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MSc Thesis

Bearing capacity of subsea permafrost soils on the Laptev Sea shelf

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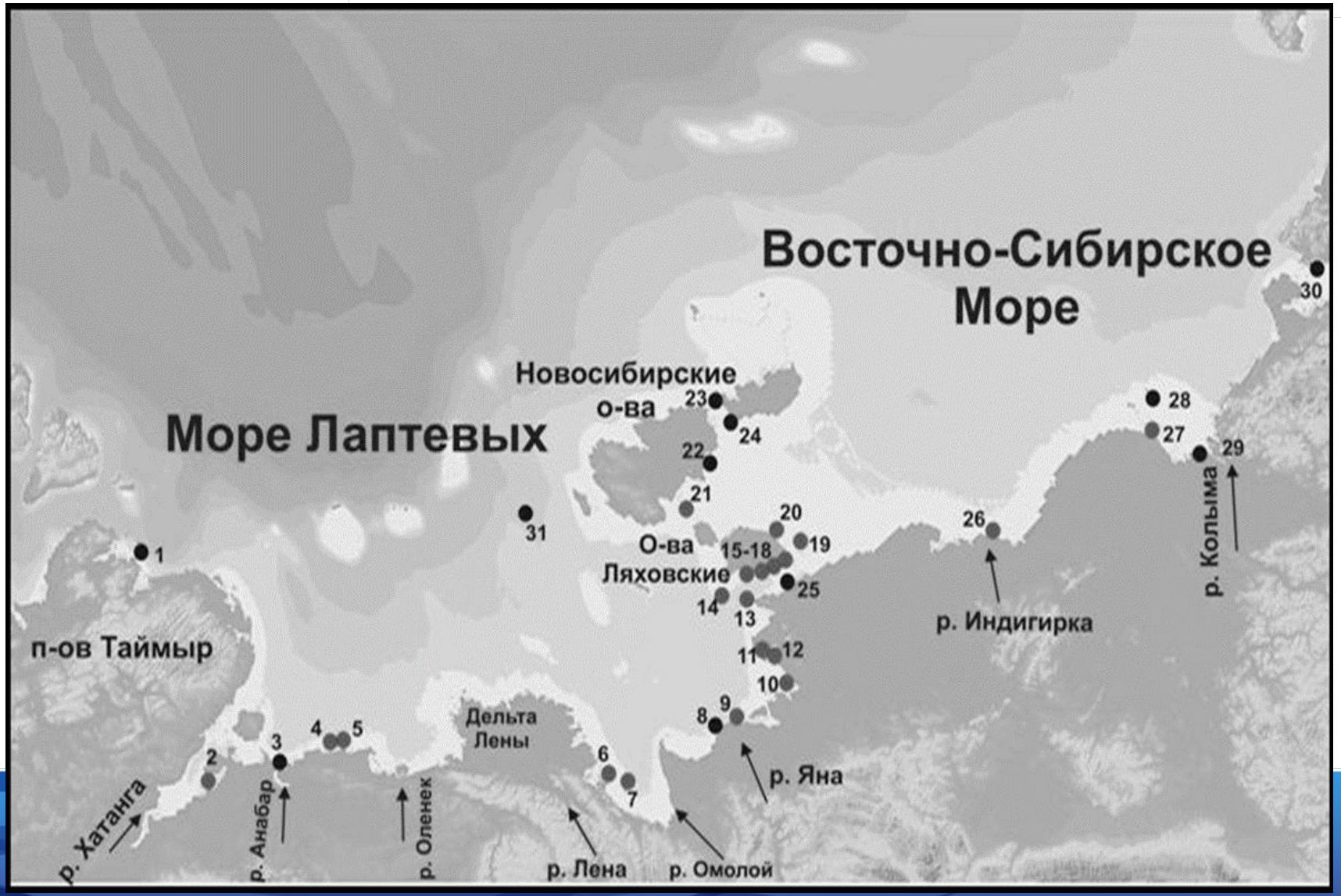
Introduction

A feature of the Arctic water areas is the presence of a permafrost soils on the shallow-water shelves. Because of the construction of structures on the shelf, it is necessary to study the current state and dynamics of frozen rocks under warming conditions.

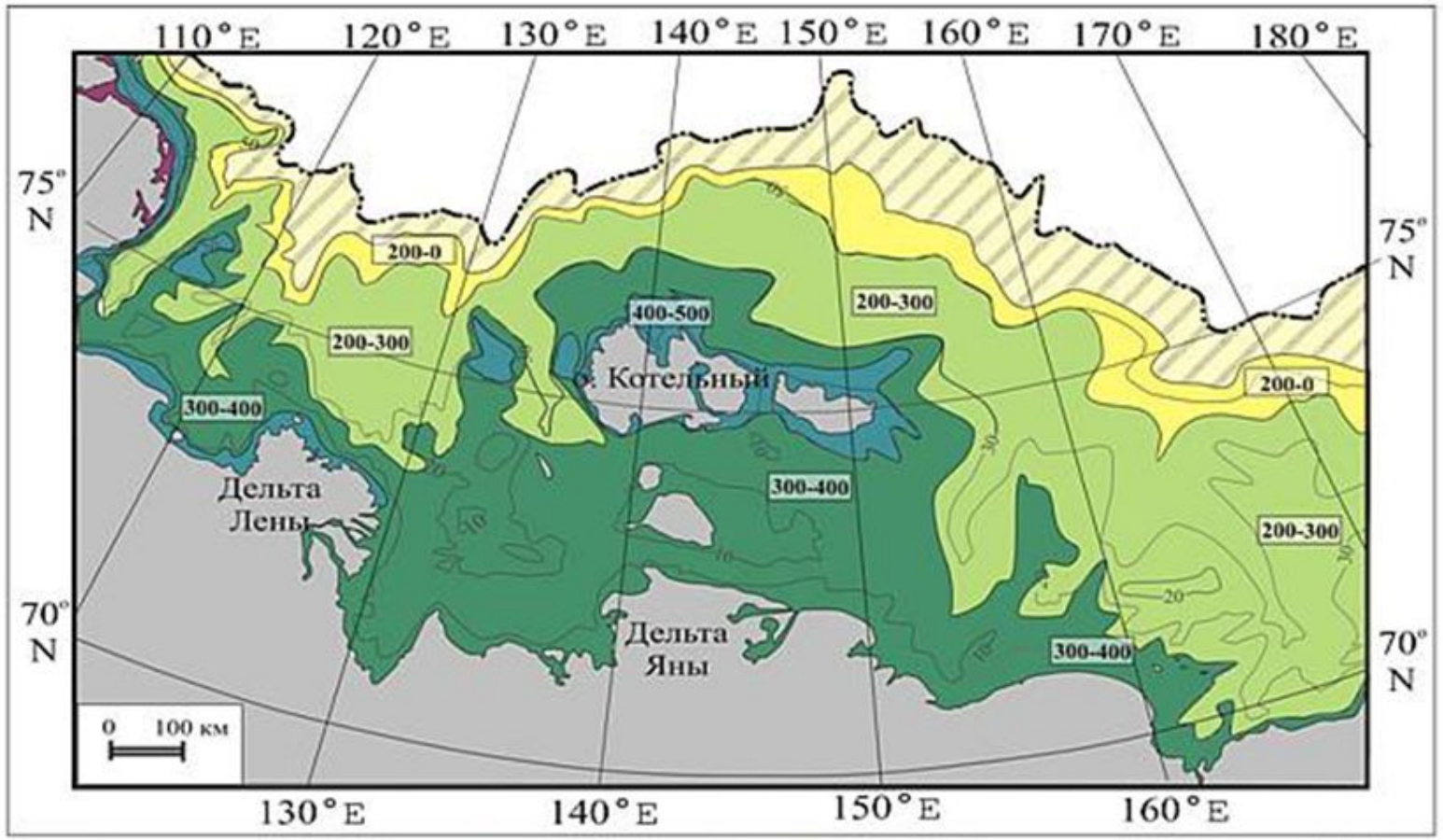
Chapter 1

1	The end of the 19th century – 30 years of the 20th century	**E.V.Tol ‘, M.V. Brusnev, F.A.Matisen, A.V. Kolchak, K.K.Neupokoev, H.U.Sverdrup, V.P.Kalyanov, P.V.Vittenburg**
2	The 30-40's of the 20th century	**V.M. Ponomarev** Researching wells with a depth of 400-500 m in the Kozhevnikov Bay of Khatanga Gulf
3	Year 1937	**S.G. Parkhomenko** The depth of the Arctic shelf’s permafrost rocks on the permafrost map of the USSR
4	Year 1953	**V.N. Saks** Distribution and thickness
5	Year 1970	**I.S.Baranov, F.E.Are, V.A.Kudryavtsev, N.N.Romanovsky, S.M.Fotiev** Typification according to the ratio in its section of the layers of frozen rocks and cooled below 0 °C rocks, its formation in continental or coastal-marine conditions
6	1980-1990	**Ya.V.Neizvestnov, V.A. Soloviev,L.A. Zhigarev, I.D.Danilov** Geocryological studies in the coastal zone of the shelf

Drilling works in the Laptev Sea



Map of distribution and thickness of the permafrost zone in the north of Russia



Theoretical and mathematical models of permafrost soils

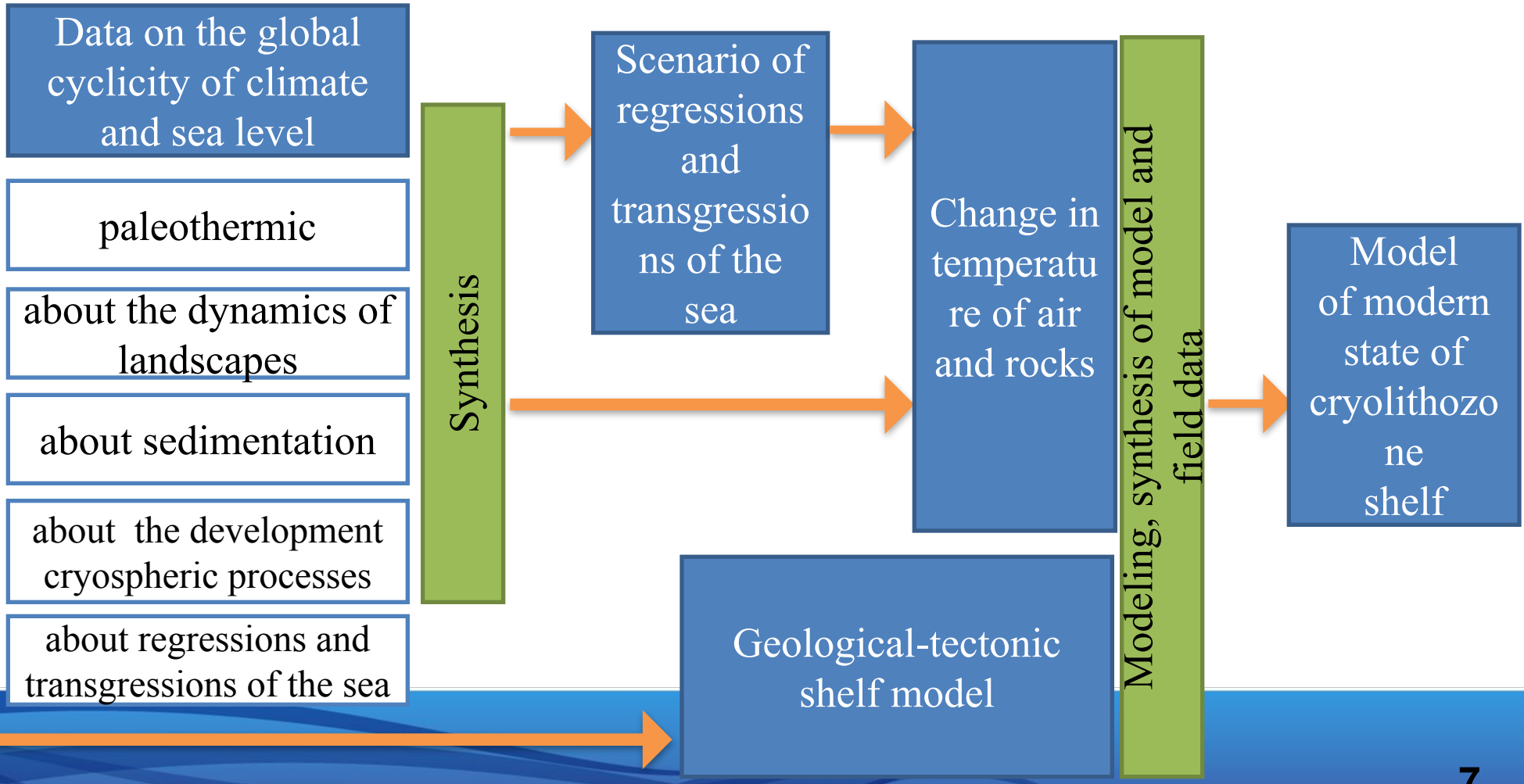
Methods of research

1

Initial data	Mathematical model	Results
changes in air or water temperature	the heat equation and Stefan's condition	upper and lower boundary of permafrost
geothermal heat flux		

Conclusions	Researchers
The dynamics of thawing of permafrost depends on the geothermal heat flux	V.V. Malakhova [2014] D.J Nicolsky, V. E.Romanovsky [2012]

Retrospective approach to the study of the shelf cryolithozone



Theoretical model

paleogeographic

geological-tectonic

Results

distribution and thickness maps
cryolithozones of the Laptev Sea;
influence of various factors on the cryolithozones thickness.

Researchers

A.V. Gavrilov,
A.L. Kholodov,
A.A. Eliseeva,
G.S. Tayenko,
N.N. Romanovsky,
V.E. Tumskoy [2011]

Problems

1.There is no regional continuous record of climate change and landscapes for the Eastern Arctic;

2. Properties of rocks and sediments, data of thermal properties in the East Arctic shelves are unavailable;

3.The amount of heat flow is also not available;

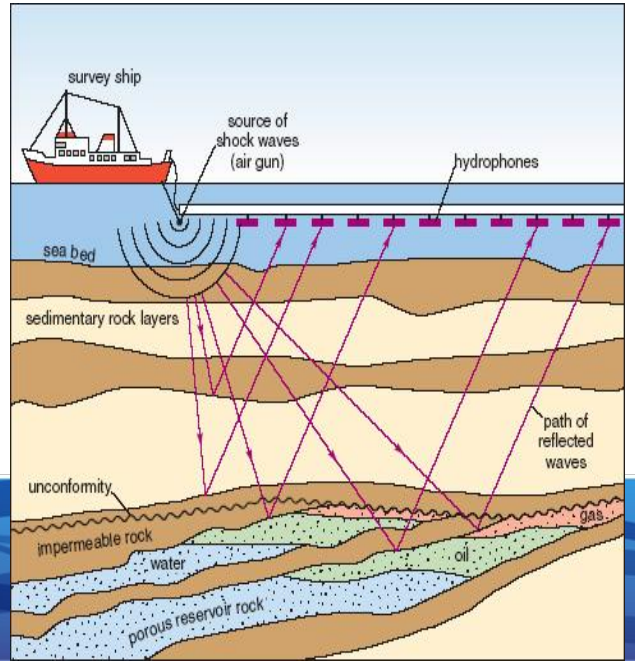
4. Accurate field data

Methods of experimental studies of underwater permafrost

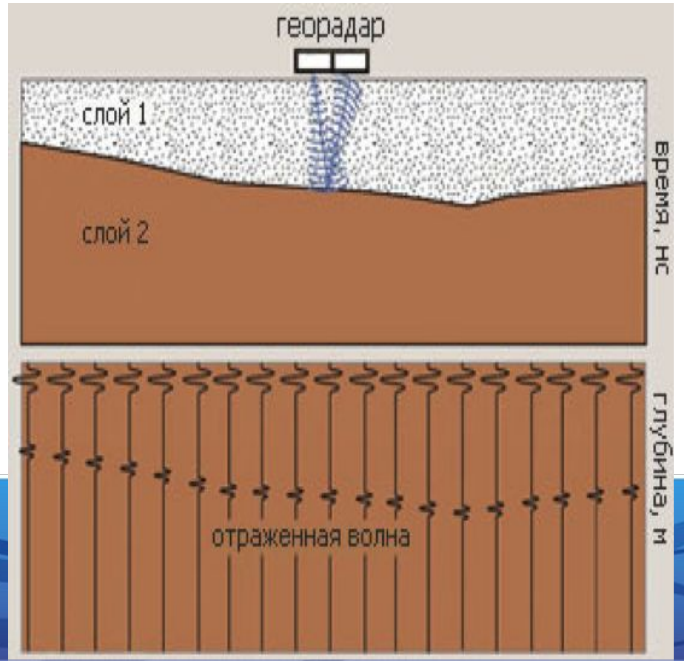
Geophysical methods of exploration

Seismic exploration

V.P. Melnikov…, [2010]
A. A. Shmatkov, [2014]



Georadiolocation survey



Electrical Exploration

V.Ph.Grigorev…,[2013]

1-Observation area ;
2-bipole-source

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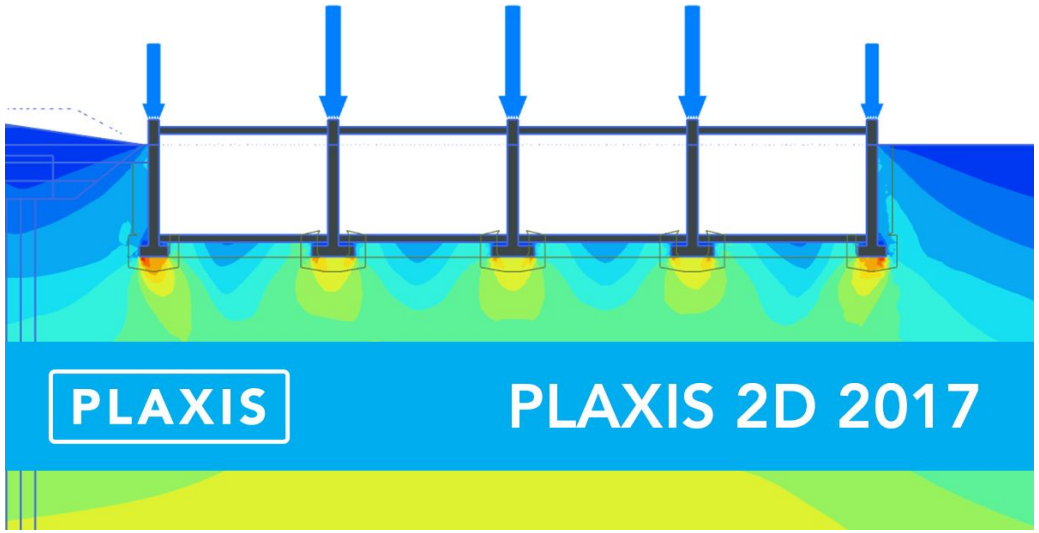
Mathematical modeling of the stress-strain state of soils



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GEOSLOPE

- ✔ Underwater relict permafrost and the zone of stability of gas hydrants exist in most of the coastal-shelf zone of the Laptev Sea.
- ✔ The published maps, showing the features of the distribution and properties of the Arctic subsea permafrost, are not complete. Such materials are prepared on the basis of indirect data (geophysical sounding, modeling, etc.), not experimental data.
- ✔ Reliable drilling data are obtained only in shallow water areas, many drilling results are not published. It is not known whether there are frozen rocks in the deepwater areas of the shelf.
- ✔ In the shallow coastal zone degradation of frozen rocks is more active, due to the proximity to the bottom surface and more intensive hydrodynamic and thermal processing.

Goals and objectives of the research

The goal of the work is to sum up the bearing capacity of the structure's foundation with the layer of frozen soil on the example of the geological conditions of the Khatanga Bay of the Laptev Sea.

Objectives:

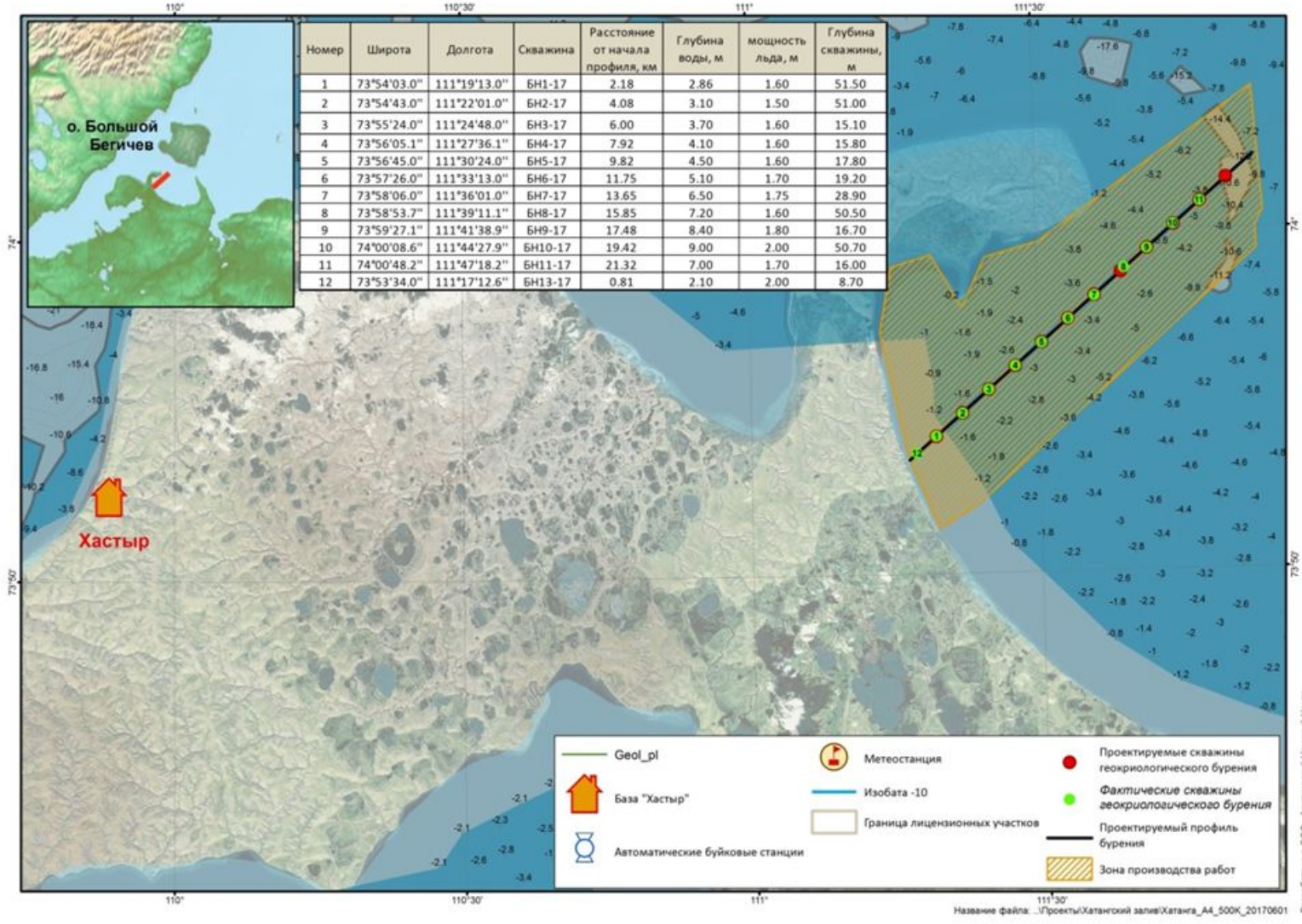
1. To review researches and methods for calculating frozen soils.
2. To analyze the geological conditions in the Khatanga Bay based on the results of the drilling works of the 2017 season.
3. To do evaluation of the bearing capacity of the base with frozen soil.
4. To recommend a method for evaluation of melting frozen soils' bearing capacity under the effect of thermal and mechanical effect.

Area of interest -Khatanga Bay

1 Красноярский край

2 Республика Саха (Якутия)

Drilling works in the Bay of Noordwijk of the Hatanga Bay of the Laptev Sea [FEFU, 2017]

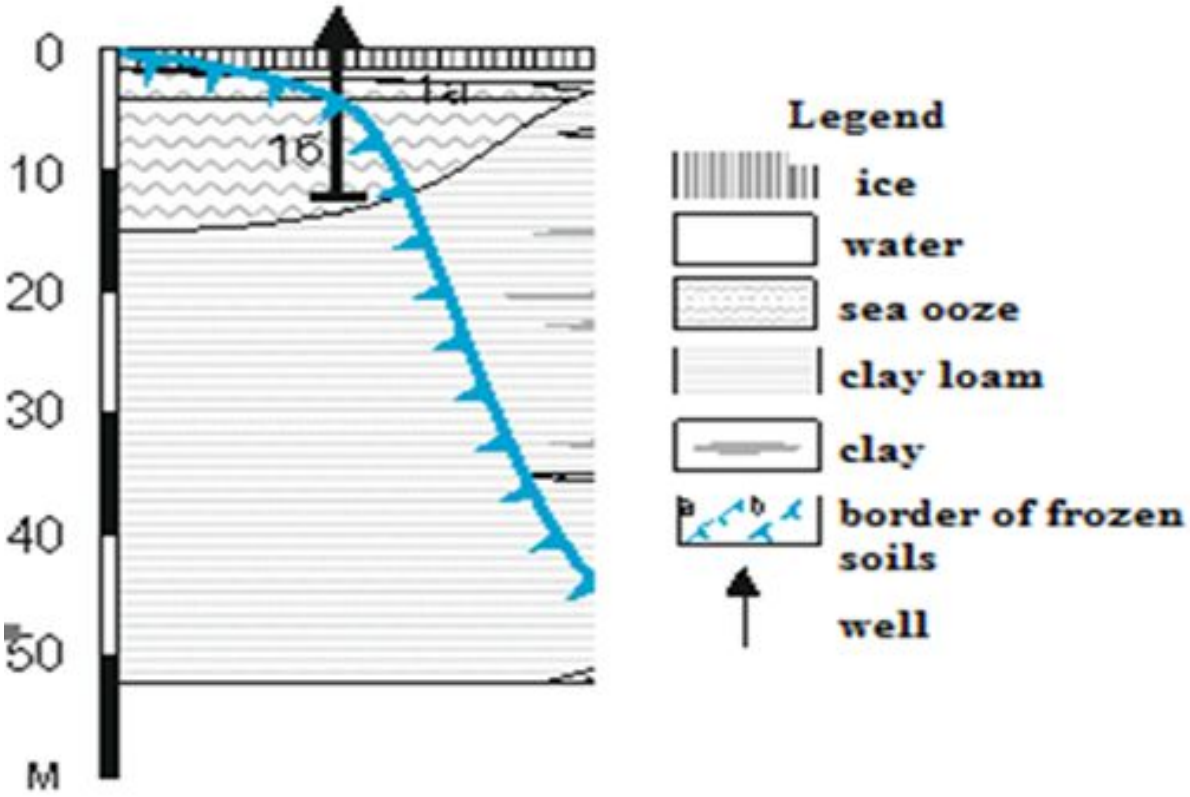


Номер	Широта	Долгота	Скважина	Расстояние от начала профиля, км	Глубина воды, м	мощность льда, м	Глубина скважины, м
1	73°54'03.0"	111°19'13.0"	БН1-17	2.18	2.86	1.60	51.50
2	73°54'43.0"	111°22'01.0"	БН2-17	4.08	3.10	1.50	51.00
3	73°55'24.0"	111°24'48.0"	БН3-17	6.00	3.70	1.60	15.10
4	73°56'05.1"	111°27'36.1"	БН4-17	7.92	4.10	1.60	15.80
5	73°56'45.0"	111°30'24.0"	БН5-17	9.82	4.50	1.60	17.80
6	73°57'26.0"	111°33'13.0"	БН6-17	11.75	5.10	1.70	19.20
7	73°58'06.0"	111°36'01.0"	БН7-17	13.65	6.50	1.75	28.90
8	73°58'53.7"	111°39'11.1"	БН8-17	15.85	7.20	1.60	50.50
9	73°59'27.1"	111°41'38.9"	БН9-17	17.48	8.40	1.80	16.70
10	74°00'08.6"	111°44'27.9"	БН10-17	19.42	9.00	2.00	50.70
11	74°00'48.2"	111°47'18.2"	БН11-17	21.32	7.00	1.70	16.00
12	73°53'34.0"	111°17'12.6"	БН13-17	0.81	2.10	2.00	8.70

The following results were achived:

- ✔geocryological and engineering researches were carried out;
- ✔a description of the core-sample was done;
- ✔the geophysical characteristics of the work profile was studied;
- ✔the gas composition of bottom sediments was studied;
- ✔core samples were studied in laboratory conditions, 598 tests were performed to determine the physical and mechanical properties of soils.
- ✔the boundary of permafrost was shown on the geocryological section.

Geocryological profile of well No.1

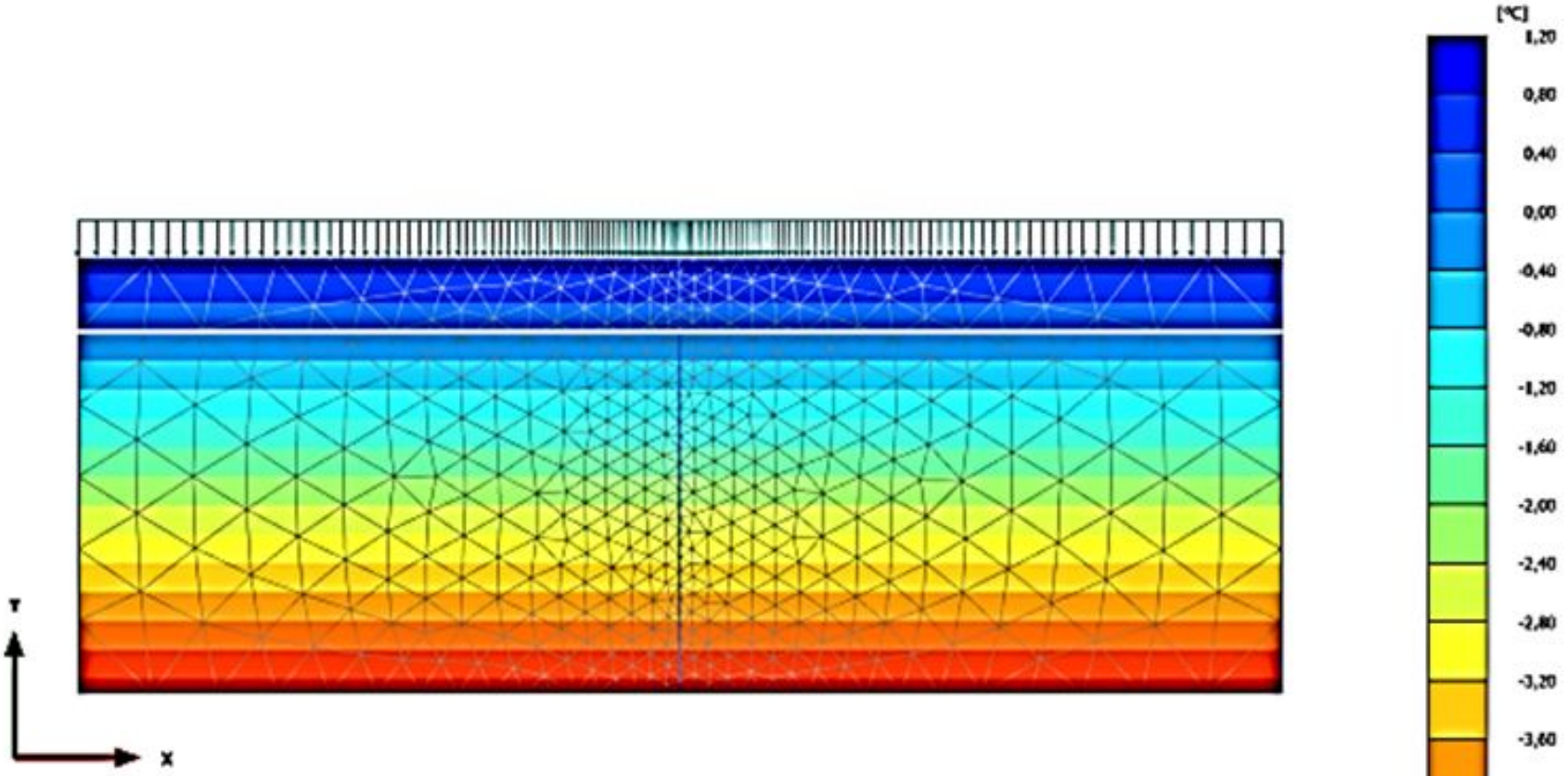


- about 1 km from the coast,
- depth of water is 2.1 meters
- depth of the well is 8.7 meters

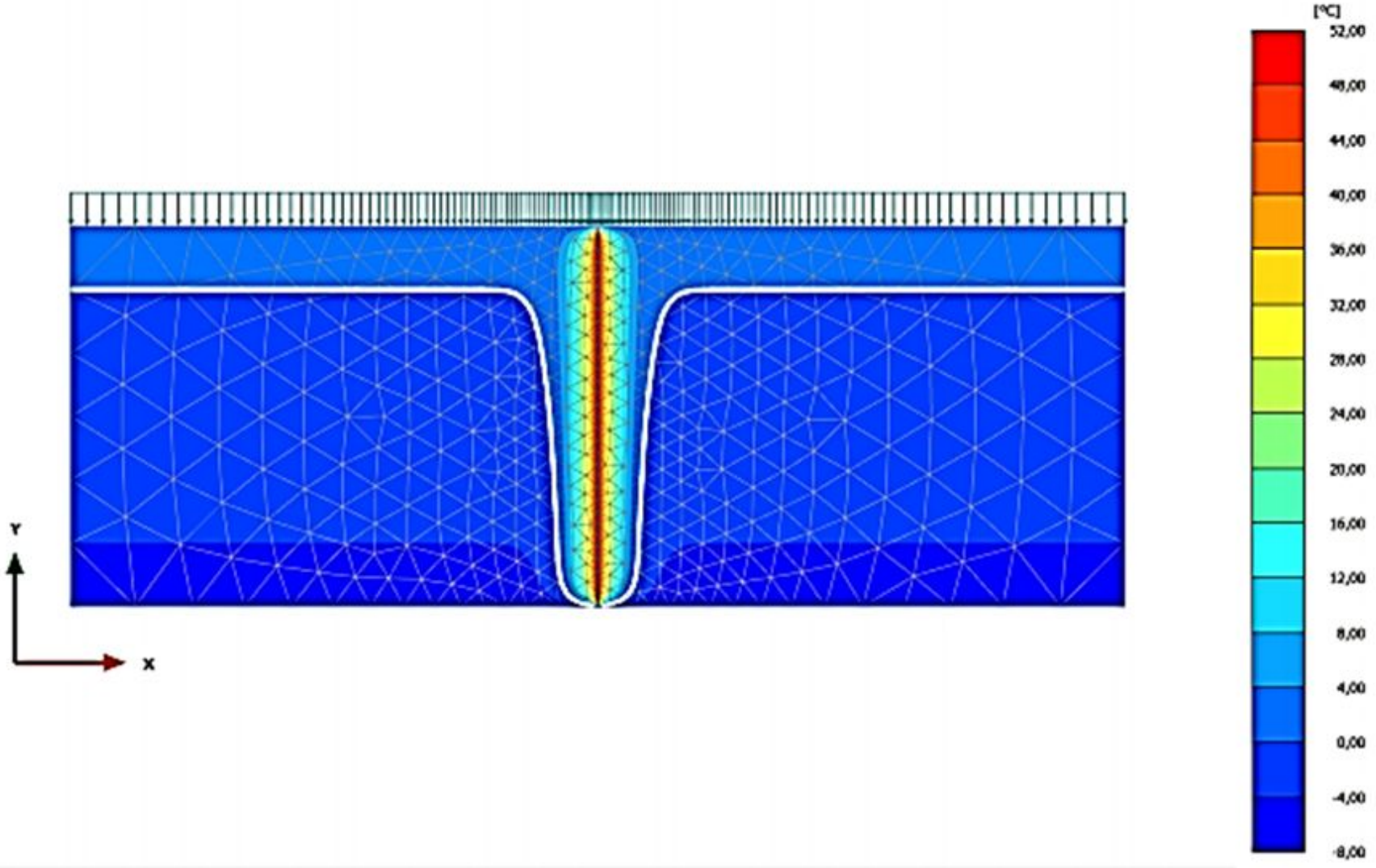
The problem of determining the settlement is divided into two points:

1. Determination of the **thawing layer thickness** (determined by the temperature calculation in the Plaxis).
2. Determination of **settlement** (defined in the Plaxis and for comparing the results by calculation according to SP 25.13330.2012 in the program " Foundation 13.3").

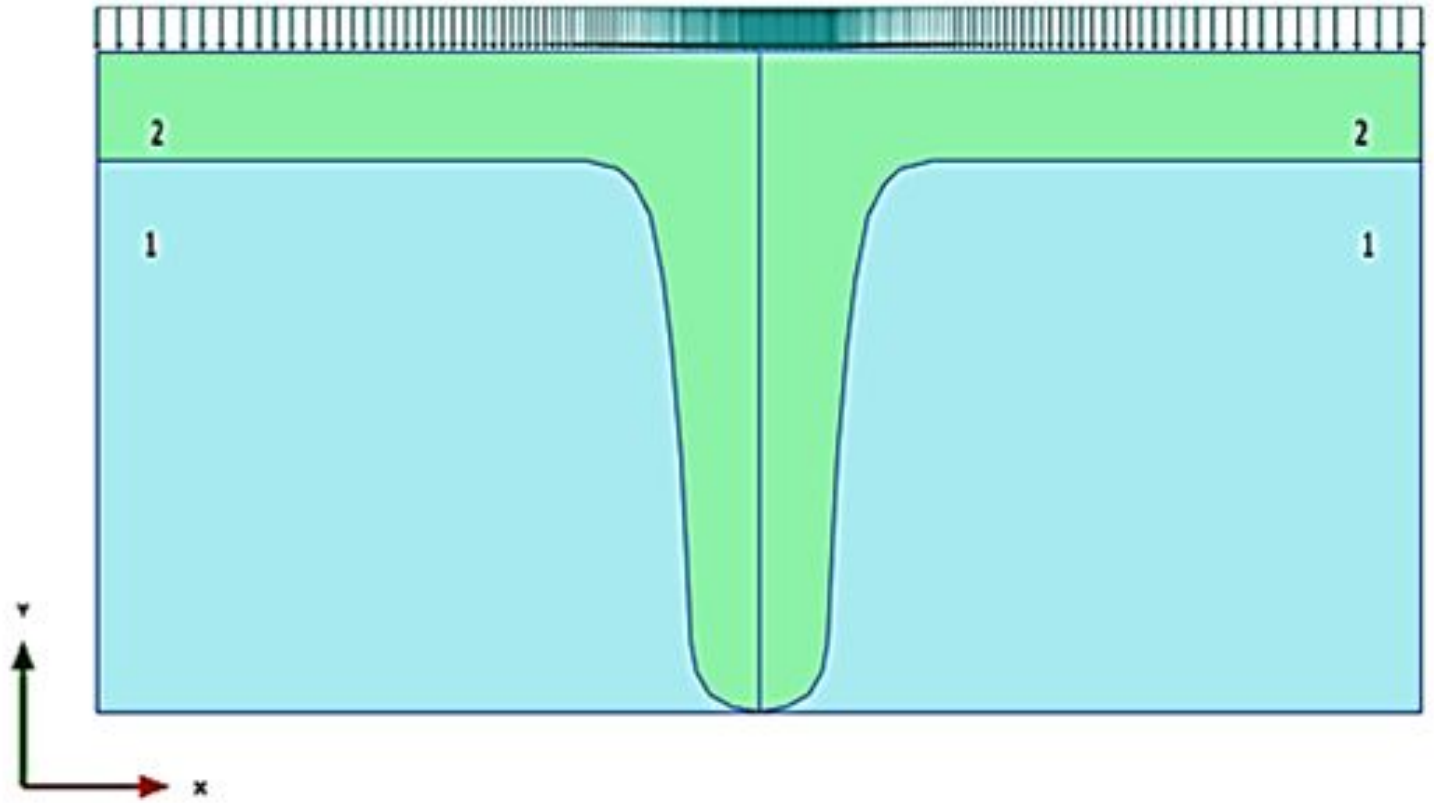
Structural model. Temperature distribution



The distribution of the soil temperature from the heating device



Geometric model for calculating settlement of the drilling platform with the results of solving the temperature problem



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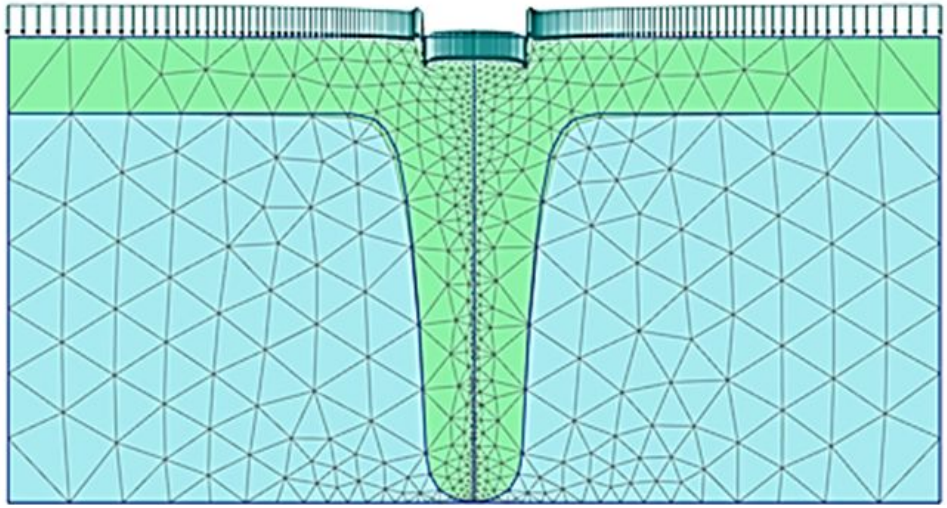
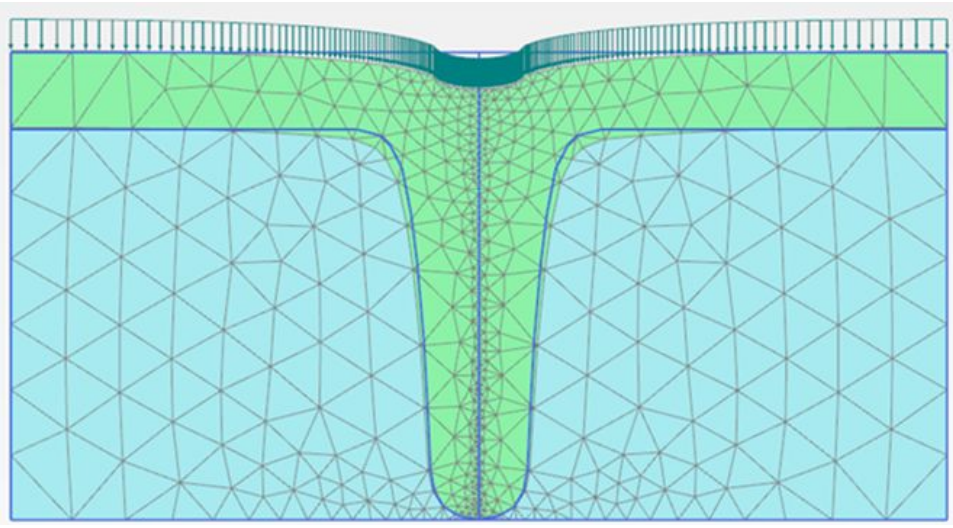
Vertical displacement of the lower point of the foundation (10x10m) under load :



F=500 kPa



F=100 kPa

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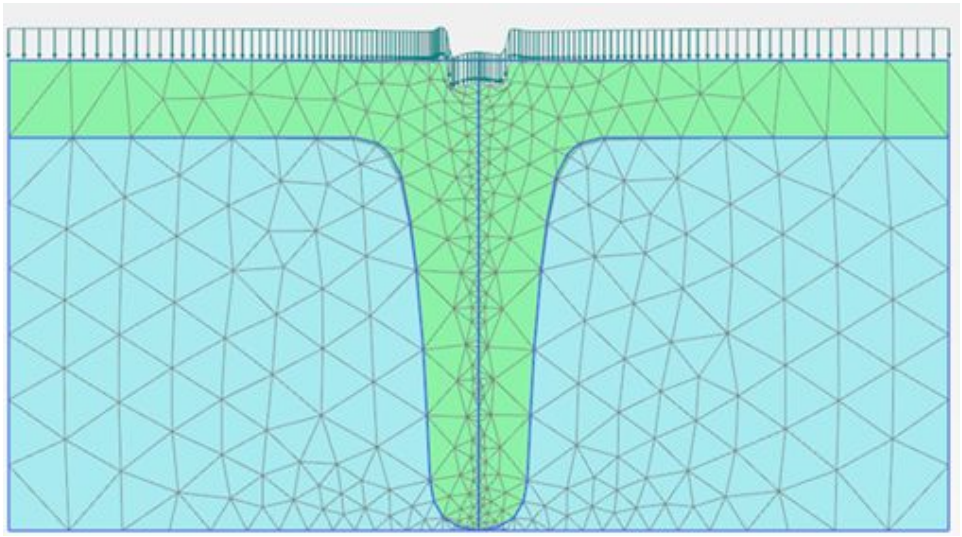
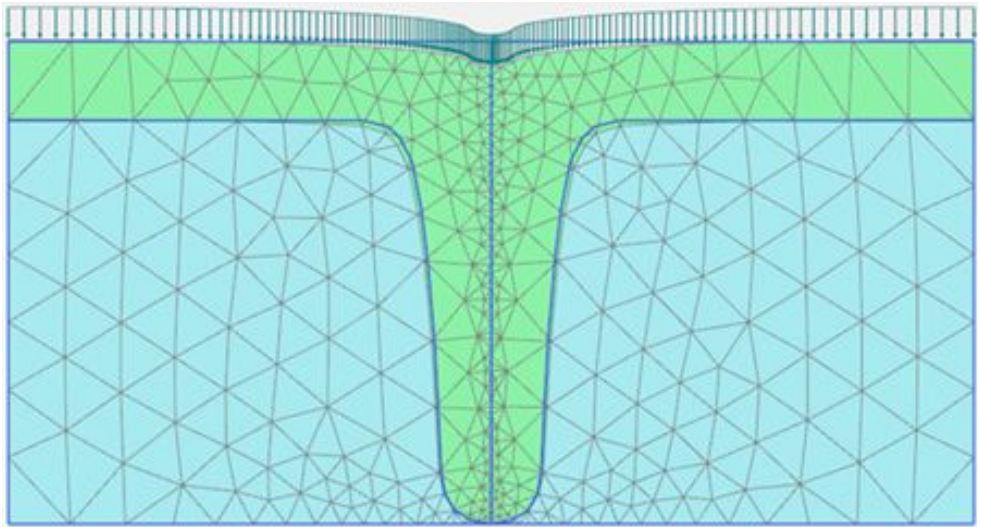
Vertical displacement of the lower point of the foundation (5x5m) under load :

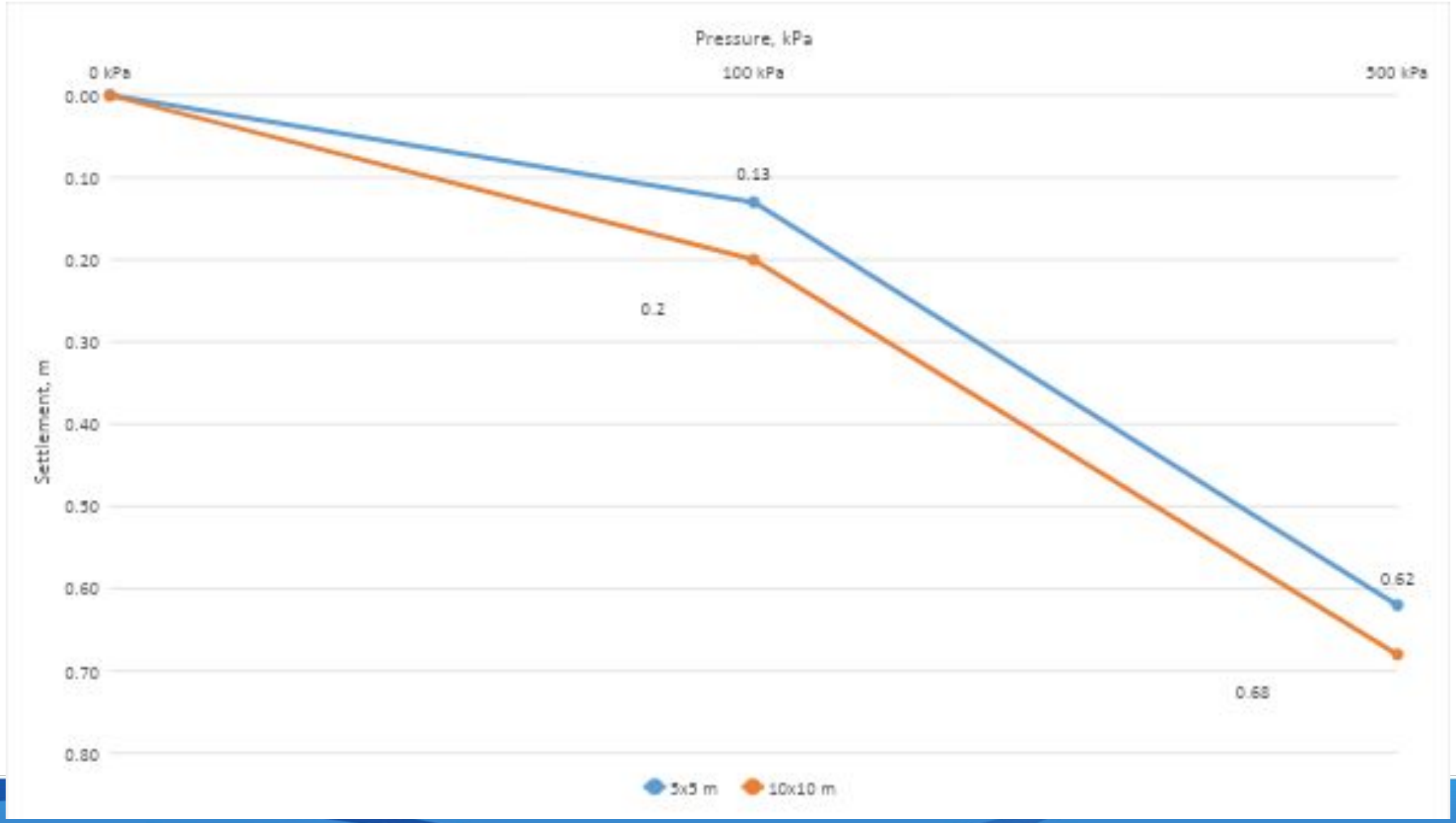


F=500 kPa

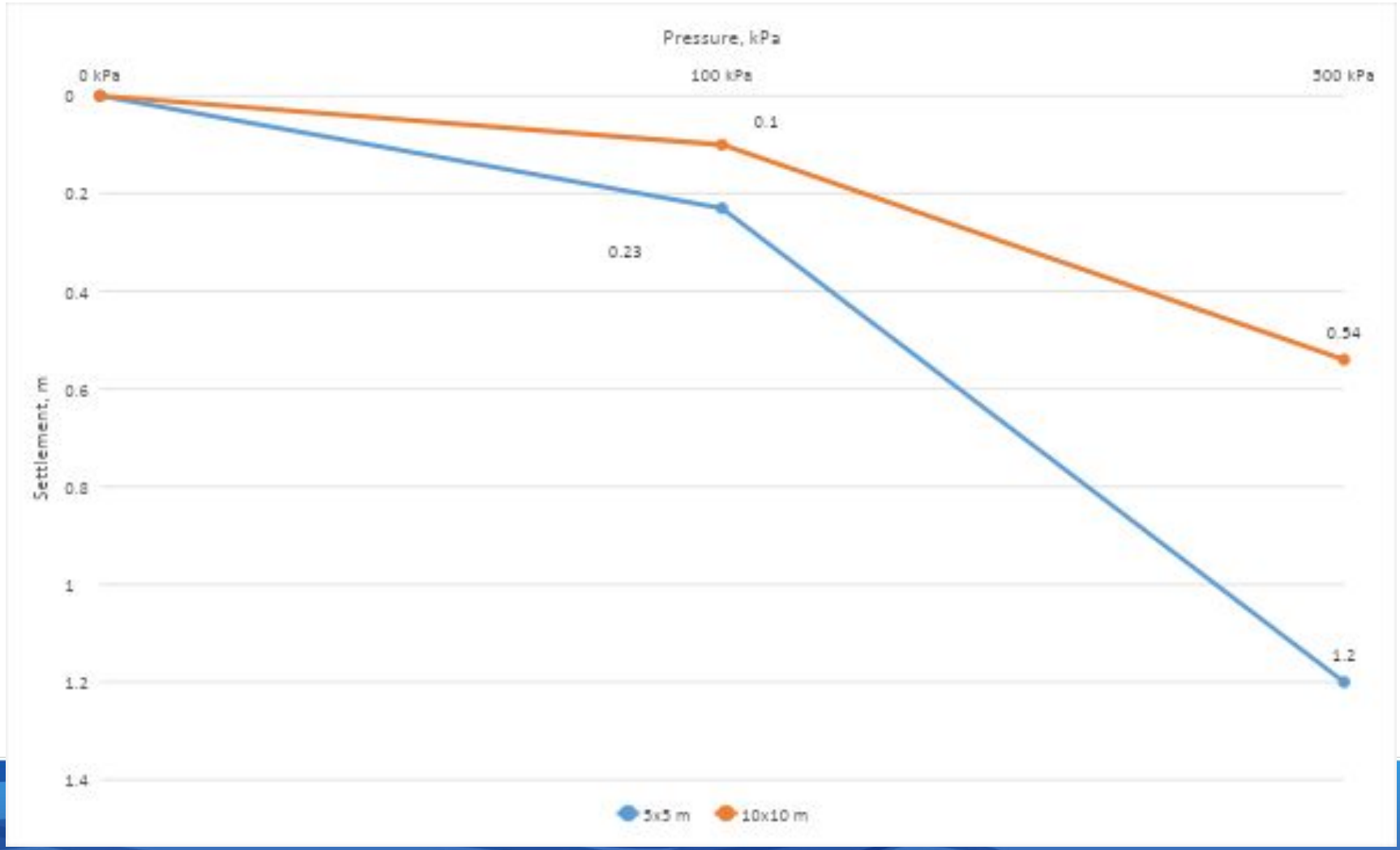


F=100 kPa

Stress-strain relation (calculated by Plaxis)



Stress-strain relation (SP 25.13330.2012)



Conclusion

- A method for predicting the change in temperature fields and thermal settlement of the drilling platform in areas with permafrost soils is proposed.
- A mathematical description of the deformation process of thawing soils under thermal action is used.
- Express methods for determining the deformation of thawing soils are proposed.
- The possibility of using mathematical modeling to determine the deformations of thawed soil is shown.

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Thank you for attention!