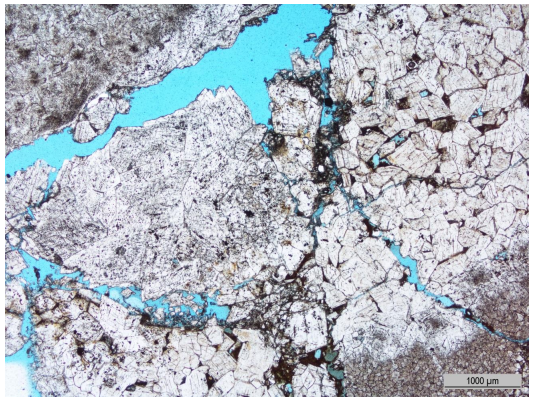
Cl + Q + Fsp

PPL, XPL and Fluorescence Light Microscopy
Image analysis – Optical porosity

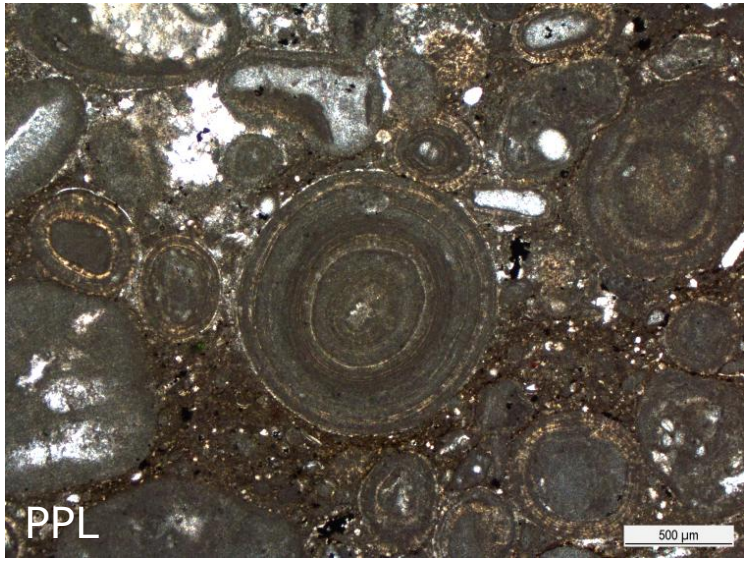


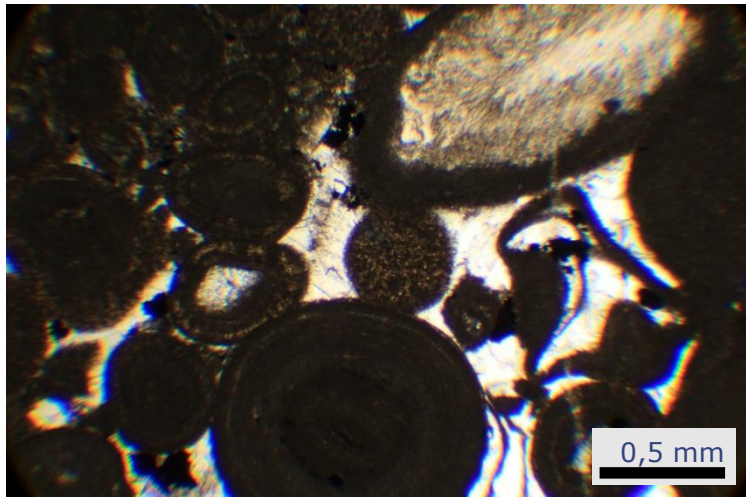




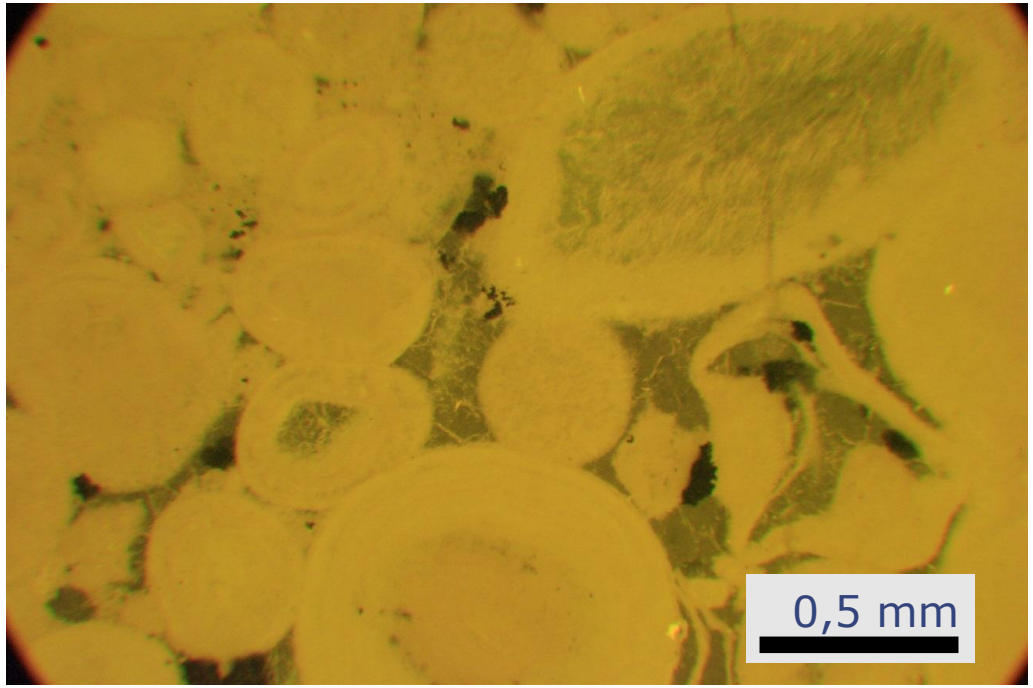


Oolitic limestone impregnated by oil, pressure solution

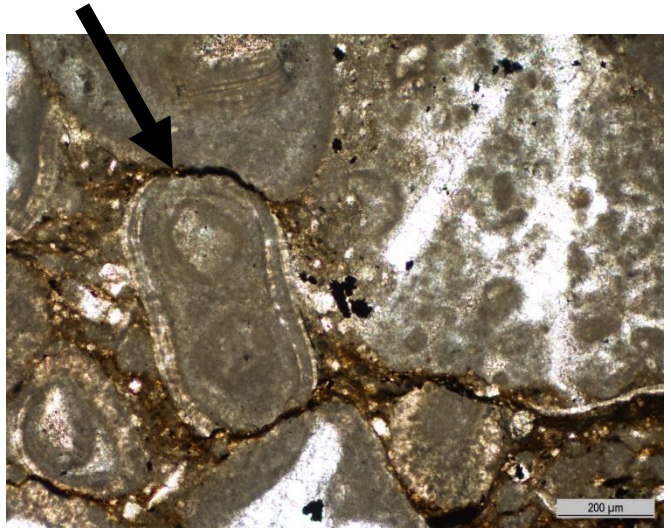




Non-polarized light



Fluorescent light

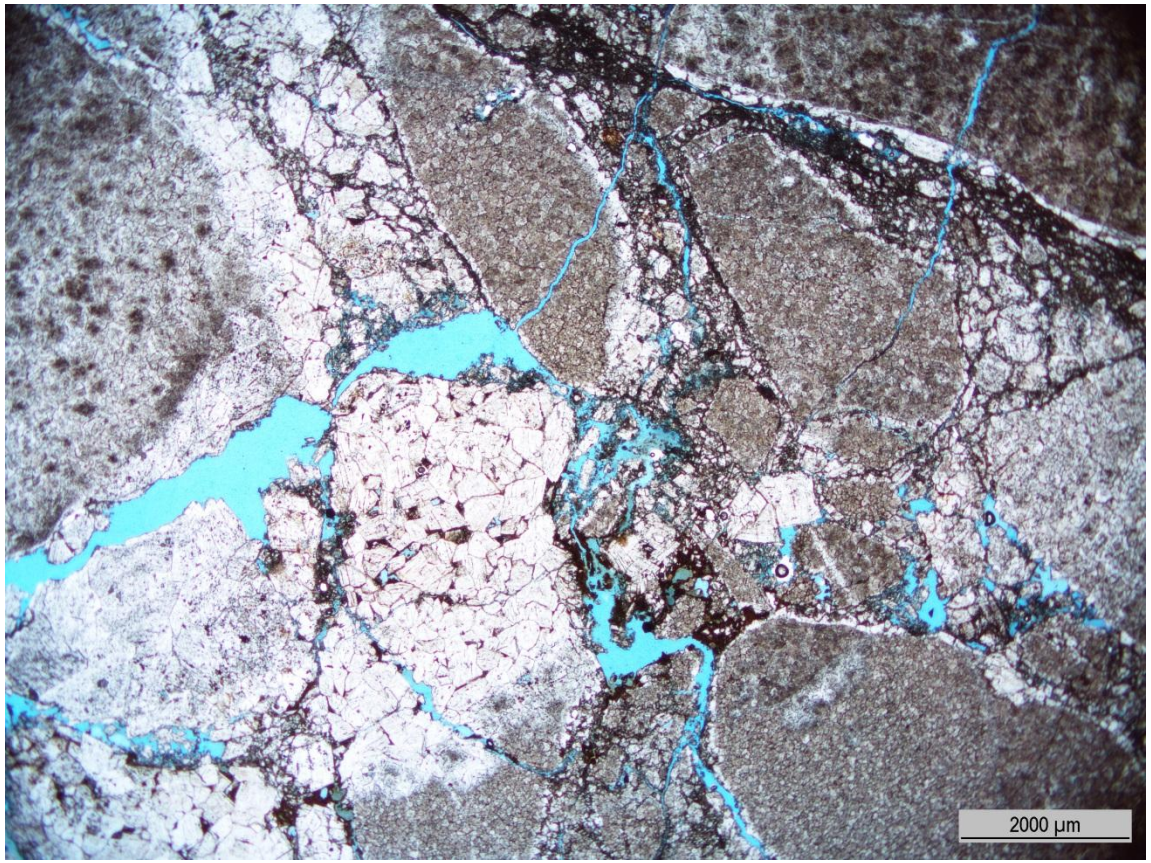


PPL

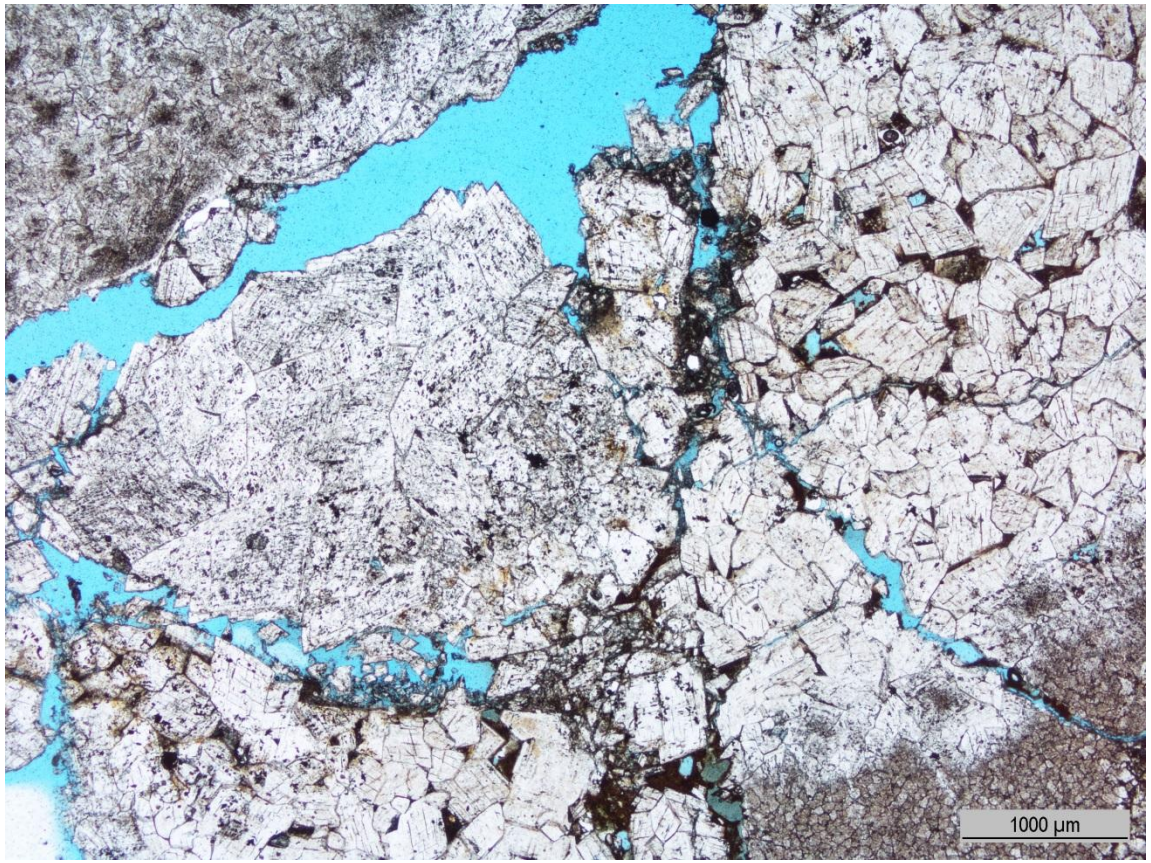
Jurassic,
reservoir – upper part
ZA5H, TVDSS 1467 m

Vuggy & fracture porosity

Blue epoxy resin impregnation of the reservoir rock



PPL

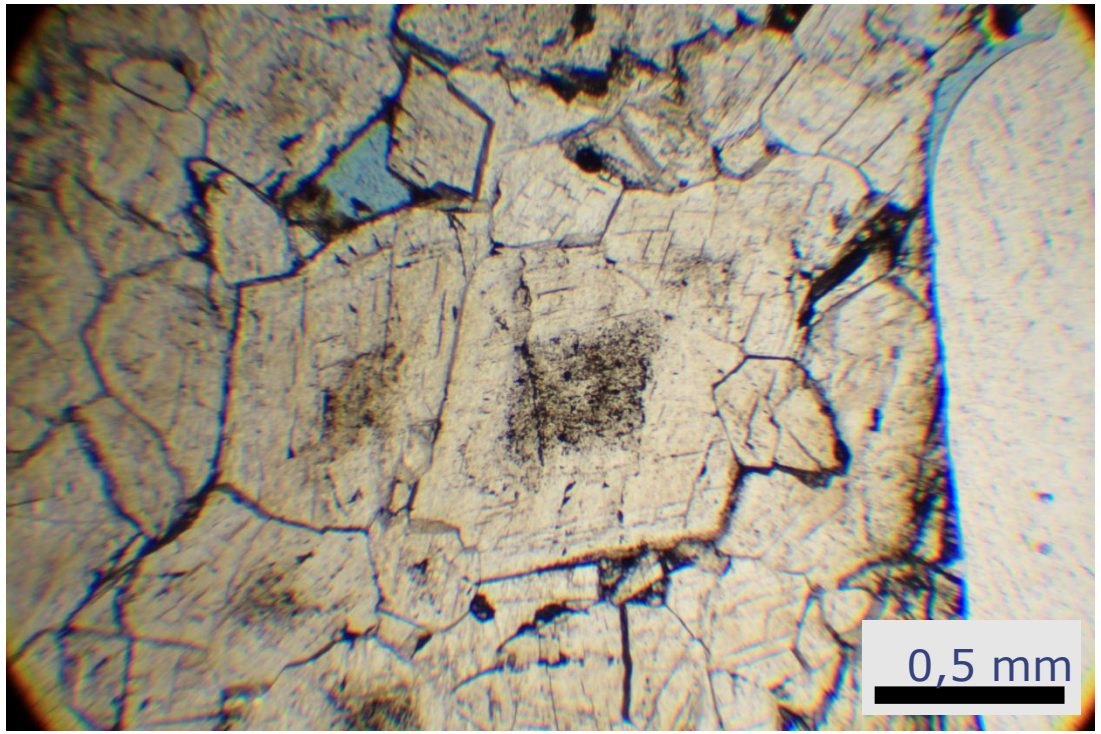


PPL

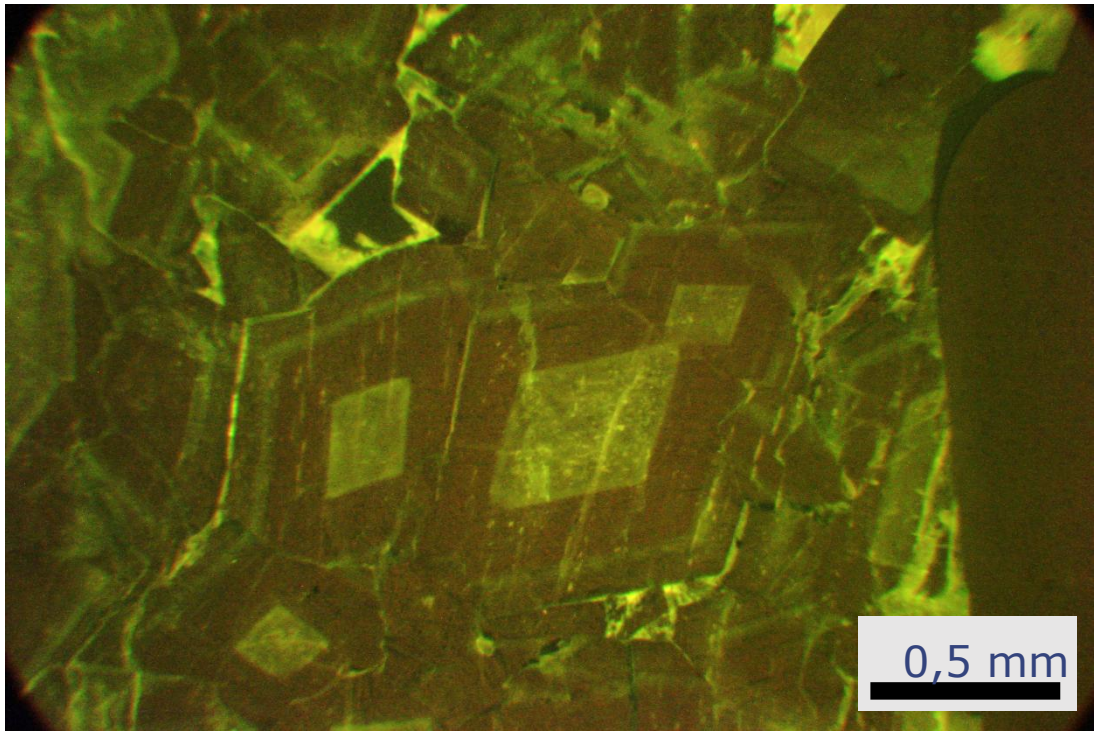
U. Jurassic, Vranovice Fm., ZA4A, TVDSS 1507 m

Zonal crystals of dolomite

Change in chemistry evidenced by dark and light green fluorescence



Translucent light

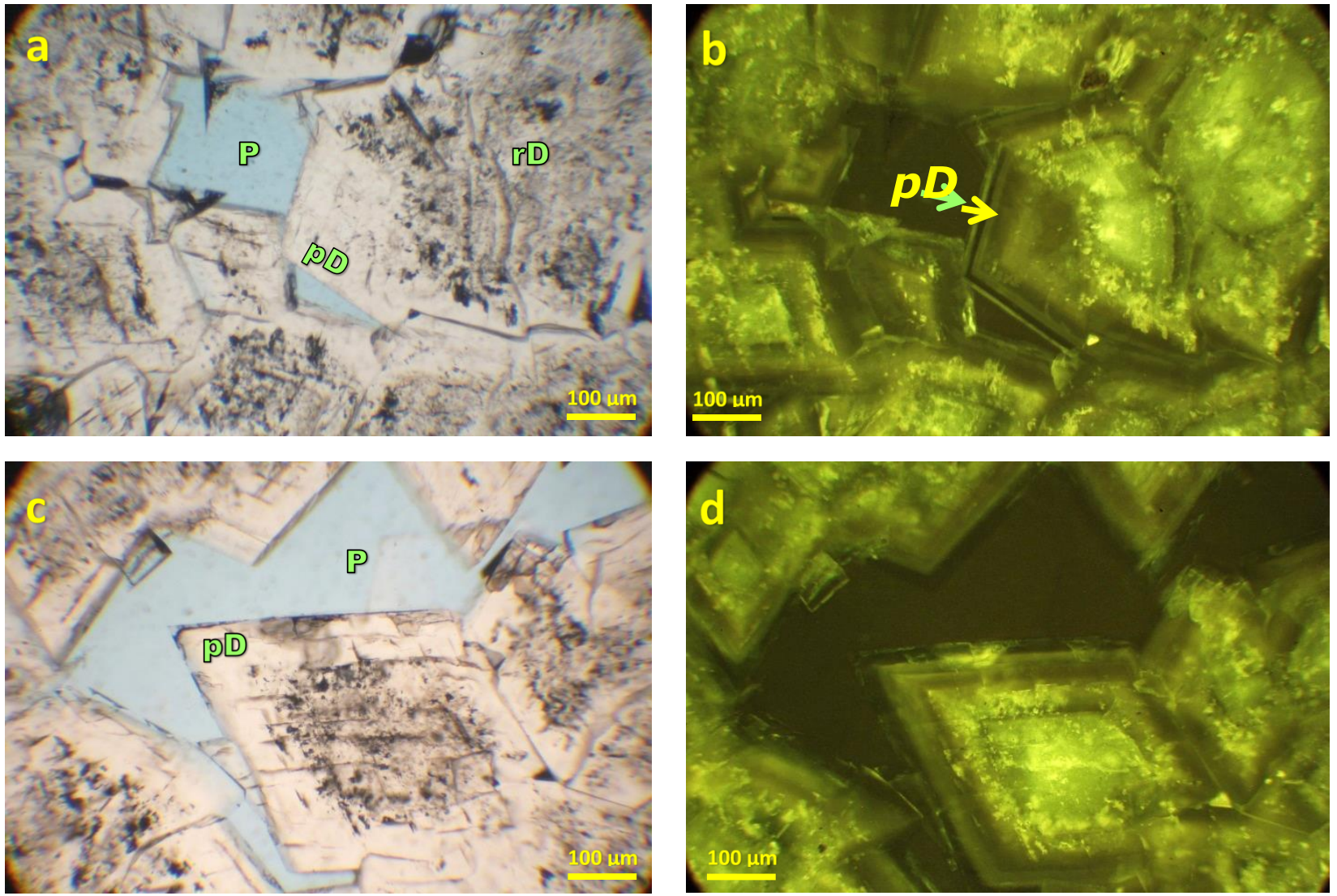


Fluorescence

U. Jurassic, Vranovice Fm., ZA4A, TVDSS 1523 m

Vranovice Fm. – Dolomitic limestones

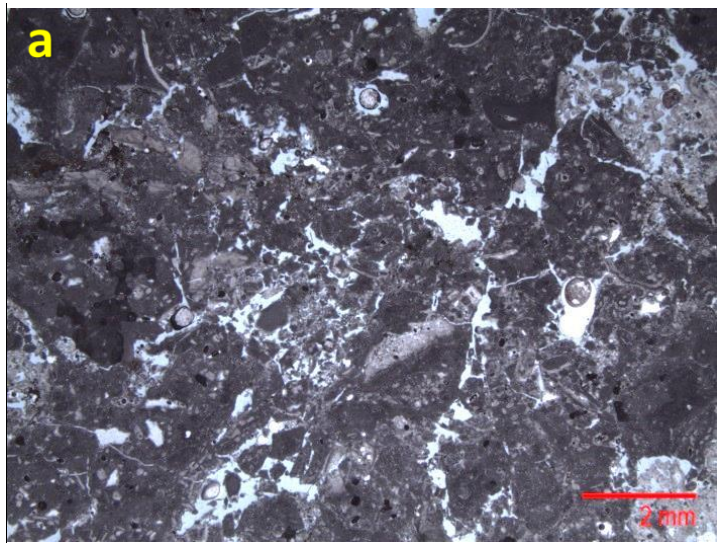
PPL **Fluo**

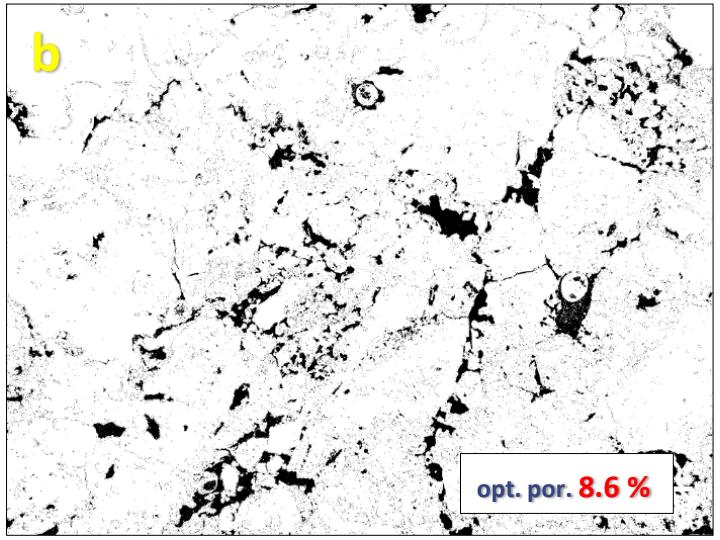


P – free pore space *filled with blue epoxy resin ,*
rD – replacement dolomite

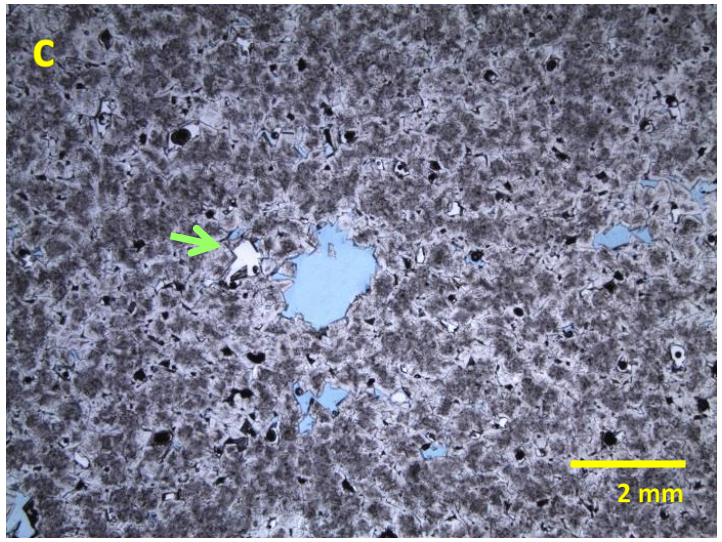
pD – pore-lining dolomite *(arrow in fluorescence light)*

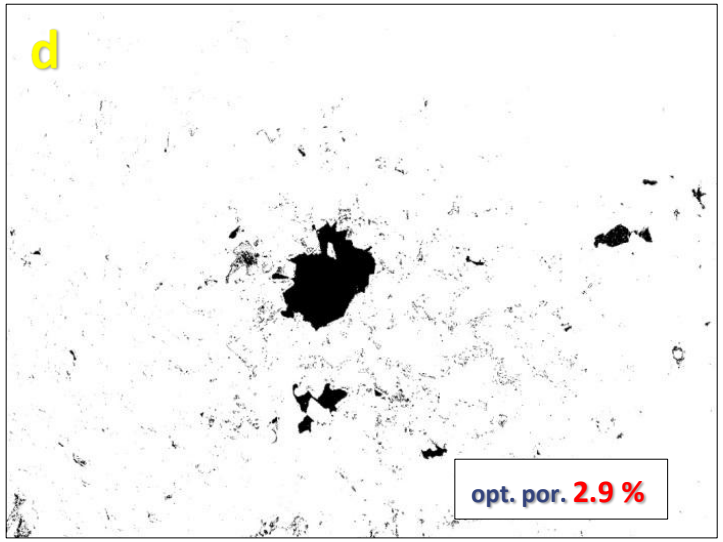
Optical porosity estimated by image analysis of color-coded pore space





altered peloidal-bioclastic wackestone with fracture porosity

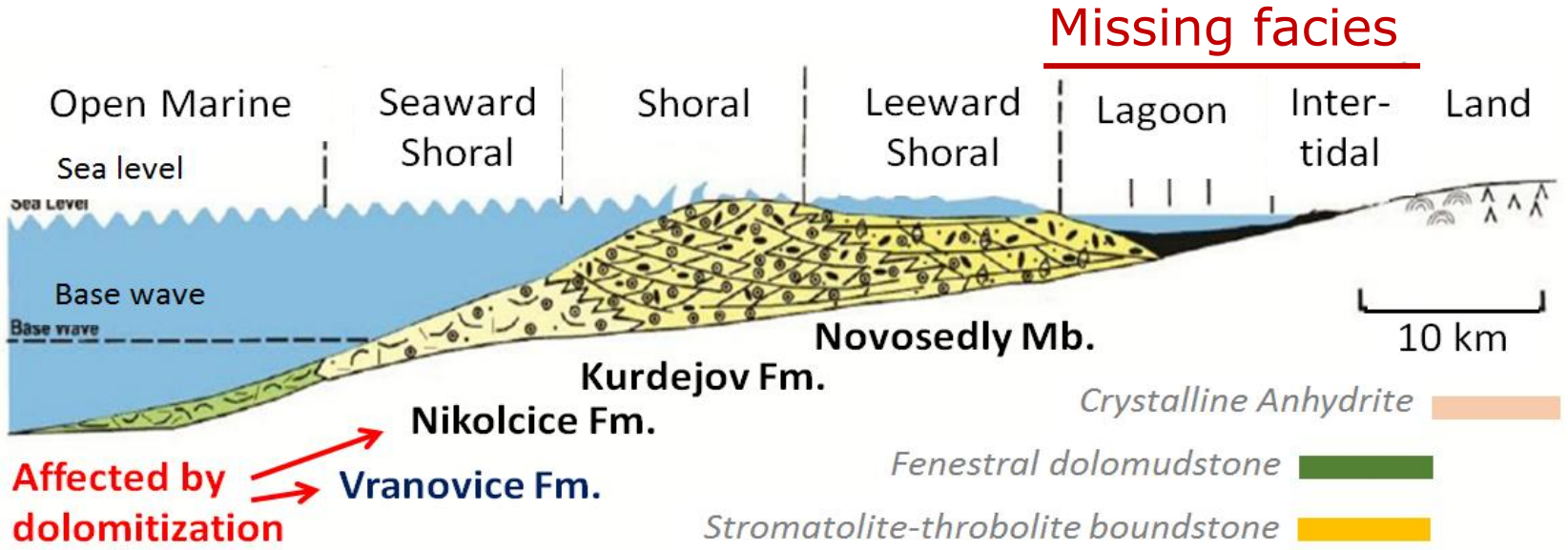




polymodal planar-s dolomite with cavernous porosity

Reservoir - Vranovice Fm.

Carbonate Depositional Environments & Lithofacies



Crystalline Anhydrite

Fenestral dolomudstone

Stromatolite-thrombolite boundstone

Evaporite nodule bearing dolomudstone

Pelloid bioclast wackestone

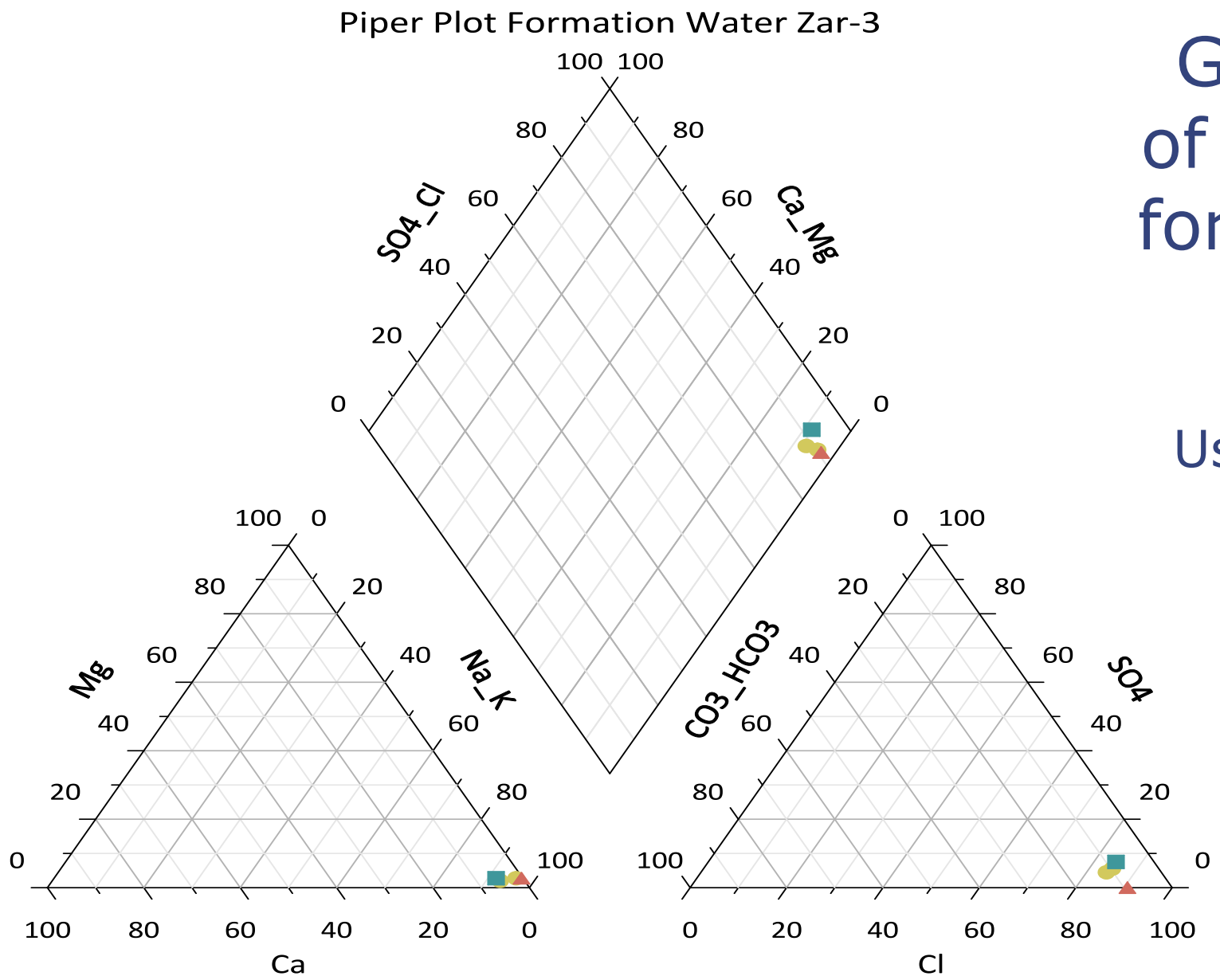
Fine grained allochemical packstone/grainstone

Ooid grainstone to dolograinstone

Coarse grained allochem. packstone/grainstone

Fossiliferous wackestone/mudstone

General scheme modified from Dunham (1962), Wilson (1975) and Nosrati et al. (2019)

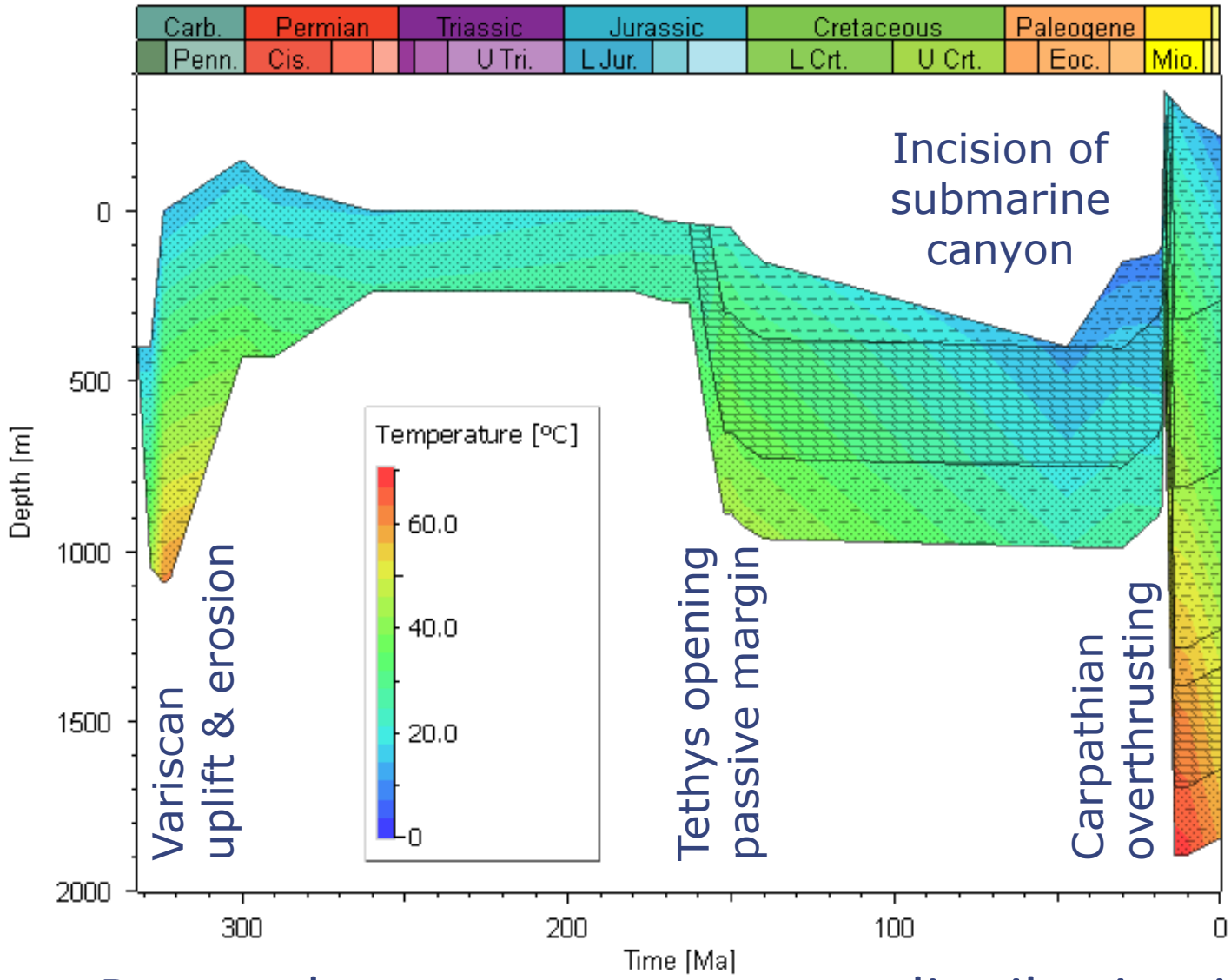


Geochemistry of the produced formation water

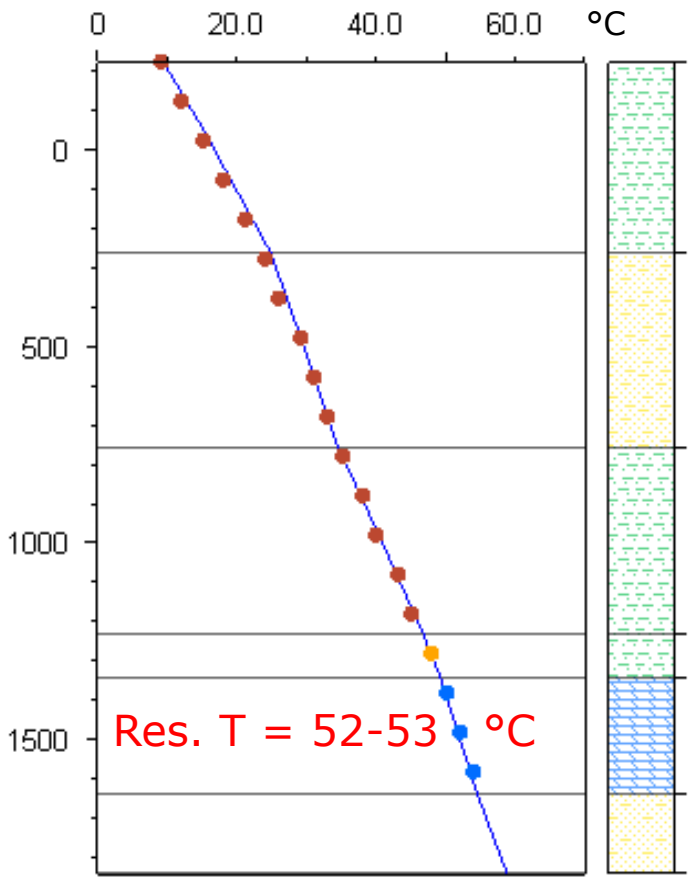
Used in geochemical CO2–water–rock modeling

NaCl type

Burial and thermal history ZA-3



Present day temperature



PSE

Zdanice Nappe seal

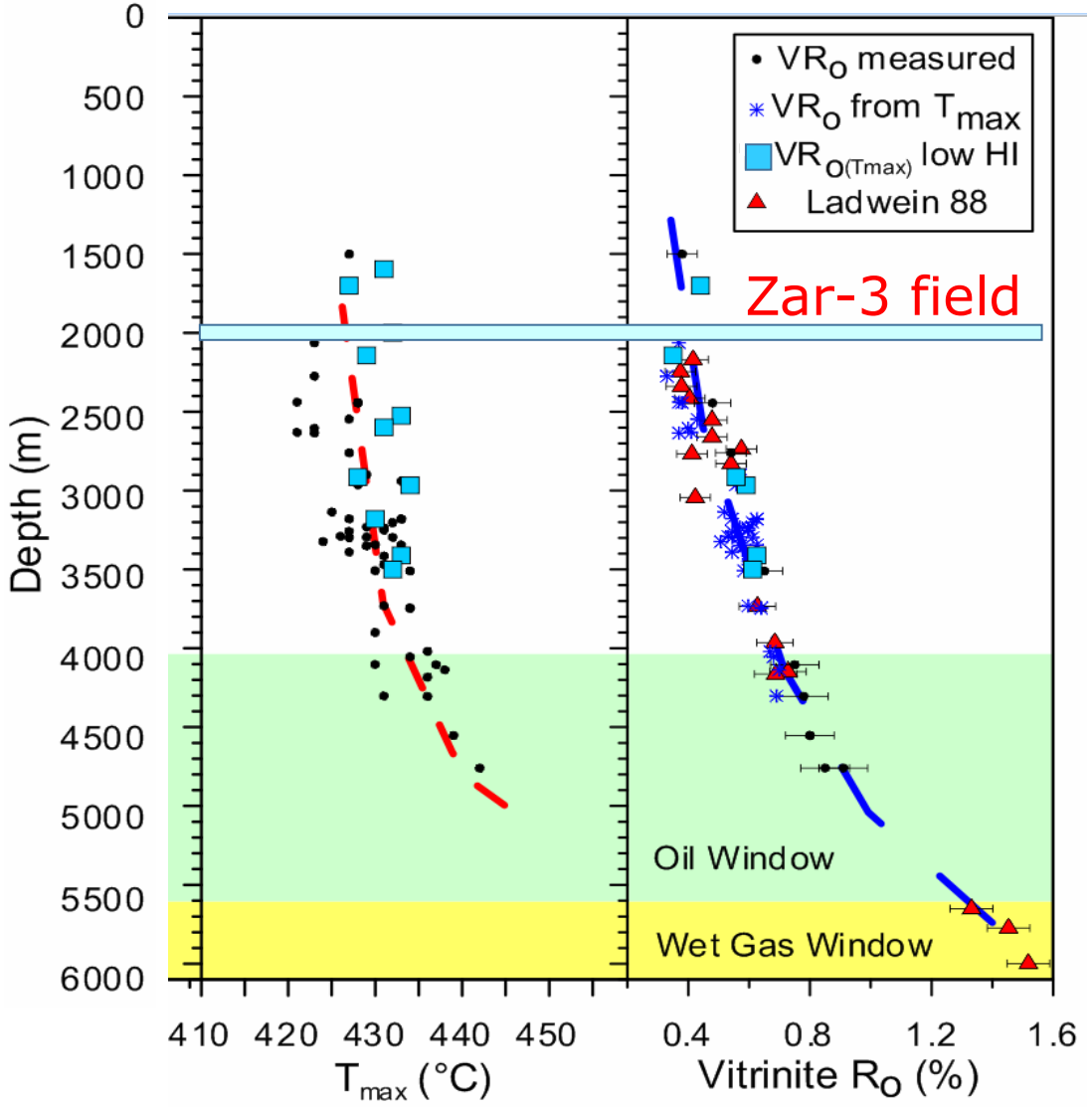
Nesvac seal

Vran reservoir

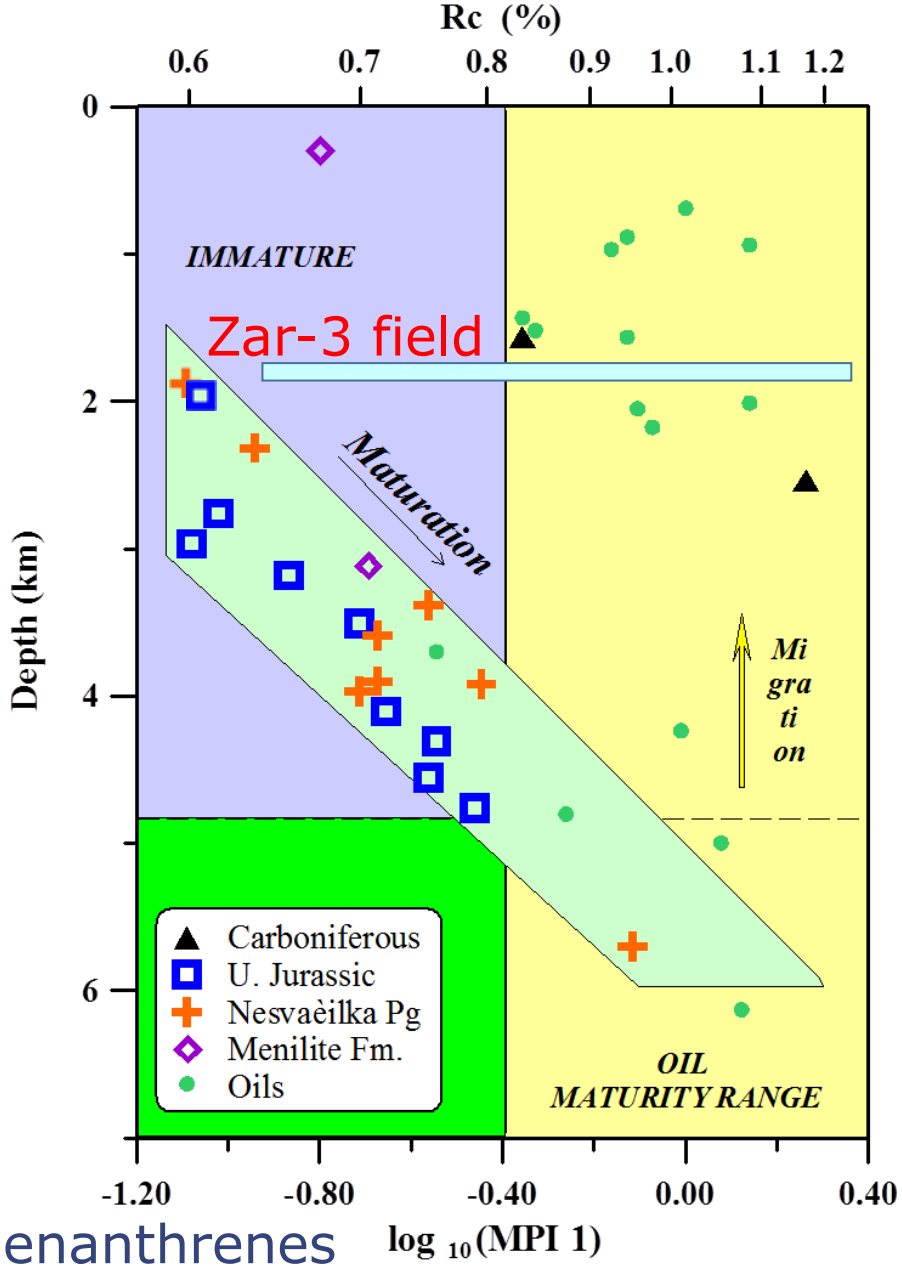
Myslej seal

Past and current temperature distribution in the subsurface

Thermal maturity of source rocks used for model calibration based on Rock-Eval Tmax, VRo and biomarkers



Jurassic and Paleogene source rocks show similar trends and are much less mature than oils down to 4-5 km



Methyl-phenanthrenes

Numerical modeling of CO_2–water–rock interactions

Aims

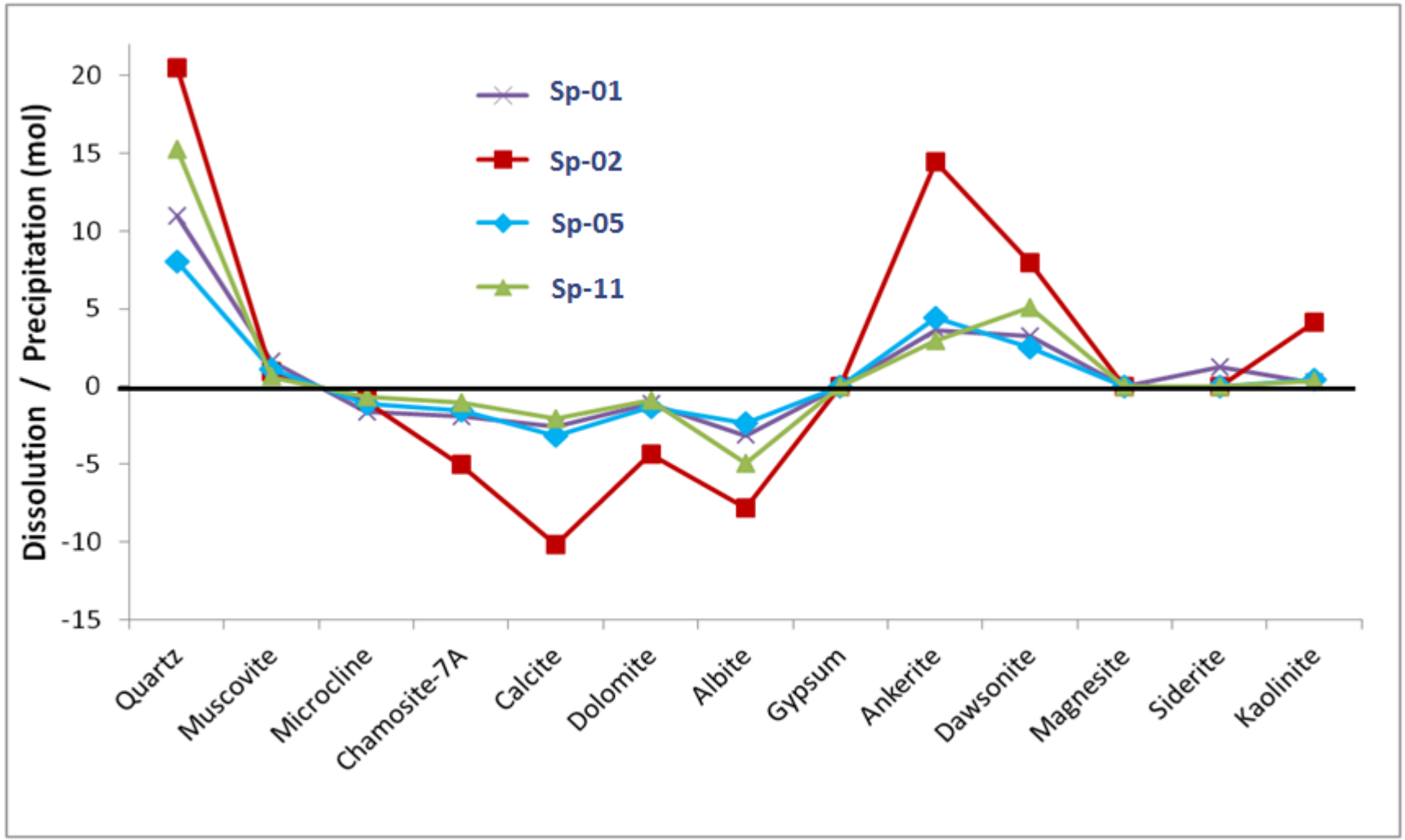
1. Prediction and understanding the changes in primary **reservoir** and **cap rock matrices** (silicate/carbonate)
2. Predicting mineral **neoformations**.
3. Identification of phases capable of mineral **CO2 trapping**

Input parameters

1. Mineralogical composition of rocks and porosity data
2. Formation water chemical composition
3. Temperature 51,53 – 53,43 °C, **Pressure** 17,59 – 12,47 MPa
4. Temperature of stored supercritical CO2 - Cooling effect in reservoir
5. Relevant equilibrium and kinetic data to parametrize the model

Predicted CO_2 – Water – Rock Interactions

Equilibrium model



Dissolution:
- microcline
- albite
- chlorite-chamosite
- calcite
- dolomite

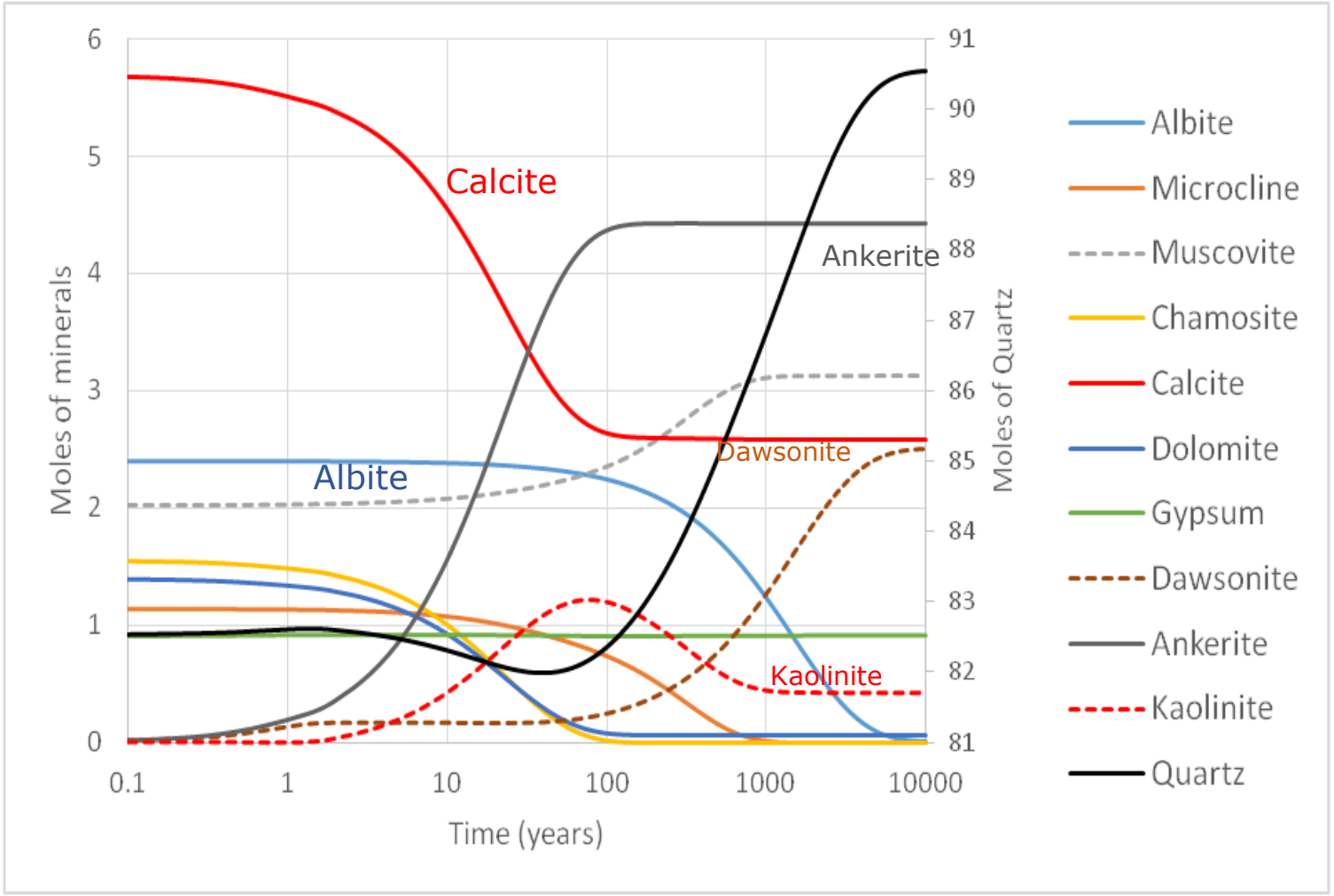
Precipitation:
- quartz
- muscovite
- ankerite
- dawsonite
- kaolinite

Predicted CO_2 – Water – Rock Interactions

Kinetic model of the caprock

CO_2 injection and acidification lead to:

- Dissolution of primary carbonates (calcite, dolomite)
- Complete dissolution of feldspars
- CO_2-trapping phases:
  ankerite
  $Ca(Fe,Mn,Mg)(CO_3)_2$
  dawsonite
  $NaAl(CO_3)(OH)_2$



Conclusions

- Mid term results of the CCS pilot project provide details on the
  - improved geometry of the oil field
  - chemistry and mineralogy of the reservoir and caprocks.
- PetroMod shows the burial and thermal history related to the rock properties.
- Equilibrium and kinetic modeling predicts a series of dissolution and precipitation reactions following the injection of CO_2 into the reservoir.
- Next phase modeling aims to extend the reaction simulations to the 3D space.
- Primary importance: storage integrity, seal efficiency, and safety.

Acknowledgements

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PROJECT PARTNERS

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NORCE

Norway grants

Programme Kappa

TA ČR


Thank you
for your attention