

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Maksim Zhmaev

PhD Program: Petroleum Engineering

Title of Thesis: Experimental evaluation of filtration properties of cryolithozone rocks under conditions of formation and decomposition of gas hydrates

Supervisor: Dr. Evgeny Chuvilin

Name of the Reviewer: Vladimir Yakushev

I confirm the <u>absence</u> of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	Date: 10-11-2024
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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.**

Thesis is dedicated to actual and poorly studied problem of gas permeability of frozen and hydrate-containing sediments. Thesis content corresponds to its topic completely. Structure of thesis is logically clear and scientifically valid.

- **The relevance of the topic of dissertation work to its actual content**

Topic of dissertation completely corresponds to its actual content.

- **The relevance of the methods used in the dissertation**

Methods of experimental modelling are original in many aspects and informative.

- **The scientific significance of the results obtained and their compliance with the international level and current state of the art**

Scientific results obtained are novel, original. Practically they are first steps in study of natural gas permeability of permafrost sediments. This question was very discussed in international science, since there were not special studies on permafrost rocks permeability dependence on different factors. Thesis gives some important answers in this area.

- **The relevance of the obtained results to applications (if applicable)**

Some obtained results can be used for prediction of natural gas flowrates when production well testing in some Arctic gas fields.

- **The quality of publications**

All publications, but one, correspond to the Thesis topic and are published in high-rating peer-reviewed journals and conference proceedings. The only 1 publication (2. Bukhanov B., Chuvilin E., Zhmaev M., Shakhova N., Spivak E., Dudarev O., Osadchiev A., Spasennykh M., Semiletov I. In situ bottom sediment temperatures in the Siberian Arctic seas: Current state of subsea permafrost in the Kara sea vs Laptev and East Siberian seas. *Marine and Petroleum Geology*. 2023, 157, 106467) does not correspond to the topic completely, but it gives some initial natural data for experimental modelling.

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

There are few comments for the content of the Thesis:

Abstract

Cryolithozone contains gas also in water-dissolved form and in adsorbed/absorbed form (coalbed methane, shale gas)

Technogenic hydrate formation in the downhole zone can occur not only in Arctic gas fields.

Introduction

Again, other forms of existence of natural gas in permafrost are not indicated.

Leak of references to publications of Dr.Gilichinsky et.al (1992-1997), where microbial gas concentration at the bottom of seasonal thawing layer (depth 0,5 -3 m) as result of seasonal freezing was studied. These depths are shallower than indicated in the thesis.

Chapter 2

p.38 "Outside the GHSZ, gas hydrates cannot form, but can exist in a metastable state even at shallow depths in the form of relict hydrates..." – sentence is not completely correct. Hydrates can form in permafrost zone outside current GHSZ in places, where local GHSZ can appear for a short period due to geodynamic processes like talik zone freezing.

Experimental chapters

How effective PEEK polymer material prevents gas slippage along sample/holder wall contact when filtration experiments?

Table 12 – incomplete mineral composition for Sand 1 and Sand 2. No stratigraphic index for Polymineral loam

No information about sands washing and dewatering before experiments. No data about residual pore water salinity in natural samples. No data about pore water freezing/thawing temperature in prepared samples.

Figure 24. Such experiments need to be repeated few times to receive statistics about temperature of filtration start.

No information about pressure gradient values along samples in the section “5.1 Effect of the gas pressure gradient on gas filtration in ice-bearing frozen sediments”

Figure 33. How these results were obtained? No explanations in text.

In **Chapter 6**, where experimental assessment of the gas permeability of sediments under conditions of formation and decomposition of pore hydrate and ice, no data about hydrate textures formation during gas hydrate formation in sandy samples. Although author mentioned about hydrate textures formation when hydrate formation in sandy sediments (p.70) it is not clear: was hydrate textures formation took place in the experiments on permeability measurement or not. And, if yes, how it reflects in gas permeability of sample.

In section **6.3** where CH₄/CO₂ replacement process is studied, there is no data about CO₂ dissolution in pore water during experiments, especially when temperature conditions are close to 0°C.

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