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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

Name of the Reviewer: Professor S.Stanchits

I confirm the absence of any conflict of interest	**Date: 07-04-2022**

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

In his Ph.D. thesis, Tagir Karamov presented a systematic study on the assessment and patterns recognition of void space evolution and organic matter transformation during high temperature treatment of Bazhenov Formation rocks. There are many technological concepts for extracting oil from black shales, and the most promising of them are based on high-temperature exposure. However, nowadays there is no technology with proven efficiency, because there are many uncertainties related to the void space, mineral matrix, and organic matter, and there is a definite need for research. Therefore, I consider the topic of Tagir's study to be important, and I have found a good correspondence of Ph.D. topic to the scientific and actual content of the thesis. During his Ph.D. study, Tagir performed a series of high-temperature laboratory experiments and comprehensive analysis of the results obtained using a set of advanced lithological, geochemical, and petrophysical methods. A novel approach to determining the thermal properties of kerogen on rock cuttings has been developed and patented, which allows the continuous determination of TOC in shale core samples. Tagir conducted a high-pressure air injection laboratory experiments into the combustion tube, which allowed him to analyze changes in shales at different temperatures related to the mineral matrix and organic matter. He has demonstrated that the evolution of pore space varies in different lithotypes depending on mineral composition, organic matter content and initial porosity. The results of Tagir's study suggest an increase in the prediction ability of high-temperature technology modelling and the efficiency of the application of new technologies.

The thesis is well-written, 171 pages long, contains seven chapters, including a detailed literature review, a description of experimental modeling of the mineral matrix alteration and void space evolution during high temperature treatment, detailed characterization of kerogen microstructural transformation during thermal maturation, summary, conclusions and recommendations.

I have a few questions to Tagir Karamov related to the text of the thesis.

- The thesis contains detailed study of pore space evolution in organic matter. According to the results the precursor of organic pores is "bubble" structures. Have you analyzed the composition of the bubbles? Are they already oil? This is important question, because this particular result contributes to the fundamental understanding of primary, very first oil generation and migration from its source - kerogen.
- According to the results of the chapter devoted to the mineral matrix transformations, there are numerous alterations in mineral matrix during high-temperature treatment. Does these alterations in mineral matrix will influence mechanical properties of shales and why.
- Are the results of PhD study applicable for other rock types (not shales), or even in other mining industries?
- Based on the results of his Ph.D. study, Tagir gave detailed recommendations that allow to select the most appropriate intervals/lithotypes for the application of technology. However, it seems to me that in the "Conclusion" section it would be good to specify – where and how can the results of his Ph.D. study be applied in Industry?

In general, Tagir Karamov has demonstrated the ability to conduct a detailed analysis of the results of laboratory experiments on high-pressure air injection into a combustion tube, revealing changes in shales at different temperatures associated with the mineral matrix and organic matter. The results of his Ph.D. study have been presented at five international conferences and published in seven papers, five of which are in the Q1 ranking journals. I would also like to mention that Tagir is the coauthor of Russian patent for the invention of a new method for determining total content of organic matter in rocks.

Summarizing the above, I believe the candidate is definitely qualified for a PhD degree.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*