Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 189 (2017) 459 – 465

Procedia Engineering

www.elsevier.com/locate/procedia

Transportation Geotechnics and Geoecology, TGG 2017, 17-19 May 2017, Saint Petersburg, Russia

Problems and technologies of offshore permafrost investigation

Andrei S.Loktev[a]*, Mikhail Y.Tokarev[b], Eugeny M.Chuvilin[c]

[a]*Marine Research Center of Lomonosov Moscow State University, Moscow, Russia*
[b] *Lomonosov Moscow State University, Moscow, Russia*
[c] *Skolkovo Institute of Science and Technology, Moscow, Russia*

Abstract

The article describes the state of the art methods and technics of soil investigation in specific Arctic offshore areas. Underwater sediments can be frozen and hazardous for various offshore constructions, particularly, for marine pipelines, platforms and near-shore terminals. Sub-bottom permafrost is an object of special investigation and technologies. The zone is currently exposed to severe climate and was chilled for a long time in the past. Reliable thickness of offshore permafrost is up to 100m according to direct methods. Both top and bottom permafrost are hardly detectable offshore. Special knowledge and good experience are indispensable even to recognize its location and extent.
Standard methods are not always applicable for its recognition, that is why more sophisticated technique is required. Combination of integrated approaches is the only way to detect marine permafrost and characterize its properties and location.

Keywords: permafrost, Arctic offshore, in-situ testing, geohazard

1. Marine permafrost and its distribution

Permafrost is a result of low-temperature freezing of soil pore water. It is wide spread at high latitudes (over 70th N deg). Estimated thickness of onshore permafrost can be up to 0.7km [1] and even 1km in Russian Siberia [2].

* Corresponding author. Tel.: +007 911 3024593.
E-mail address: andrei.loktev@oilgascenter.ru

doi:10.1016/j.proeng.2017.05.074

Frozen offshore sediments can old relict onshore permafrost that submerged later or a newly generated phenomenon. Marine sediments can freeze up when sea bottom temperature is below the freezing point and pore water is less saline than the overlying seawater.

Vast area of the northern hemisphere was covered by seawater (at marine transgression) after the last glaciation. Although global sea levels rose by about 120m, the actual submergence may vary between 80 and 200m due to local effects of isostasy. It means relict permafrost can exist at this water depth in the Arctic Ocean. The area of future permafrost should be exposed and affected by below freezing temperatures and it could not covered by glaciers. As it is estimated, the mean annual air temperatures could be down to -20^{0}C at the Late Pleistocene glacial maximum in West Siberia, 14-16k years ago, when sub-aerial exposition may have been as long as 12000 years (21 to 9k years ago) [2].

There is still discussion on the extent of the glaciation of the Russian Arctic area: some scientists suppose maximum spread with a Pan-Arctic cap of 3km while others deny any glaciation at all [3]. Because of this disagreement, various offshore permafrost reconstructions can be produced [4-10]. Mast of the maps of sub-sea permafrost are based on paleo-geographical, geodynamic, mathematical and geothermal modeling or/and some geophysical survey. It should be recognized that even recent maps provide significantly different contouring of the shelf cryolite zone (fig 1). Actual permafrost data based on direct and reliable results are very limited and are applicable just to the Western Arctic offshore (fig. 1b).

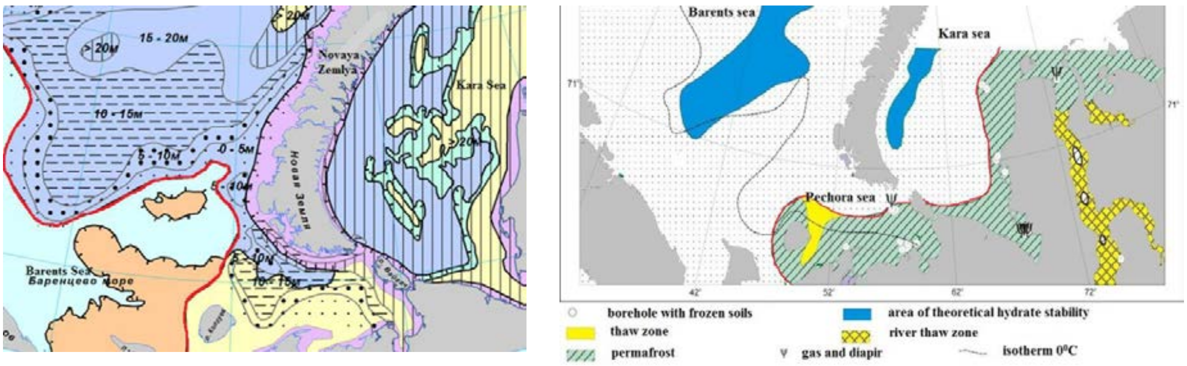

Fig. 1. Schematic map of expected sub-bottom permafrost (Barents and Kara sea): (a) by Vasiliev, 2011; (b) by Loktev et al, 2012. Red line marks permafrost extent

The eastern part of the Arctic offshore area cannot be described in terms of factual data where no boreholes, shallow sampling and in-situ testing was performed except very few boreholes drilled in shallow waters in the River Lena delta and between the New Siberian Islands [5].

The issue is getting very important with development of the Arctic for hydrocarbon supply. As experts estimate, frozen soils might be the biggest challenge for the industry in coming years. New offshore developments are still put aside including widely announced Shtokman and some other projects in the Barents and Kara seas. For example, it is planned to use a pipeline for hydrocarbon transportation from the Shtokman field. Developments in the Kara sea envisage near shore terminals and shorter pipelines for product transit toward the land.

Some objects had been built and exploited in the Western Arctic Shelf in 1990-2000th. Surveyors and designers can understand and must use the experience from investigations of the Baydara Cross in the Kara sea (GAZPROM pipeline system of gas transportation from the Yamal peninsula to Europe); Prirazlomnaya oil produced platform or LUKOIL terminal on Varanday island. All these objects are situated in shallow water of the Pechora and Kara seas and are built on sub-bottom permafrost. This is mostly discontinuous permafrost, which is more dangerous for constructions because of heterogeneous soil conditions and less predictable behavior. The irregular limits of the permafrost top are illustrated in Fig 2. This boundary is variable and is very complicated for any facility above.