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Formation Water Characterization of the Shale Reservoir Rocks Using Integrated Workflow

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The paper presents the results of a novel integrated solution of formation water content and salinity determination of the low permeability reservoir rock of Bazhenov formation (West Siberia, Russia) for petrophysical characterization. The workflow is based on three techniques: evaporation method (EM) with isotopic composition analysis, analysis of water extracts, and cation exchange capacity (CEC) study. The EM offers a fast, efficient, and accurate measurement of the residual water content with breakdown to free and loosely clay-bound types. The isotopic composition reveals the origin and genesis of pore water. The chemical analysis of water extracts delivers a lower bound salinity in terms of NaCl. CEC describes rock-fluid interactions. The two methods of cation exchange capacity (CEC) measurement were applied – alcoholic NH_4Cl ((NH_4Cl)Alc) and hexammnninecobalt(III) chloride (CoHex) method. Both showed similar results. 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 and depends on the clay content. Ca, Na, Mg, K form 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.

The target rock samples contained 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.

We found that water extract composition depends on the core mineral content, except chlorine and bromine, which originates from the pore water. Using the thermodynamic modelling in PHREEQC program, next ratio of cations in pore water was found - Na (up to 91%), Mg (up to 5.6%), Ca (up to 2.6 %) and K (up to 0.8%). According to the calculation using the water extracts results, the pore water salinity as NaCl changes from 1.23 to 21.96 g/L. The corresponding isotopic composition indicated the deep formation genesis and generally correlated to that of the deep stratal waters of the West Siberia. Isotopic composition proved the formation origin of extracted pore water samples.

The study made a qualitative step up towards the quantitative characterization of formation water in shale reservoir rocks with the initial water content of less than 1 wt.%.

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