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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Anastasia Gabova

PhD Program: Petroleum Engineering

Title of Thesis: Experimental investigations of thermal properties of unconventional hydrocarbon reservoirs at formation temperatures

Supervisor: Professor Yuri Popov
Co-supervisor: Dr. Evgeny Chekhonin

Name of the Reviewer:

I confirm the absence of any conflict of interest Dr. rer nat. habil. Andrea Förster (Alternatively, Reviewer can formulate a possible conflict)	**Date: 22-12-2021**

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

The doctoral thesis is presented with clarity in English language. The style of the thesis is economic without only little repetition and duplication of scientific aims. There is a logical and rational link between the component parts of the thesis. The components consist of Chapter 1 – Introduction (including the statement of the problem addressed in the thesis, goals and objectives of the thesis and the resulting outline of the thesis), Chapter 2 – A literature review and the current state of problems, Chapter 3 – Research methods, Chapter 4 – Experimental results, and Chapter 5 – Conclusion. One essential part of the thesis is the measurement of thermal conductivity as function of temperature on a variety of sedimentary rocks including clays and clayey rocks with different amounts of organic carbon. The measurement of these rocks from unconventional hydrocarbon reservoirs was performed using a standard device (the DTC-300 technique) available on the market. Measurements were made with different sample configuration (thickness, plane roughness) to study the reliability of measuring results due to sample preparation. This is an important research subject as the physical-contact methods are sometimes under debate for their reliability. In this thesis, the logistics of sample preparation for the measurements under elevated temperatures was assisted by the scanning of samples under ambient conditions using the TCS technique. The application of the two techniques (the DTC-300 and the TCS) proved valuable as the rocks of unconventional oil reservoirs are clayey rocks and argillites exposing a high degree of anisotropy. In addition, effects on physical properties by an inhomogeneous distribution of organic matter in the reservoir rocks have been revealed by using the TCS technique, giving insight in the complexity of properties from those rock types. The TCS data also were used to evaluate the effects on the samples during heating. This provided valuable insight into the subsurface alteration of geological formations, which is the occurrence of microcracks and other loss of intergranular contact and thermal resistance. The DTC-300 data show different thermal conductivity decrease in the temperature range between 30°C and 300°C depending on rock type and degree of organic matter content. The findings are compared to those from other sedimentary rock. In this regard the data are unique. However, the large data set obviously was investigated under dry conditions. It would have been thereby of interest to what degree different porosity would affect the temperature dependence of thermal conductivity.

The work is of an adequate thesis standard, which also is evidenced by two peer-reviewed ISI publications on the subject, in which the doctoral student serves as the first author. Although the candidate was part of large laboratory team it can be seen that the scientific outcome of the thesis is on a level of independent work by the candidate.

The thesis could have been improved by citing just full papers and not, in addition, published abstracts. This would strengthen the scientific merit of the thesis. Citation of original literature would be advantageous and would excel over the citation of secondary sources (overview/review papers). This would better show the candidate's detailed knowledge of original sources and a thorough knowledge of the field. Improvements that could be made concern chapter 1 and chapter 2 with respect to content and organization. For example, the content of section 1.1 should have been better brought to the point, which is the link to solutions of problems in oil and gas science. The chapter also should have included the state of the art from international literature on temperature relations of thermal conductivity and volumetric heat capacity for sedimentary rock in general. Statements on known relations are made late in the thesis (section 4.1.1 and section 4.4.4) and should rather be part of the introduction before they are compared to

those from shales/mudstones etc. (this study). The flaws and shortcomings of the different measurement techniques applied to this matter should have been described. This would also concern results from the LFA technique widely used to determine thermal conductivity (as function of temperature) from thermal diffusivity. This is important, as in the thesis work only one specific technique (the DTC-300) was employed for temperature-dependent thermal conductivity measurements.

The issue of pressure dependence of thermal properties is not needed here given the title and the aims of the thesis.

Unfortunately, in the citations of work by Wang et al. (2018) and Yu et al. (2015) (section 2.1) the candidate claims that these authors have used the Netzsch LFA technique of thermal conductivity measurement. This is misleading as this technique measures the thermal diffusivity of materials.

Table 1 contains "Comparator" as a measurement technique. Some explanation is needed. Figure 8 (section 3.1.1.3) is not mentioned in text. Section 3.1.2 should be renamed to "New measuring methodology for thermal conductivity by combining DTC-300 results with those of TCS". Otherwise one would think of a new machinery for those measurements. Same for section 3.1.3 "Modification of DTC-300 results".

The reference list (page 121) needs editing. References have to be brought into the right order by year. The year of publication shall consistently appear following the name of authors.

Minor grammatical mistakes need to be taken care of.

In summary, the doctoral thesis is acceptable if the minor modifications and improvements suggested by me are incorporated.

Provisional Recommendation

☐ *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*