Formation Water Characterization of the Shale Reservoir Rocks Using Integrated Workflow

Ekaterina S. Kazak[1,2], F. Bilek[3], A. V. Kazak[2]

[1] Lomonosov Moscow State University
[2] Skolkovo Institution of Science and Technology
[3] GFI Grundwasser-Consulting-Institut GmbH Dresden, Dresden, Germany

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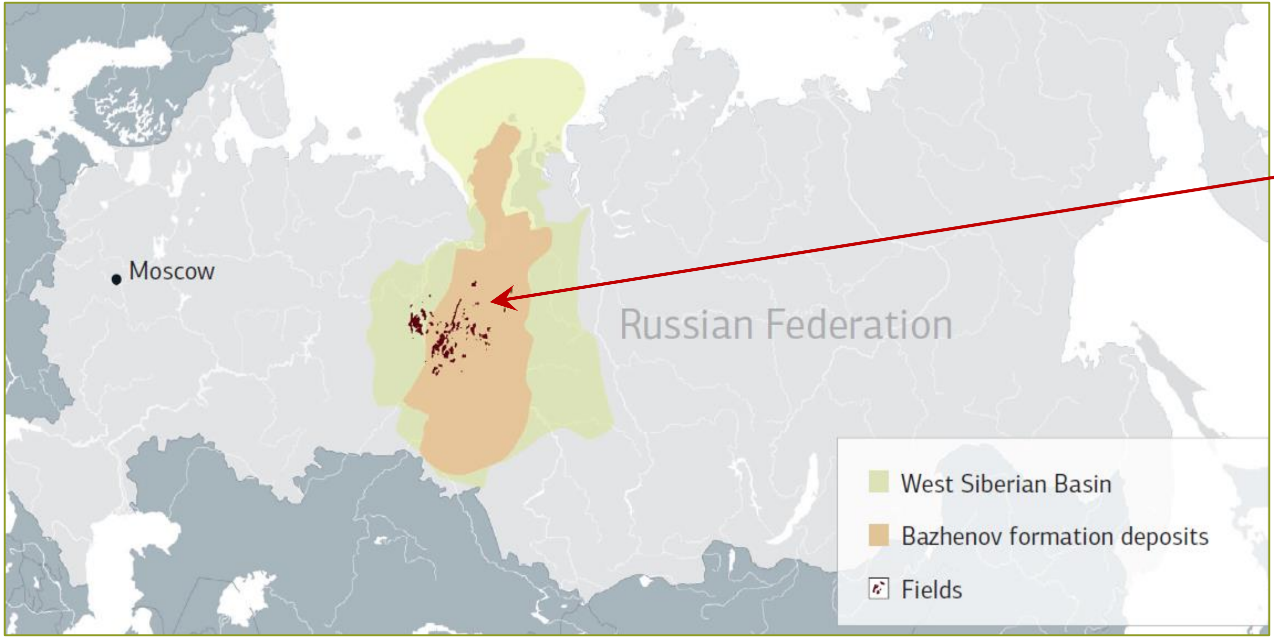
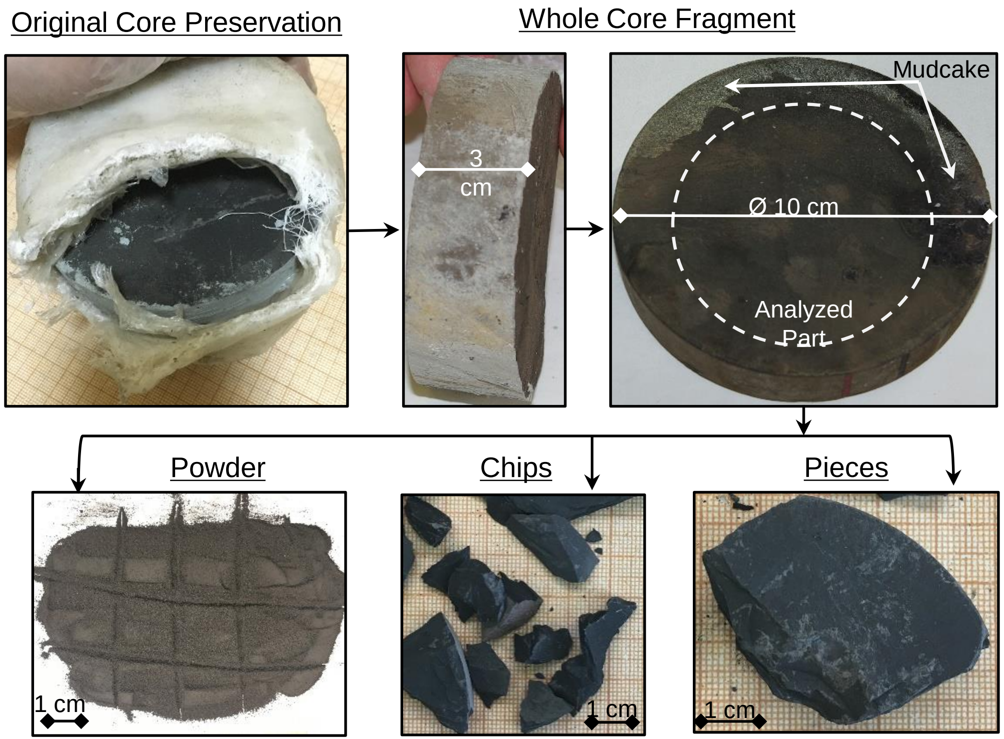
Sample Material



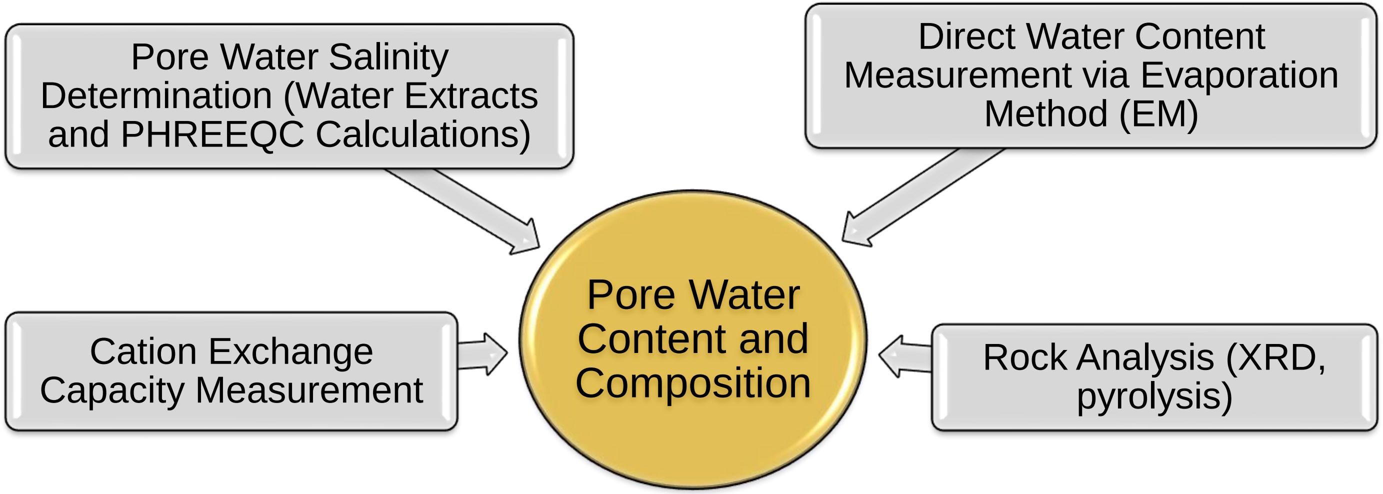
- Whole core samples of Bazhenov Formation (BF) (Ø 80÷100 mm) from 5 wells drilled in 5 various oil fields located in the West Siberia (Russia).
- The distance between the wells ranges from 80 km to 500 km.
- The coring has been performed within an interval of the BF at a depth of more than 2.5 km.

Sample Preparation



- Each whole core fragment was preserved from exposure to the environment after opening the core barrel and fragment cutting using polymer (Saran) film and then paraffin-soaked gauze.
- A rock sample preparation procedure consists of 4 steps: 1) releasing from paraffin sealing shells; 2) crushing 3) weighting the fraction on an analytical balance; 4) distributing according to the requirements and testing.
- To avoid drilling mud contamination all rock materials were collected from the central part of the core axis.

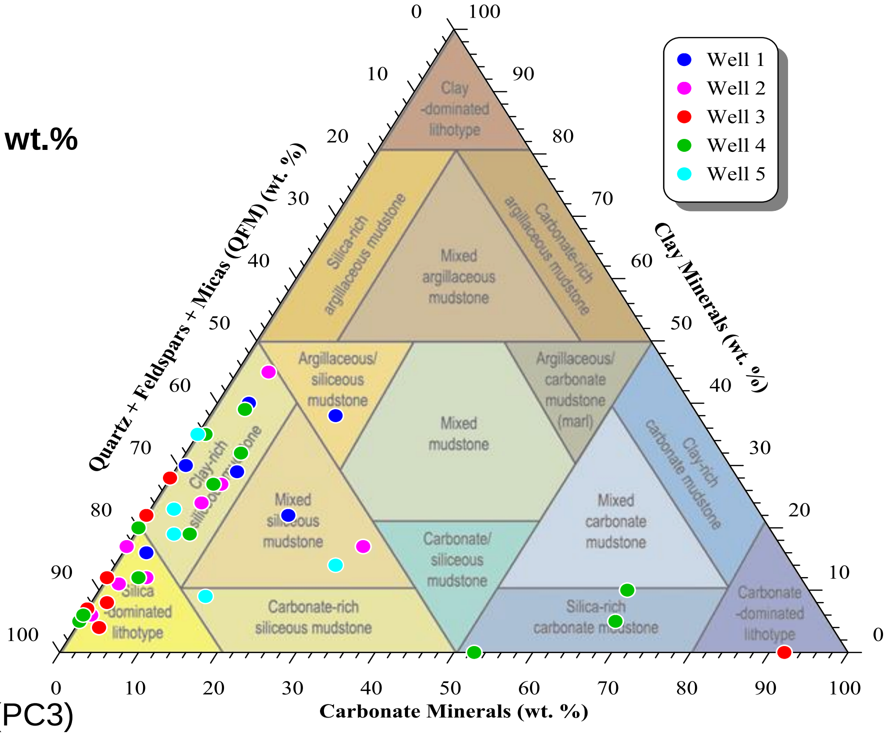
Experimental Methods



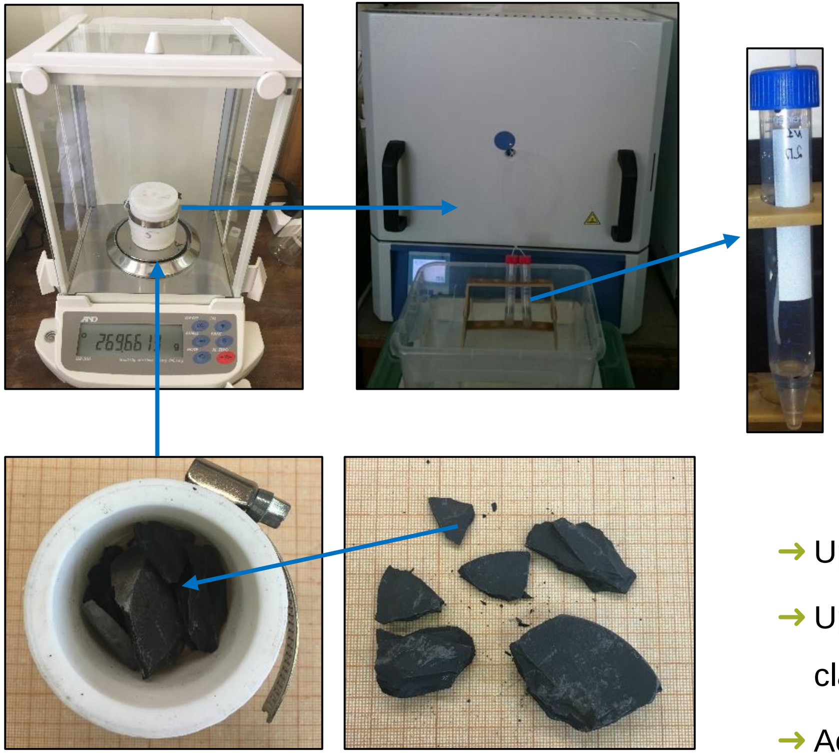
- → The accurate values of residual pore water content and salinity as a parameter for the organo-mineral model and the interpretation of geophysical data.
- → Proper resource evaluation and certainty estimation of hydrocarbon reserves for shale oil fields

Mineral Composition, Geochemistry and Rock Typing

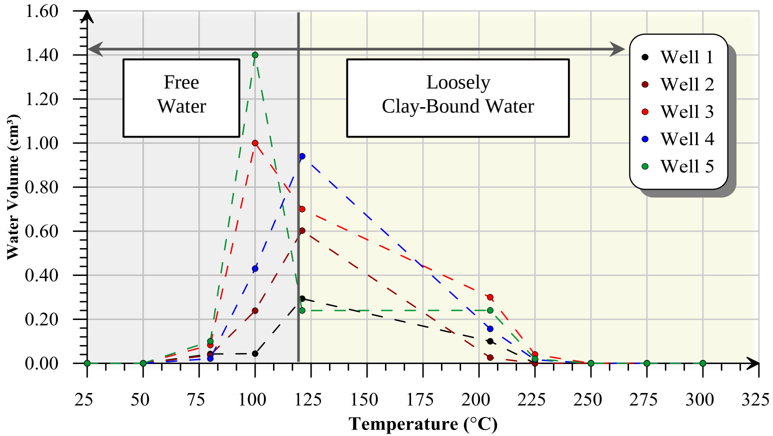
- → Gross Mineral Composition
  - → silica **up to 86 wt.%**
  - → clays (mixed-layer minerals, hydromica, kaolinite) **up to 45 wt.%**
  - → carbonate minerals
  - → remains: plagioclase, pyrite etc.
  - → No smectite or montmorillonite
- → Geochemistry
  - → TOC 1÷28 wt.%
  - → S_1 0.9÷9.22 mg HC/g rock
  - → S_2 6.37÷229.67 mg HC/g rock
  - → T_{max} 428÷437°C
- → gradual variation regarding catagenesis stage or kerogen
- → thermal maturity: from protocatagenesis or immature kerogen (PC3) to metacatagenesis or main oil window (MC3)



Direct Water Content Measurement via Evaporation Method (EM)



High-Resolution EM Study



- → Up to 121° C — free water release
- → Up to 250° C — residual water (total content of the free and loosely clay-bound water) release
- → Accuracy of the Evaporation Method is 0.2÷6.8 rel.%

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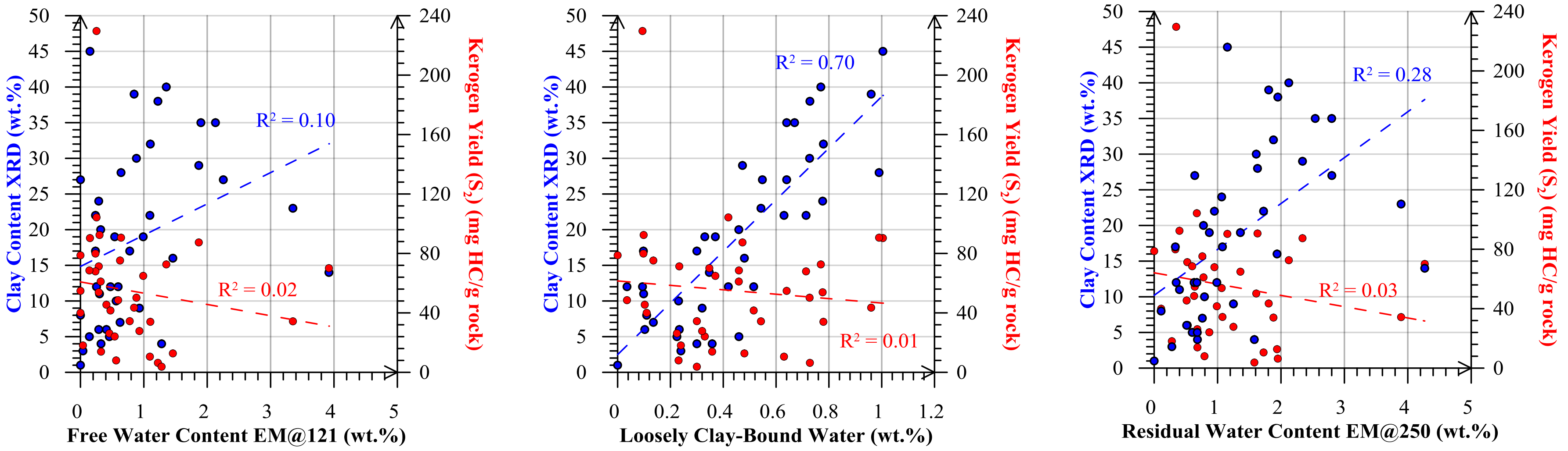
EM Water Content versus Clay Mineral Content and Pyrolysis S_2

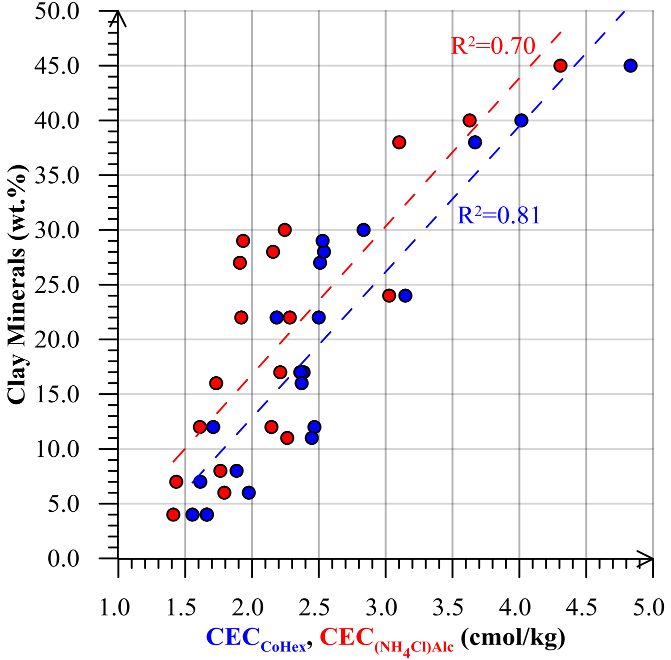


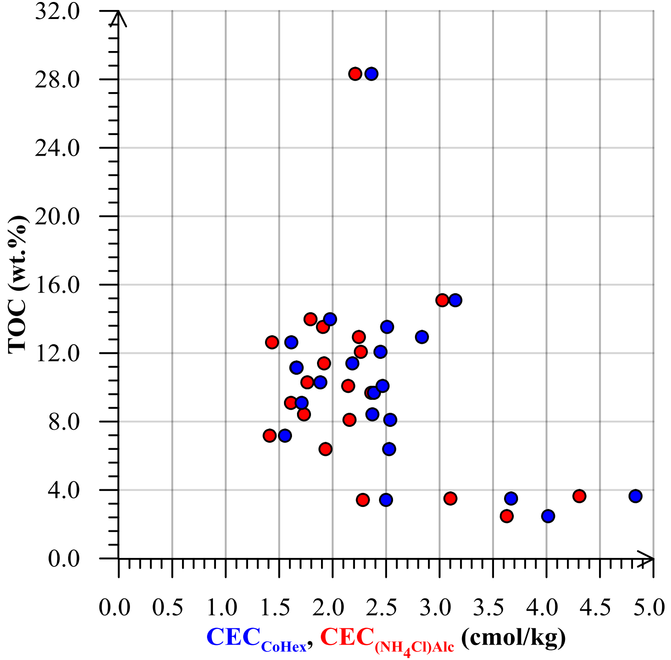
→ The target rock samples contain the residual formation water 0.11÷4.27 wt.%, including free 0.04÷3.92 wt.% and loosely clay-bound water 0.09÷0.96 wt.%.

→ The free water content, does not depend on the rock mineral composition and kerogen content.

→ The loosely bound water content correlates well to the clay mineral fraction.

Cation Exchange Capacity (CEC) Measurement





- → 2 methods of cation exchange capacity (CEC) measurement were used — alcoholic NH_4Cl $(NH_4Cl)Alc$ and hexaamminecobalt(III) chloride (CoHex).
- → Both CEC methods delivered consistent results.
- → CEC depends on the clay content.

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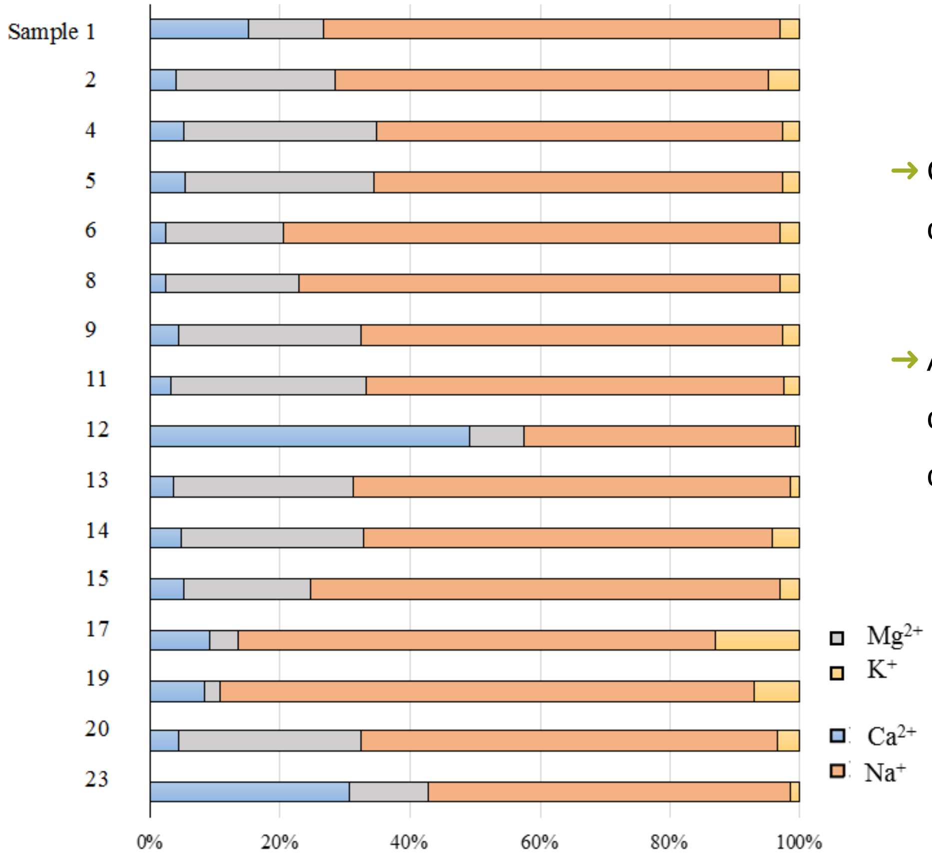
Cation Exchange Composition

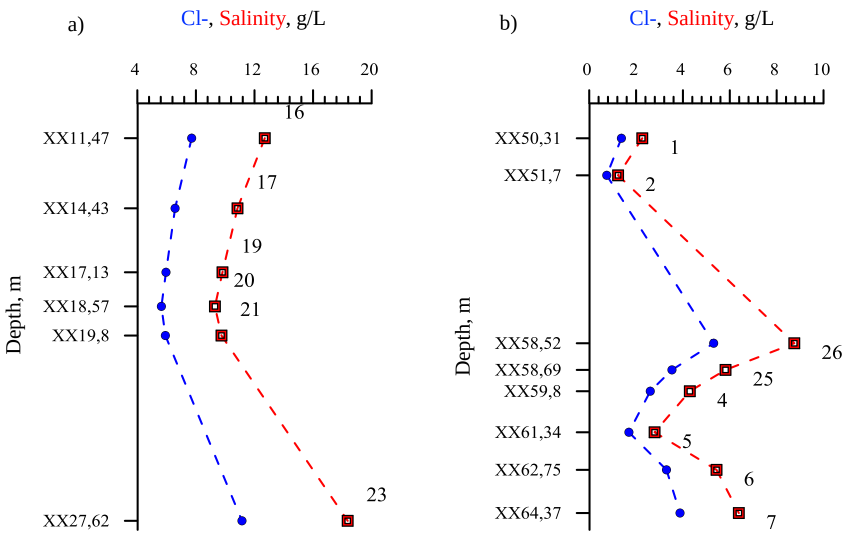


- Ca, Na, Mg, K form the exchange complex of all studied core samples.
- According to interrelation (rNa+rK)>rCa, the exchange complex type is marine and was inherited from the composition of the paleobasin seawater (Bazhevov sea).

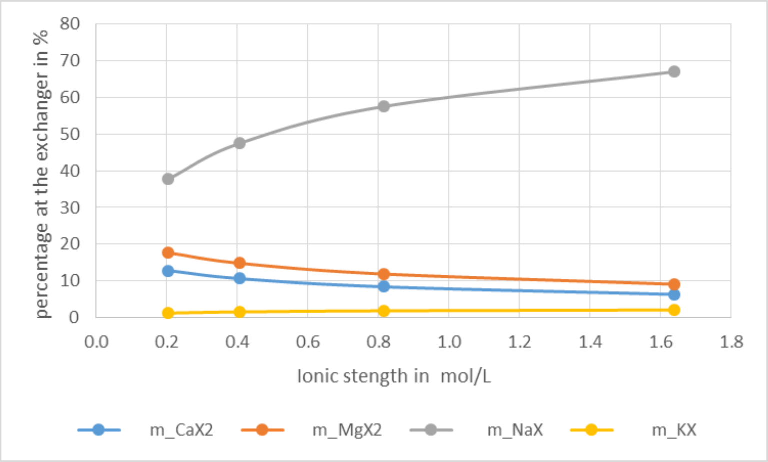
Pore Water Composition

→ Using the thermodynamic calculations with PHREEQC, the ratio of cations in pore water was estimated - Na (up to 91%), Mg (up to 5.6%), Ca (up to 2.6 %) and K (up to 0.8%).

Pore Water Salinity
for BF rock samples from Well 1 (a) and Well 2 (b)



Cation Exchange composition versus ionic strength



→ The water extracts analysis shows that the pore water salinity as NaCl is 1.23÷21.96 g/L.

→ The δ^2H (-64.5÷-63.8 ‰), $\delta^{18}O$ (-2.0÷1.4 ‰) are in a good agreement with typical values for formation waters and brines associated with petroleum systems reported for many sedimentary basins.

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Conclusions

1) The target rock samples contain the residual formation water (0.11÷4.27 wt.%), including free 0.04÷3.92 wt.% and loosely clay-bound water 0.09÷0.96 wt.%. The loosely bound water content correlates well to the clay mineral fraction. The amount of chemically bound water fell in a range of 0÷6.40 wt.% and exceeds that of free and loosely bound water.
2) CEC varies from 2.87 to 5.82 meq/kg by (NH_4Cl)Alc method and from 2.87 to 6.38 cmol/kg by CoHex method. Both methods could be used for CEC determination in BF rocks. CEC depends on the clay content.
3) Na^+ is a dominant cation in the exchange complex of all investigated samples, which means that all of them belong to the marine type.
4) The pore water of BF rocks has mainly Na-Cl composition and salinity 1.23÷21.96 g/L.
5) The presented research sheds more light on the presence and distribution of the free and loosely clay-bound water and pore water composition in the reservoir rocks of the Bazhenov formation.

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References on the Topic

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A novel laboratory method for reliable water content determination of shale reservoir rocks

Ekaterina S. Kazak (Ph.D.)[a,b,*], Andrey V. Kazak (Ph.D.)[b]

[a] Faculty of Geology, Lomonosov Moscow State University, GSP-1, Leninskie Gory, Moscow, 119991, Russia
[b] Skolkovo Institute of Science and Technology (Skoltech), Sikorskogo 11, Moscow, 121205, Russia

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