Skoltech

Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Anuar Shakirov

PhD Program: Petroleum Engineering

Title of Thesis: Determining thermal properties of sedimentary rocks from well-logging data

Supervisor: Professor Yuri Popov

Name of the Reviewer: Shaopeng Huang

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 21-08-2021**

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

The thermal properties of rocks are essential to the study of sedimentary history and resources, and therefore, are of critical importance to prospecting, exploration and development of a hydrocarbon field. However, due to their isotropic, heterogenetic and temperature-pressure dependent nature, determination of effective values of the thermal properties such as thermal conductivity and heat capacity of sedimentary rocks has been a challenging task, because it is impossible to obtain sufficient samples and to measure those samples under in situ conditions. Mr. Shakirov attempts to address this task in this doctoral thesis.

The major contribution of this thesis is the development of a new technique for determining the principal components of the thermal conductivity tensor and volumetric heat capacity of sedimentary rocks at depths, which allows for a better determination of terrestrial heat flow. This technique incorporates core sample measurements, well lithology, and geophysical logging data into a machine learning procedure. It involves the application of state-of-art theoretical models of thermal physical properties and artifical inteligent algorisms. The development of this new technique is based on the measurements on more than 5200 rock samples of thermal conductivity components along and perpendicular to the rock bedding plane, volumetric heat capacity, as well as some other properties such as porocity, radielement concentration, etc. This work is basically an experimental study. The experiment was well designed, implemented, and tested. The data is reliable, the size of the working database is sufficiently large for the selected cases, and the workflows are clearly outlined. However, the suggested well-log based approach for determining thermal conductivity and volumetric heat capacity of sedimentary rocks is rather tedious which might limit its application. Moreover, the absence of in-deep discussion on the physics behind the empirical relations among various data sets is a weakness of this work. This version of thesis reads more like a technical report of an industrial project than a desecration elaborating some physical process, in this case, heat conduction in porous anisotropic sedimentary rocks of a hydrocarbon field.

Nevertheless, the candidate has published three papers in peer-reviewed international journals, one of which he is the lead author. Overall, the thesis can be accepted for defend given that it has met the basic academic requirements despite the weakness.

A few suggestion for Mr Shakirov's consideration in revision.

1. Table 1. I don't understand why the sum of the mean mass contents excess far beyond 100%.

2. Table 2. The parallel conductivity measurements are systematically greater than the vertical ones. The thesis attributes the difference to the orientation of organic matters in the sample. However, could it be possible that the difference could be caused by the fact that the parallel conductivity is measured on the curve surface while the vertical conductivity is measured on the flat surface of the core? Please add some discussion to exclude this possibility if you think there is no technical bias here.

3. Table 3. The Depths of investigation of the applied well-logging tools are in tens of centimeters?

4. There are some typos and subscript/superscript need to be corrected.

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*