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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Tagir Karamov

PhD Program: Petroleum Engineering

Title of Thesis: Void Space Evolution and Organic Matter Transformation of Bazhenov Formation Rocks During High Temperature Treatment

Supervisor: Professor Mikhail Spasennykh
Co-Supervisor: Professor Yuri Popov

Name of the Reviewer:

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 20-04-2022**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

Mr. Tagir KARAMOV's thesis entitled, "Void Space Evolution and Organic Matter Transformation of Bazhenov Formation Rocks During High Temperature Treatment," is generally well-written and acceptable with some minor editorial changes throughout the text. The thesis research project is aimed at the evaluation and identification of patterns of void space evolution and organic matter transformation during high-temperature treatment of organic-rich shales on the example of Bazhenov Formation rocks.

Accordingly, the study involves a comparison of source rocks, pre- and post-thermal process, which include high-pressure air injection (HPAI) using a combustion tube, pyrolysis in mini-reactors and pyrolysis cells of Rock Eval and pyro-GC-TOFMS. Two principal shale components, mineral matrix and organic matter, are studied in four lithotypes of Bazhenov Formation shales during the above-noted processes. Microstructural transformations of organic matter are studied in detail. A variety of advanced lithological, geochemical, and petrophysical methods are employed to investigate mineral composition changes, organic matter transformations, and associated pore space evolution. Lithological methods included petrology, scanning electron microscopy (SEM), broad ion beam polishing, energy-dispersive X-Ray spectroscopy, X-Ray powder diffraction, and micro-computer tomography. Geochemical methods employed are pyrolysis, two-dimensional gas chromatography with time-of-flight mass spec., and isotope ratio mass spectrometry. The main petrophysical method is thermal property profiling based on optical scanning technique.

The results show significant alterations in the composition and microstructure of shales, which influenced the pore space evolution during the processes. All the components of the mineral matrix are evidently transformed. A specific combination of mineral components in a rock lithotype leads to particular processes, which is exhibited to be beneficial or unfavorable for the void space. Detailed investigation of the organic matter show that microstructural evolution of organic matter is closely associated with thermal maturation and its development related to the process temperature, duration, and rock fabric. In summary, the results of the study imply a better prediction accuracy of high-temperature-based stimulation technologies and their efficiencies. The established, high quality data will contribute towards advancing gained knowledge which will help in the development and implementation of advanced technologies for effective hydrocarbon recovery from organic-rich shales.

It is clear that Tagir has carried out a lot of original work which provides significant insights into the complexities and challenges associated with development and efficient production of hydrocarbons from shale reservoirs. I believe that he has made a good use of the existing literature. His thesis, with minor editorial corrections, will be an excellent reference resource for future studies and applications.

Mr. Tagir Karamov's thesis certainly satisfies the thesis requirements of his PhD program. Mr. Karamov has clearly demonstrated his capabilities of performing research work of high caliber. Presented PhD Thesis may be considered as complete qualification for a PhD candidate.

Provisional Recommendation
X *I recommend that the candidate should defend the thesis by means of a formal thesis defense*
☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*
☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*