St Petersburg University

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Geochemical structure of the Fe-Mn concretions of the eastern Gulf of Finland: natural processes and anthropogenic impact

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PURPOSE OF THE WORK

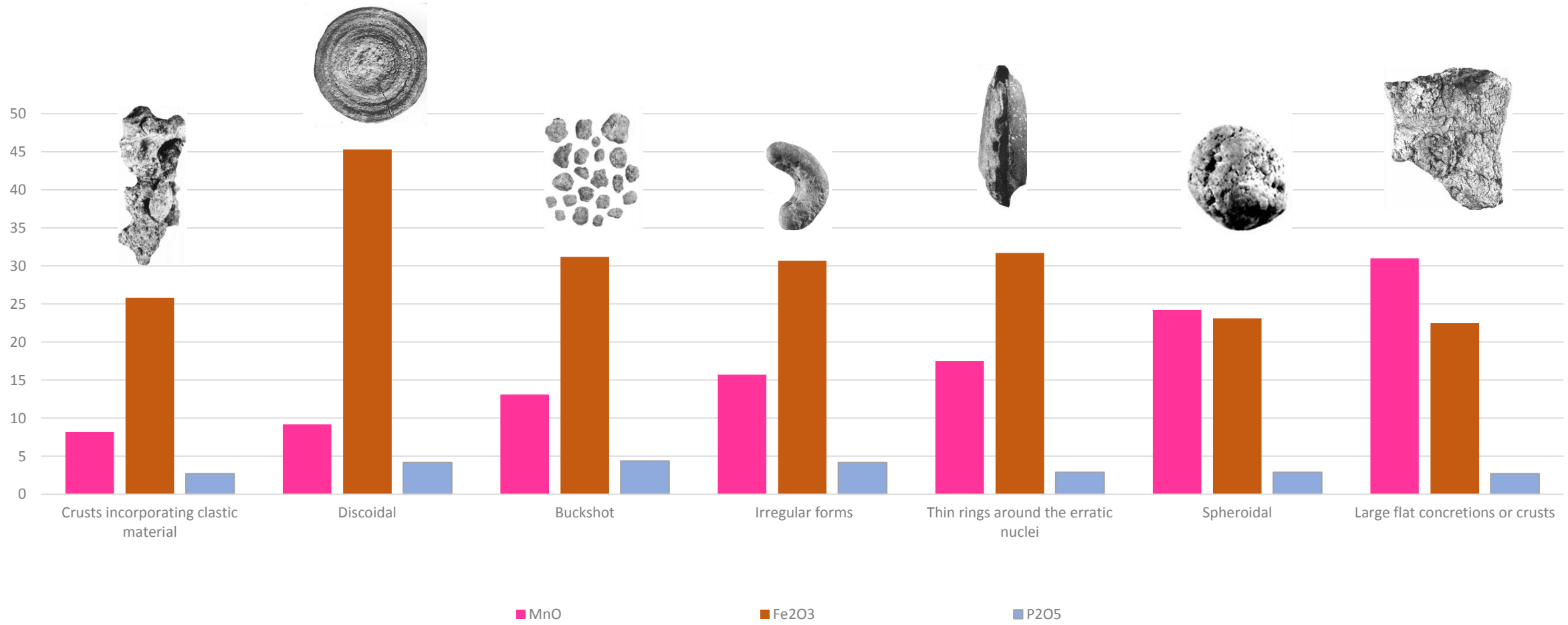
The purpose of this study is to examine the impact of the extraction of ferromanganese concretions on the marine benthic geological environment and to study the possibility of ferromanganese concretion field natural regeneration after extraction

Study area - the eastern Gulf of Finland, Vyborg Bay; **The research object –** Fe-Mn concretions;

Fe-Mn concretions – a hard, compact mass or aggregate of mineral matter, normally subspherical but commonly oblate, disk-shaped, or irregular with odd or fantastic outlines; formed by precipitation from a liquid, such as a leaf, a shell, a bone or a fossil. The concretions are often called Fe-Mn concretions (TOPCONs Glossary).

Different contents Mn, Fe, P of different Fe-Mn concretions types

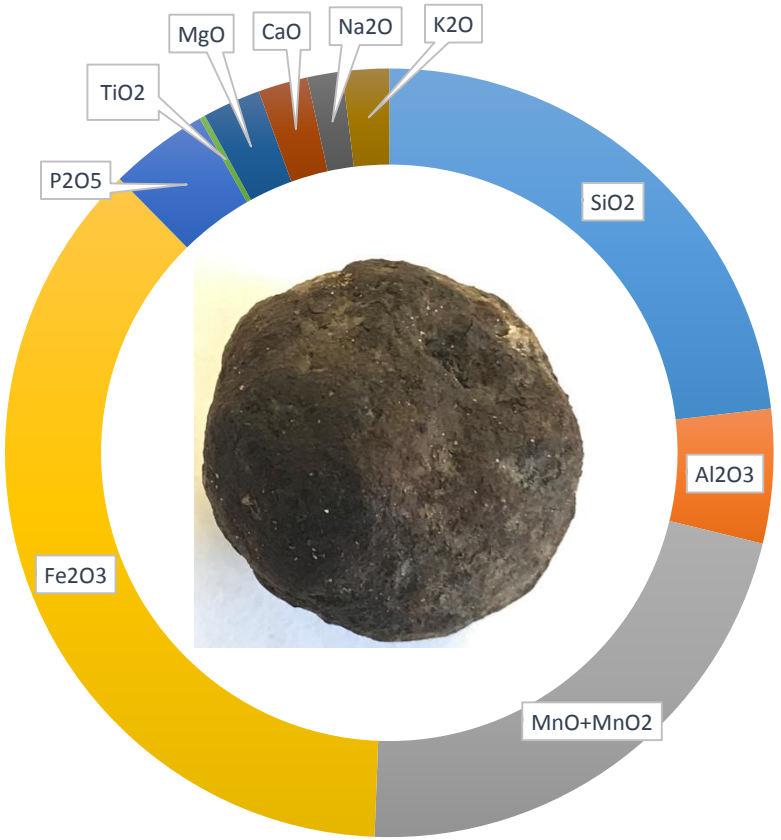
The distribution and composition of the various morphological types of concretions in the Gulf of Finland are related to the bottom relief and haracter of the sediment



CHEMICAL COMPOSITION

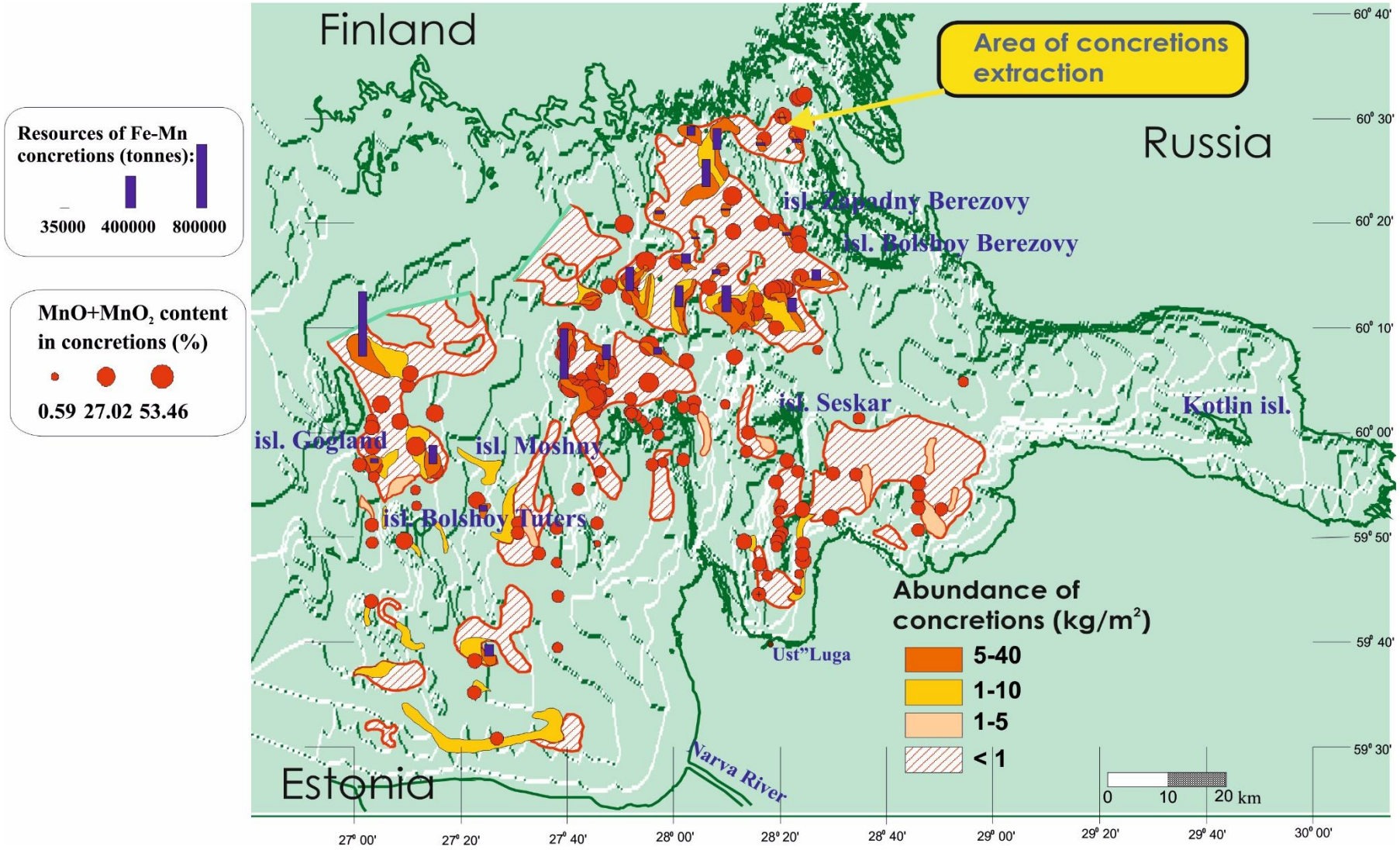
Average concentrations of major elements in the concretions from the Gulf of Finland. All analyses in %

SiO_2	Al_2O_3	$MnO + MnO_2$	Fe_2O_3	P_2O_5	TiO_2	MgO	CaO	Na_2O	K_2O
18,9	4,6	17,8	30,2	3,4	0,2	2,0	1,7	1,2	1,6

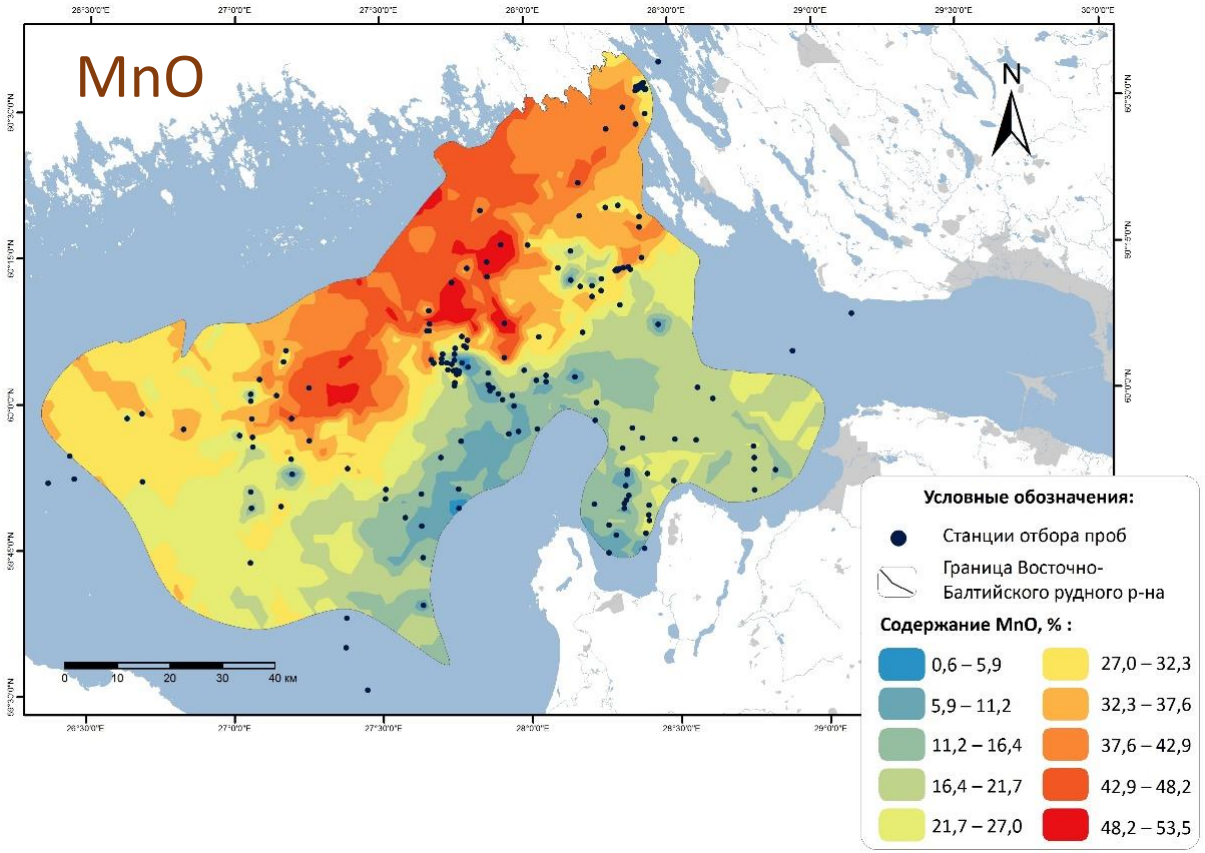


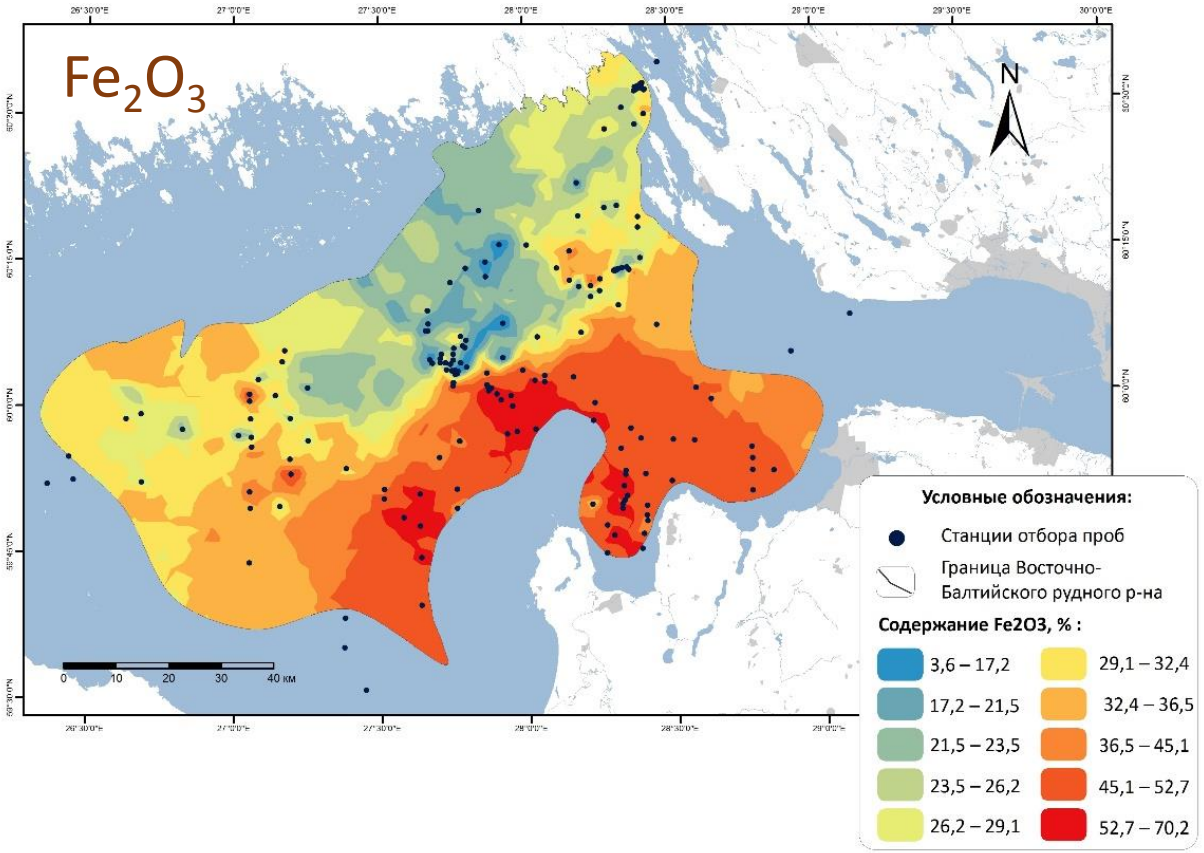
Scheme of concretions fields distribution

Total weight of spheroidal concretions in the eastern Gulf of Finland is calculated to be about 10 million tons. The abundance of spheroidal concretions locally reaches 50–60 kg/m^2 (wet weight).

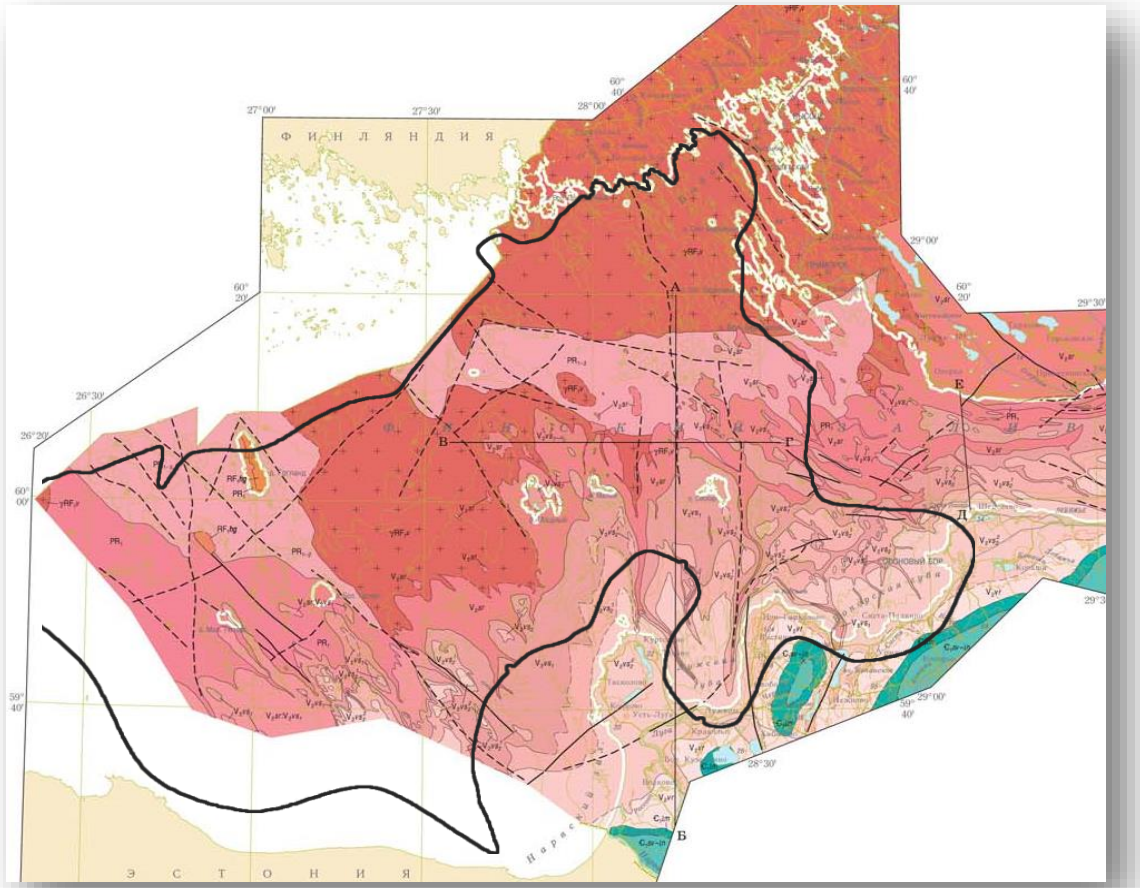


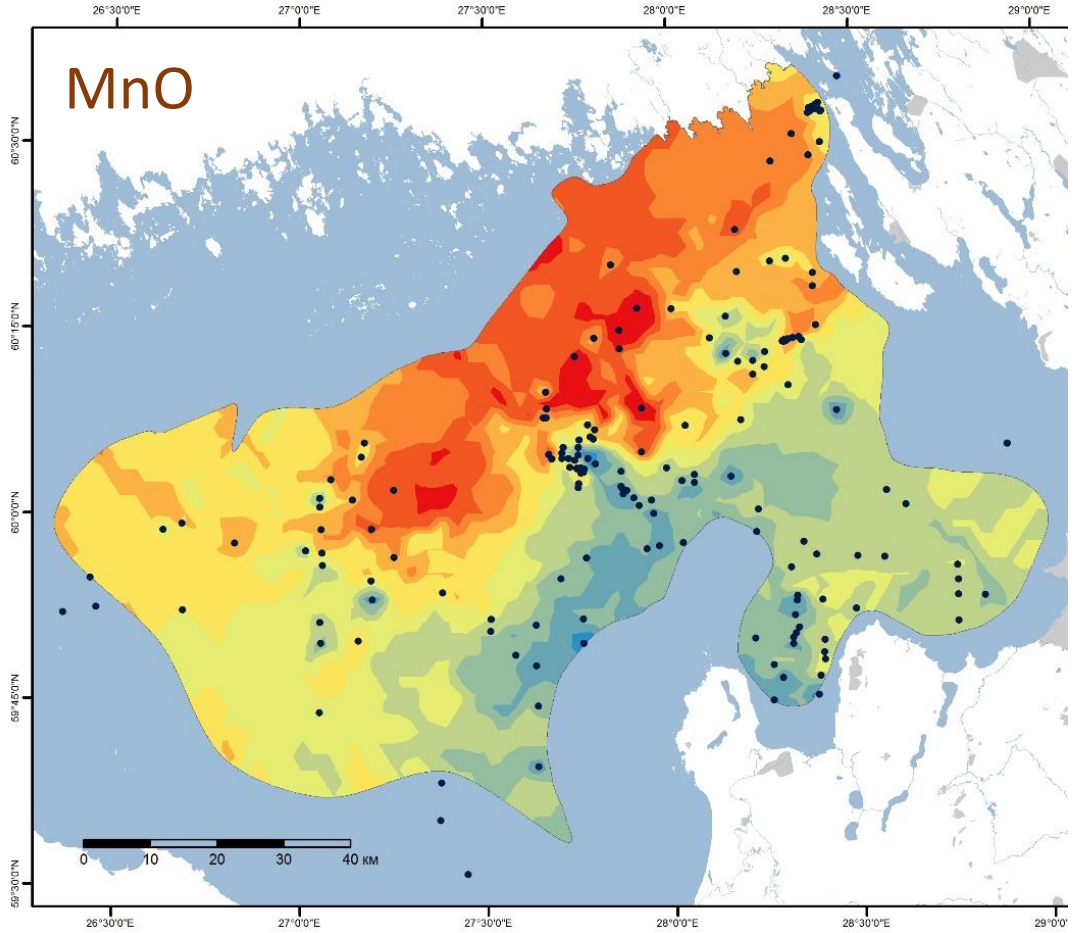
1) Fe content is growing in south-eastern direction;
2) While Mn content is decreasing





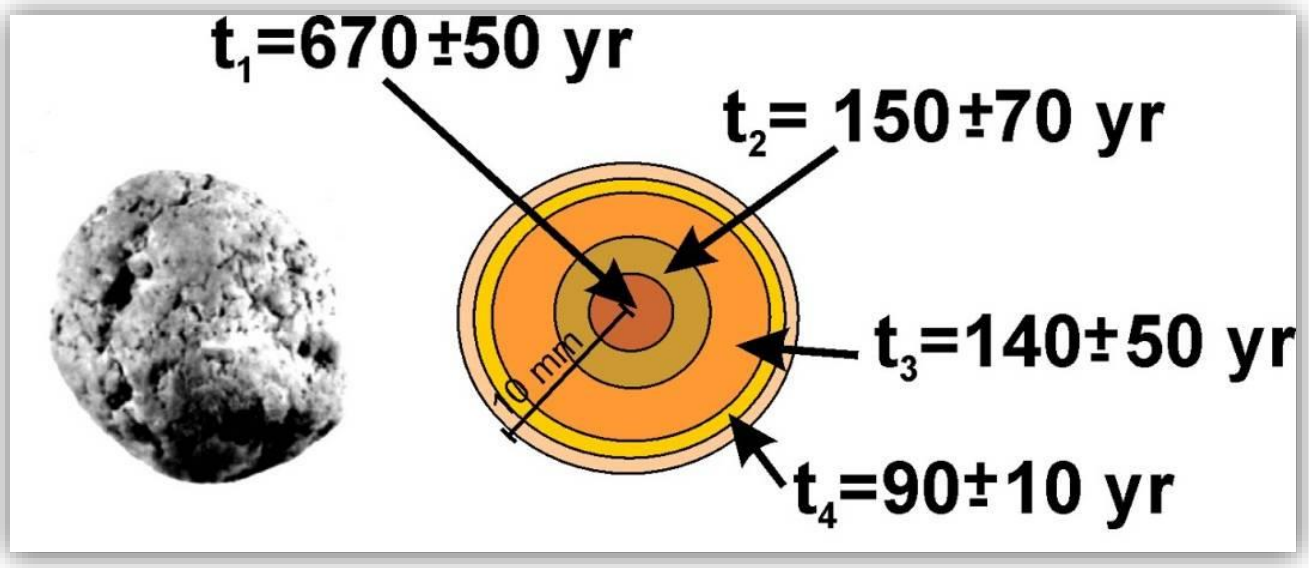
Visually, such a distribution is correlated with a map of the pre-Quaternary formation. But more data is required for final conclusions.





AGE AND GROWTH RATE

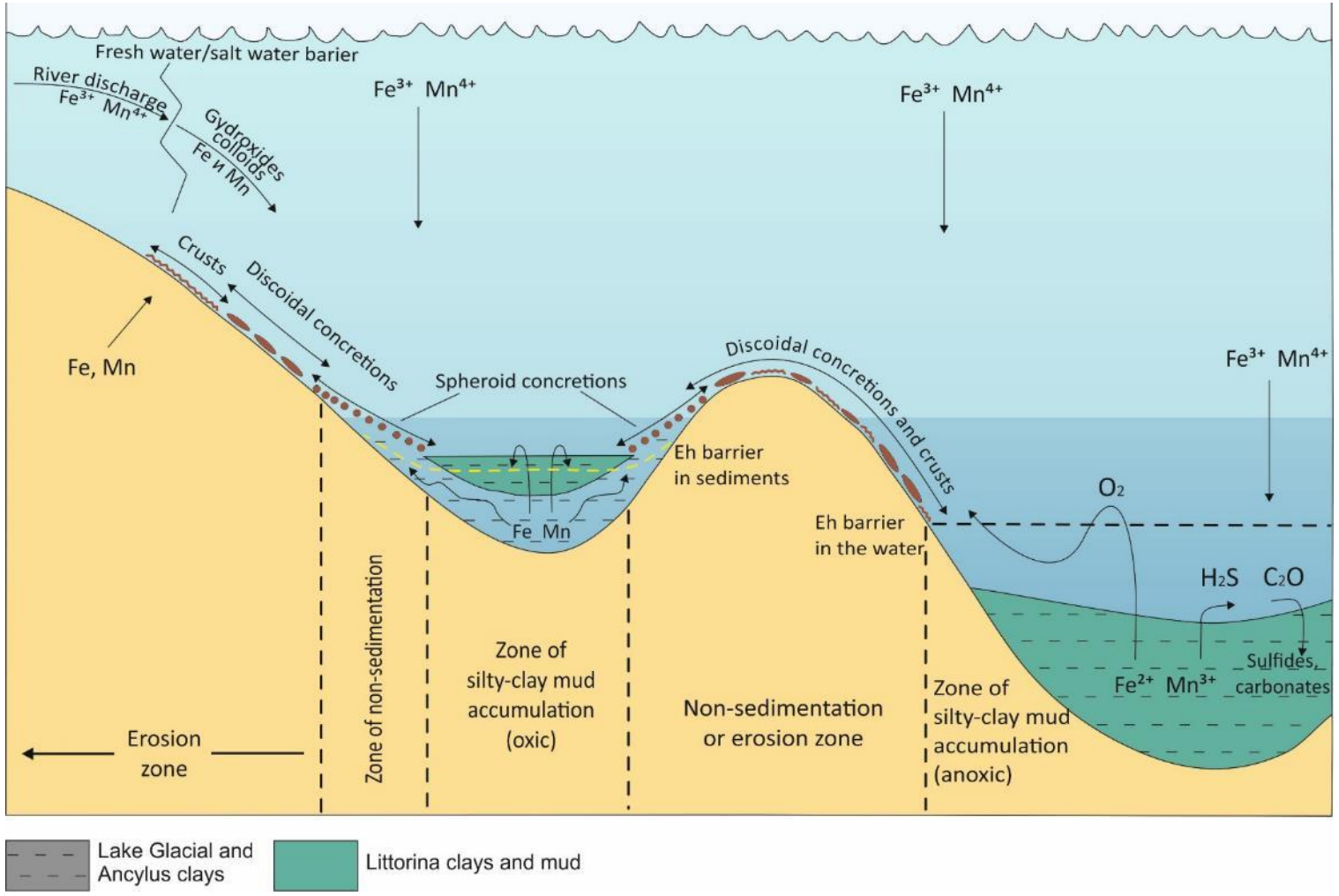
The processes of ferromanganese concretion growth are extremely active in the eastern Gulf of Finland



According to our data based on the equilibrium ^{210}Pb isotope, the age and average growth rates of spheroidal concretions from the Gulf of Finland are estimated to be 670–850 years and 0,014mm/year, respectively.

FORMATION OF FERROMANGANESE CONCRETIONS

Mostly abundant concretion fields are located at the border area between areas of reduced silty-clayey muds and oxidizing conditions.

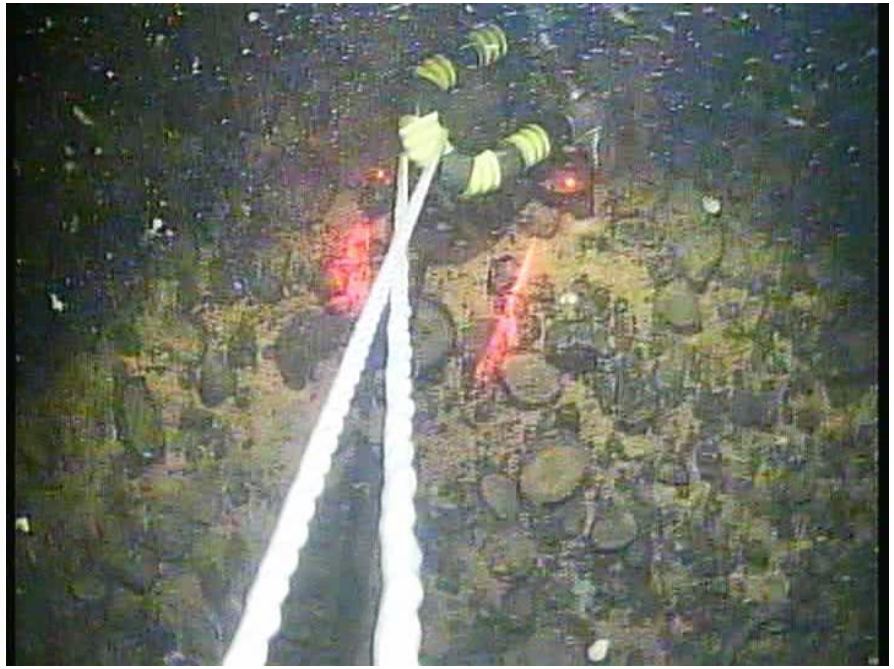


Drawn by the author based on Winterhaler, 1997

TYPICAL LAYER OF SPHEROIDAL CONCRETIONS

The thickness of the concretion layer rarely exceeds 15 cm
(up to a maximum of 50 cm)

UNDERWATER VIDEO



EXPERIMENTAL-INDUSTRIAL EXTRACTION

In 2006–2008, Petrotrans extracted concretions using the dredge pump vessel Lauwer in the Vihrevoey economic deposit area in the Vyborg Bay at the water depth 25–28,5m. In total, approximately 56,000 t of spheroidal concretions were extracted from bottom of the sea

EXPERIMENTAL-INDUSTRIAL EXTRACTION

Spheroidal Fe-Mn concretions – object of under-water extraction

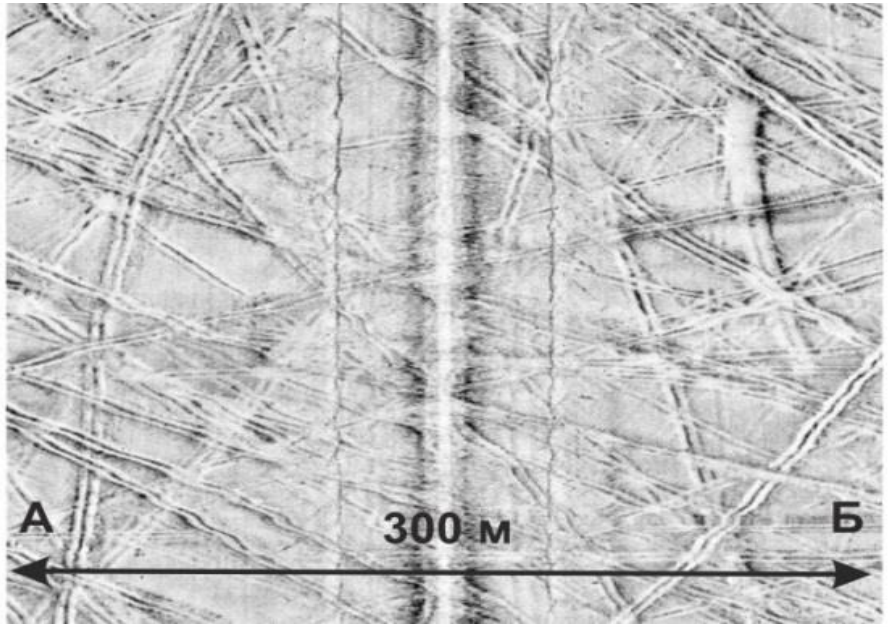
EXPERIMENTAL-INDUSTRIAL EXTRACTION

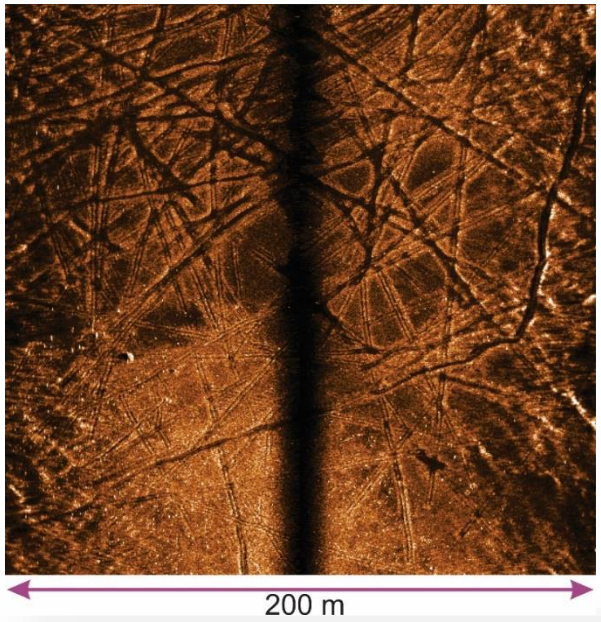
This was the first experimental-industrial extraction and processing operation of marine shallow-water ferromanganese concretions in the world.

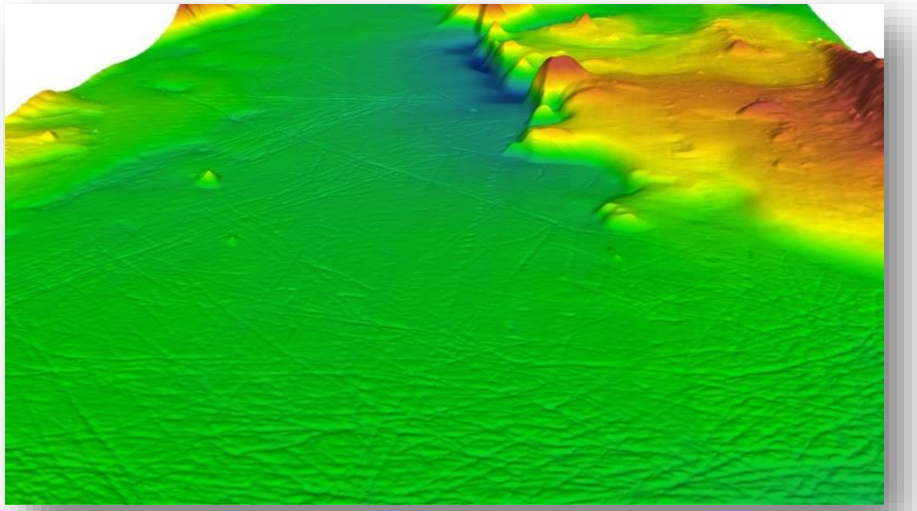
Processing of concretions into manganese concentrate

ANTHROPOGENE RELIEF

The area where consequences of extraction can be researched was formed

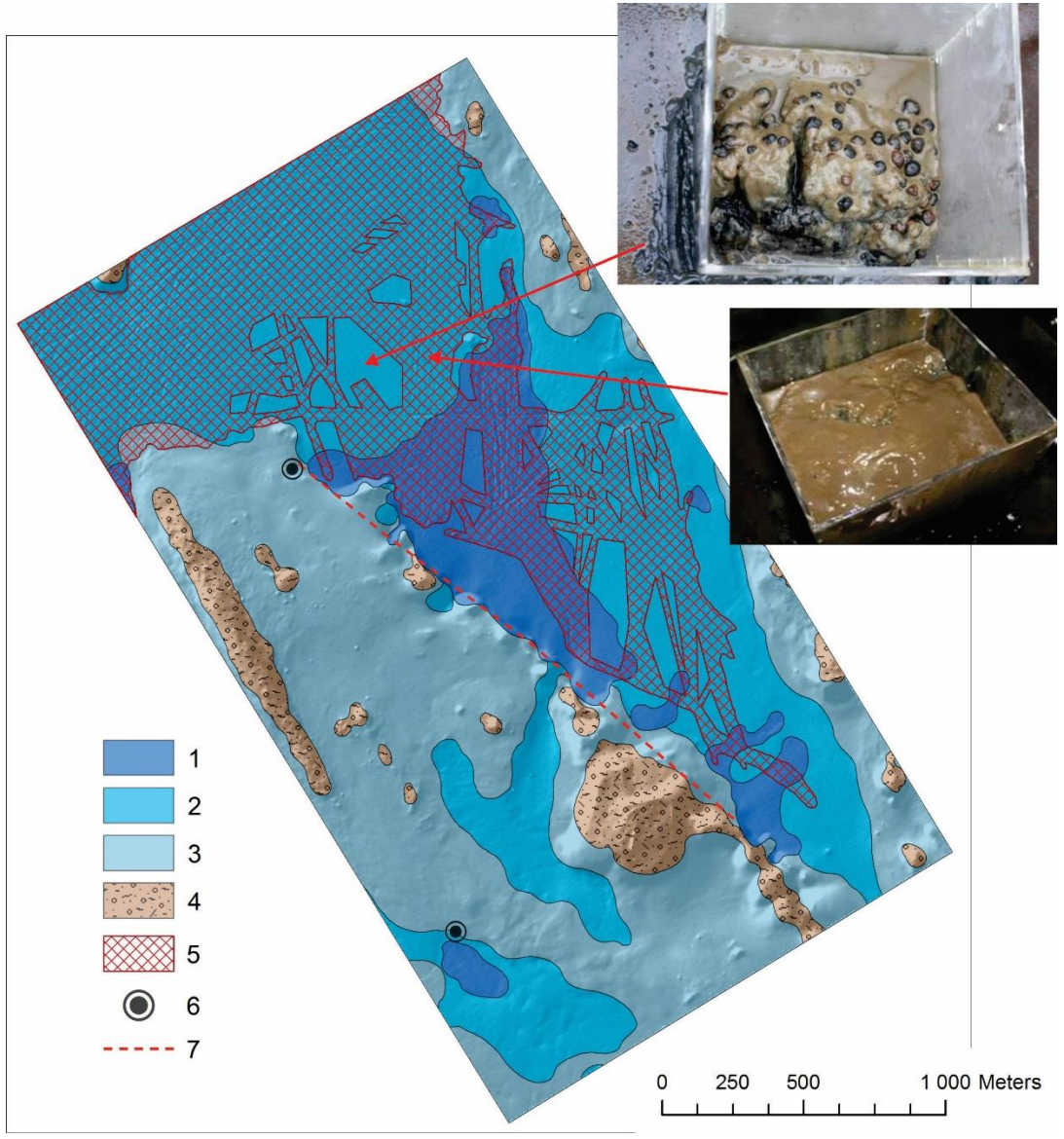






THE CONSEQUENCES OF MINING

Former slow or almost zero clastic sediment accumulation accompanied by concretions growth within the area of extraction gave way to silty-clayey mud accumulation



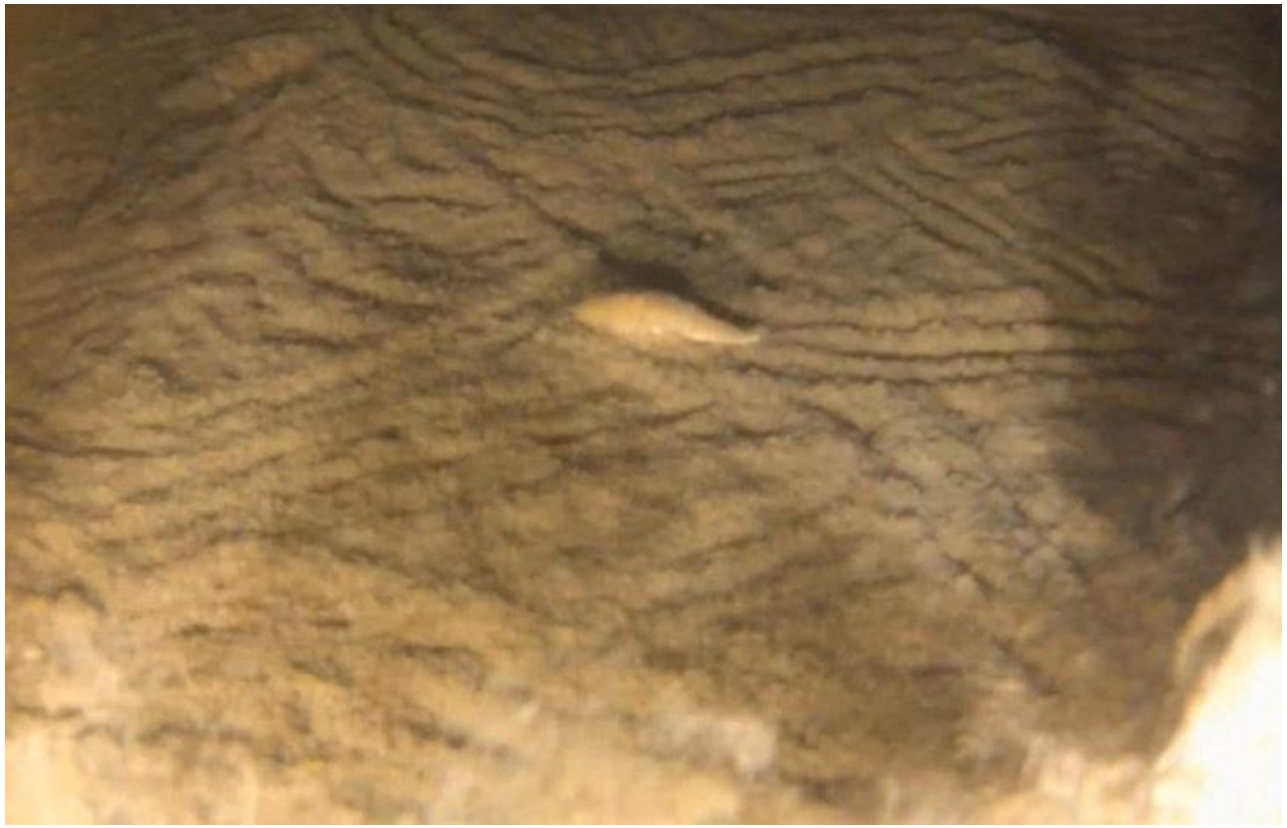
Sediment map of concretions extraction area:
1 – brackish-water mud;
2 – postglacial lacustrine clay;
3 – glacio-lacustrine varved clay;
4 – glacial till;
5 – area of concretions extraction;
6 – pockmark;
7 – supposed tectonic fault.

THE CONSEQUENCES OF MINING

Spheroidal concretions and their debris within the area of extraction are rare and mainly found buried at the depth of 5–10 cm in the sediments. The thickness of brownish-gray mud surface layer suggests significantly increased (up to 1-1,5 cm/year) sedimentation rate.

spheroidal concretions exposed on the seafloor

soft mud accumulated in the area of concretions extraction



GROW OR DISSOLVE?

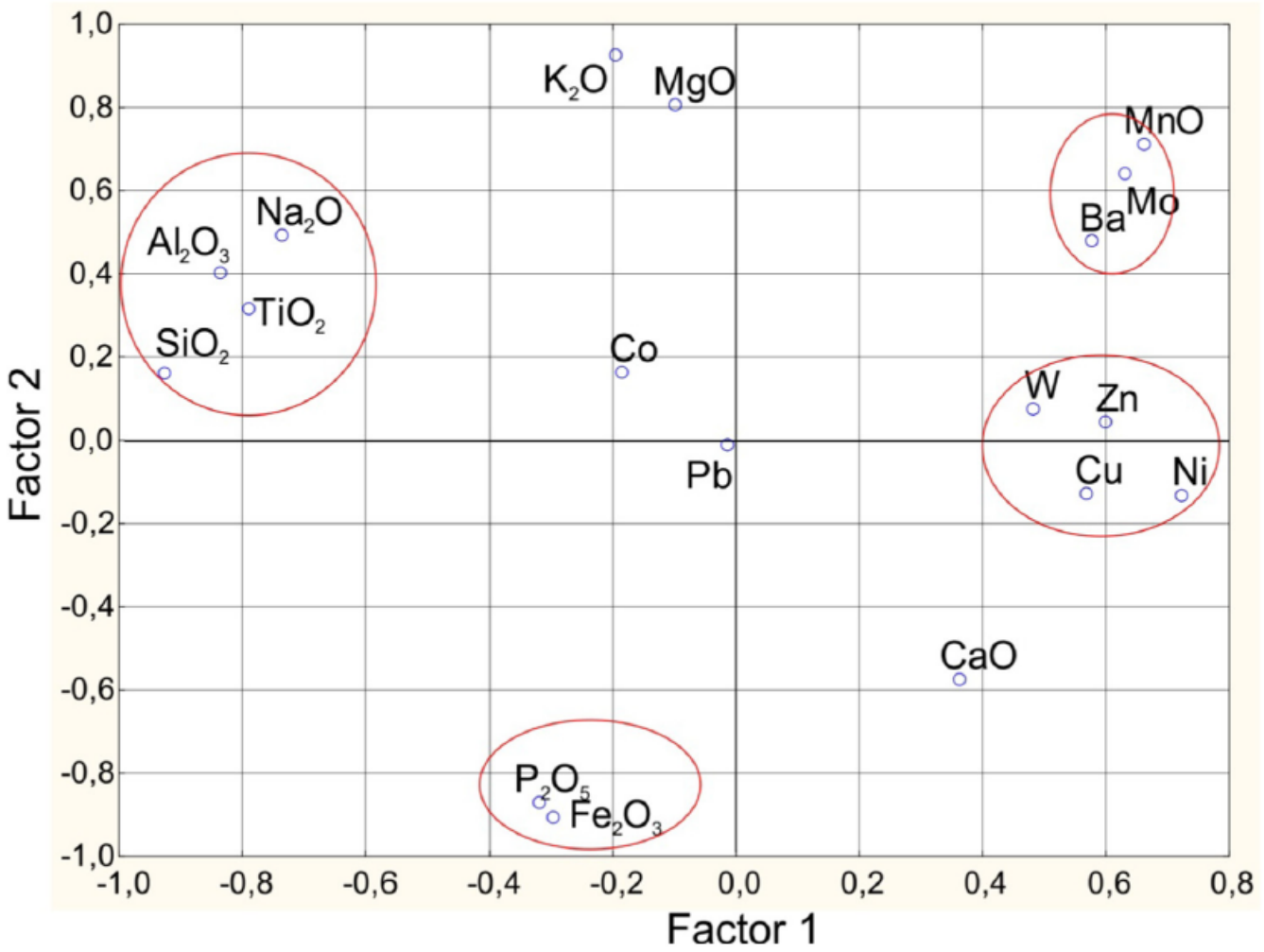
The lack of microconcretions and the smoothed surface of buried spheroidal concretions in the area of extraction indicate that they do not grow at present. Concretions conserve or, more likely, dissolve.

with granular surface (growing) – size differs from 1 mm to 20 mm

with smoothed surface (no growth), average size – 15 mm.

Results of factor analyses of chemical structure of Fe-Mn concretions of undisturbed areas

It can be assumed that concretions sampled within the area of under-water extraction essentially differ in chemical composition and geochemical structure from concretions sampled within the undisturbed areas.



4 clearly defined geochemical associations:

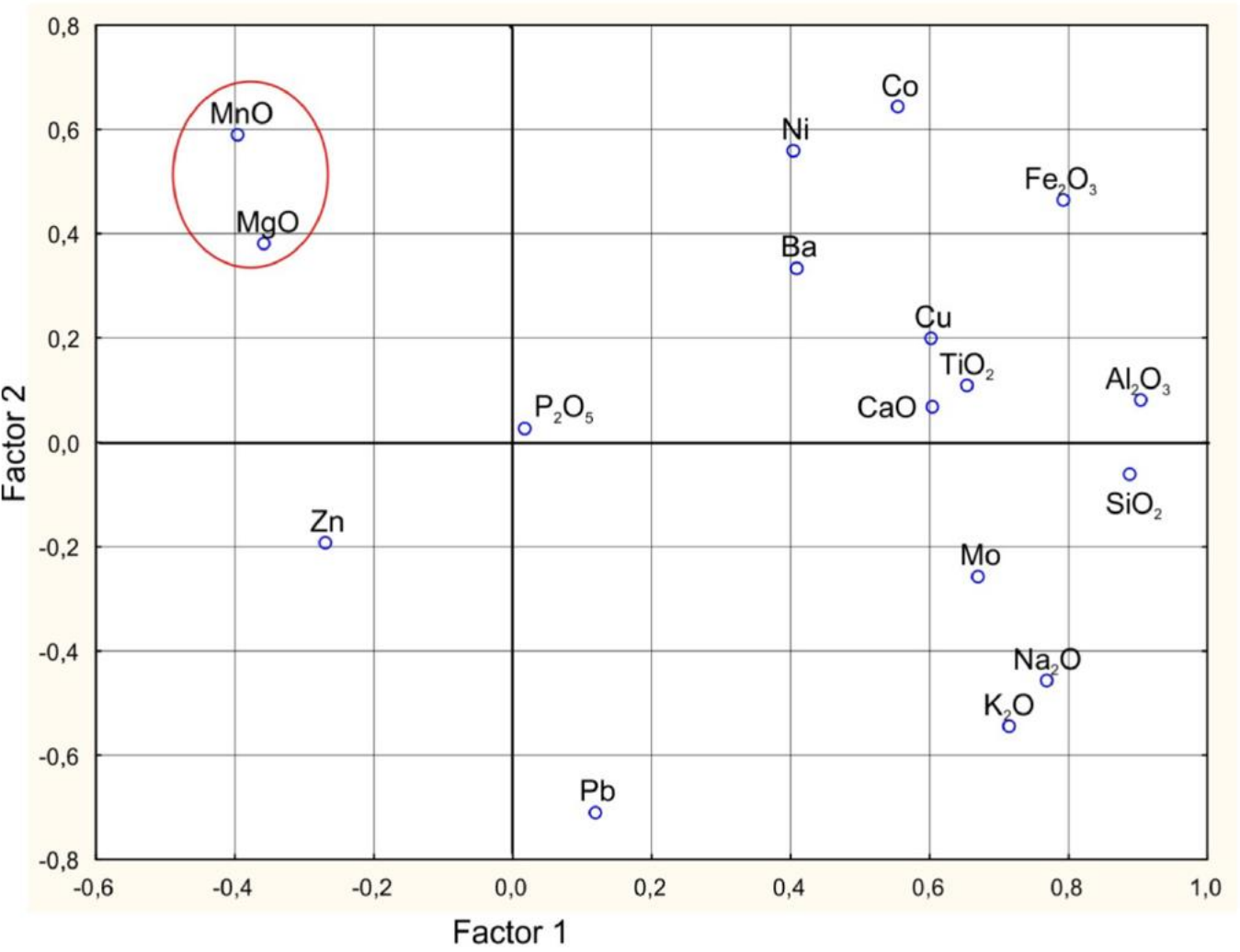
1) Mn-Mo-Ba
2) W-Zn-Cu-Ni
3) Fe-P
4) Si-Na-Al-Ti

In particular, typically Mn and Fe associations, with high values of the factor loadings, are antagonists.

P, usually closely associated with Fe-oxides

Results of factor analyses of chemical structure of Fe-Mn concretions of areas of extractions

In this case, the geochemical structure of concretions becomes indistinct and weakly expressed. Associative links typical for spheroidal concretions are essentially violated.



1) Relation chemogenic (ore) elements with adsorption centers (Fe or Mn) is very small, and these associations are almost aligned.

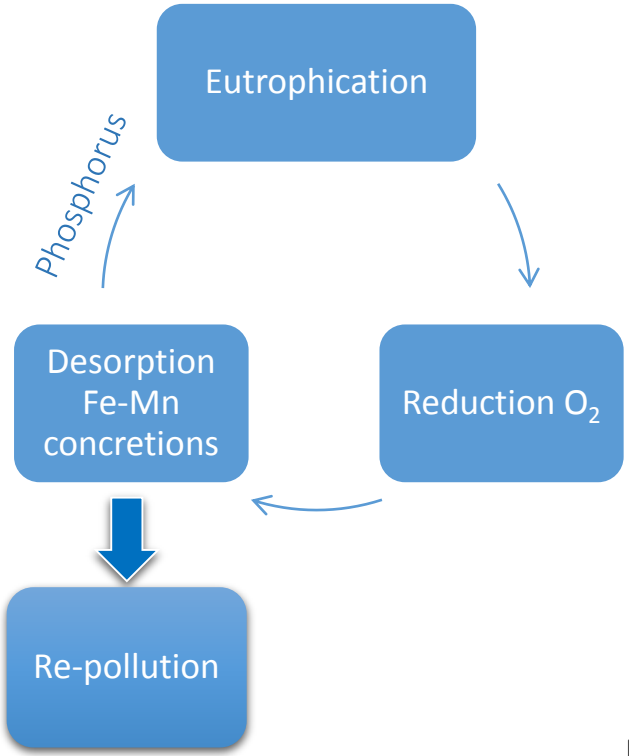
2) P is associated with Mn.

3) Ba and Mo, usually closely associated with Mn, are out of Mn association.

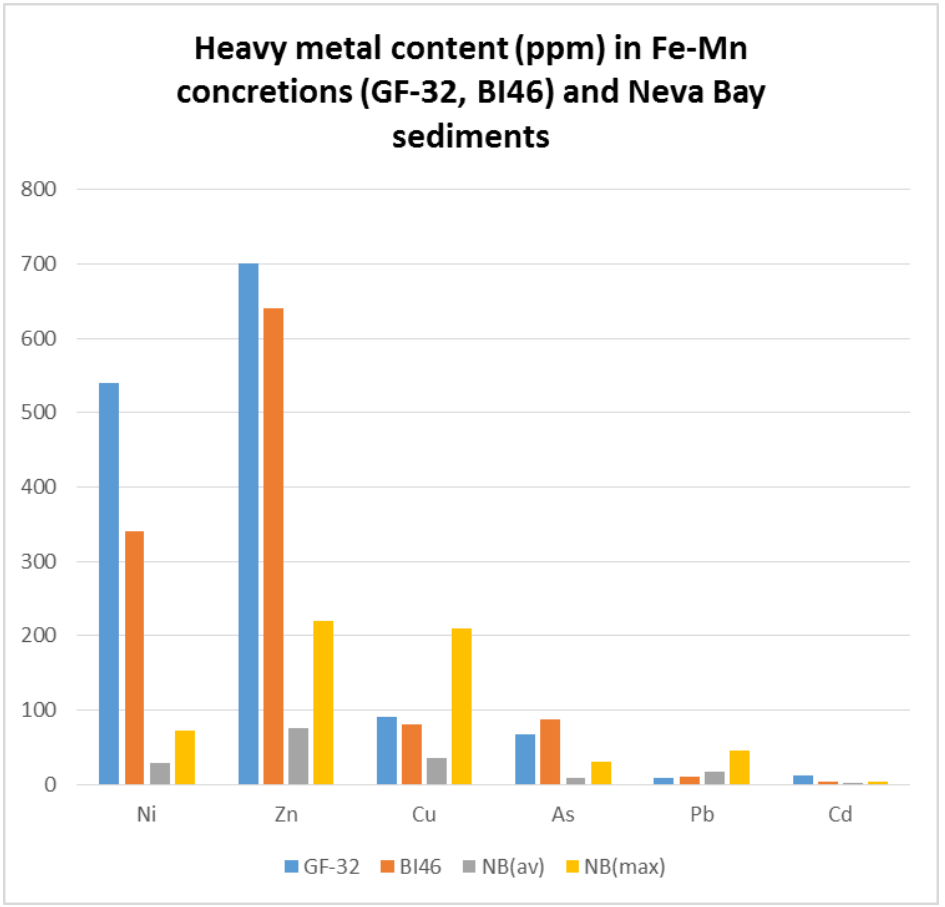
It is markedly violated, probably as a result of selective removal of elements from dissolving concretions;

ENVIRONMENTAL ASPECTS

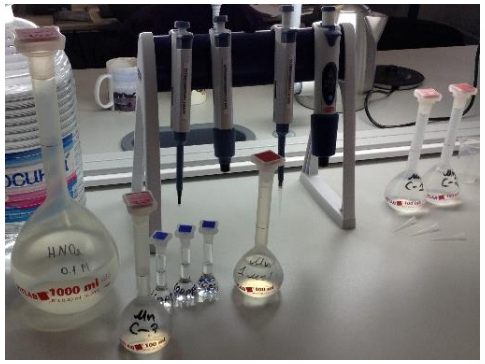
- Fe-Mn concretions have sorptive capacity and can be considered as the natural traps “cleaning” near-bottom waters from some toxic chemical elements.
- From 180 to 330 thousand tons of P_2O_5 are concentrated in the Russian part of the bay;
- Concentrations of Co, Ni, Mo in Fe-Mn concretions exceed its content in sediments by 10 times, As 30-40 times

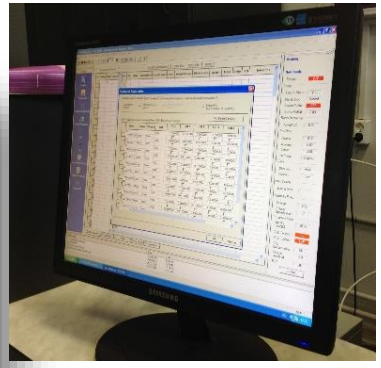


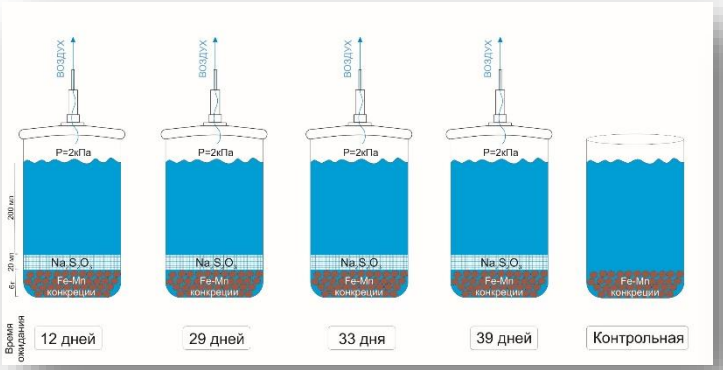
Eastern part of the Gulf of Finland, August 2013

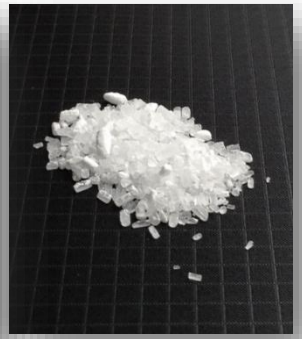


Concretions dissolution experiments



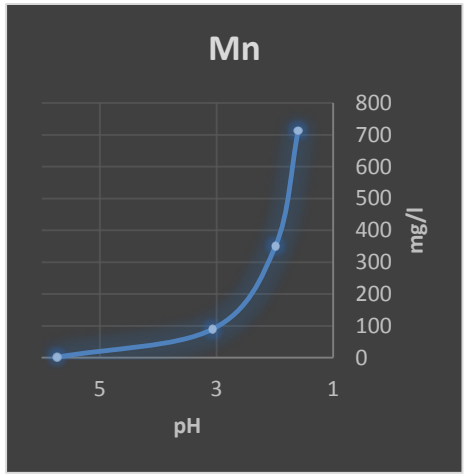


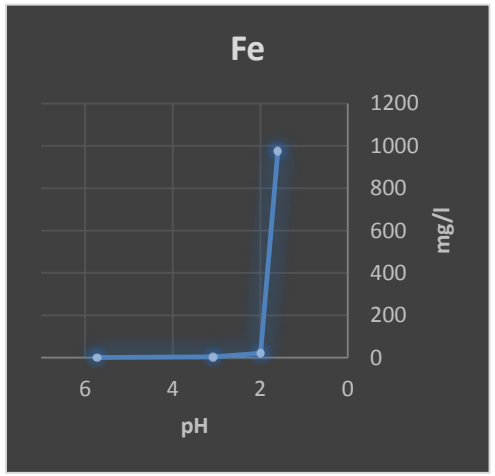


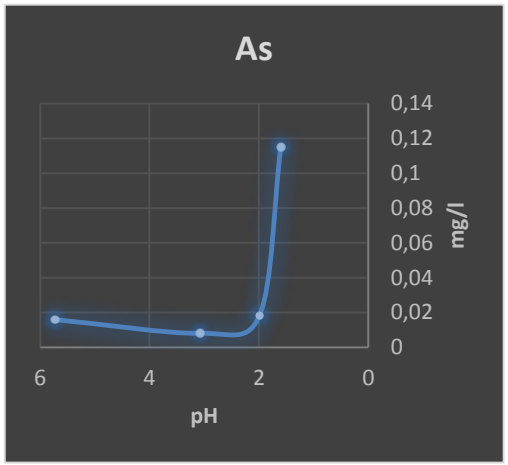


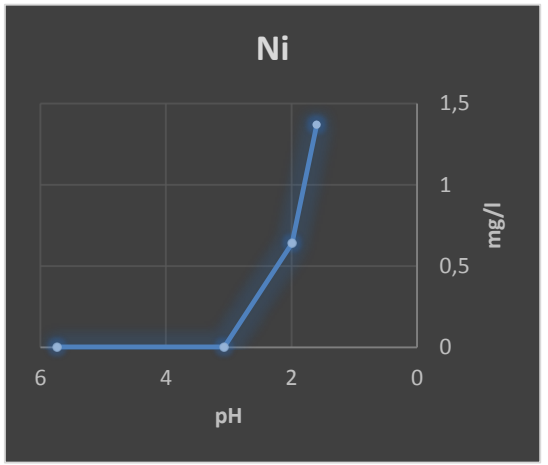
Our experiments showed contradictory results, but they all showed an active transition of chemical elements from waterϕ to water.

pH reduction

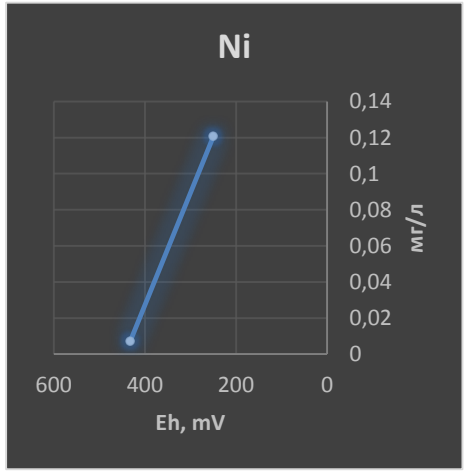


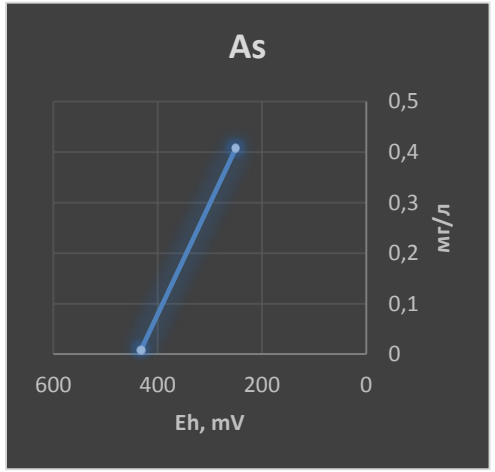




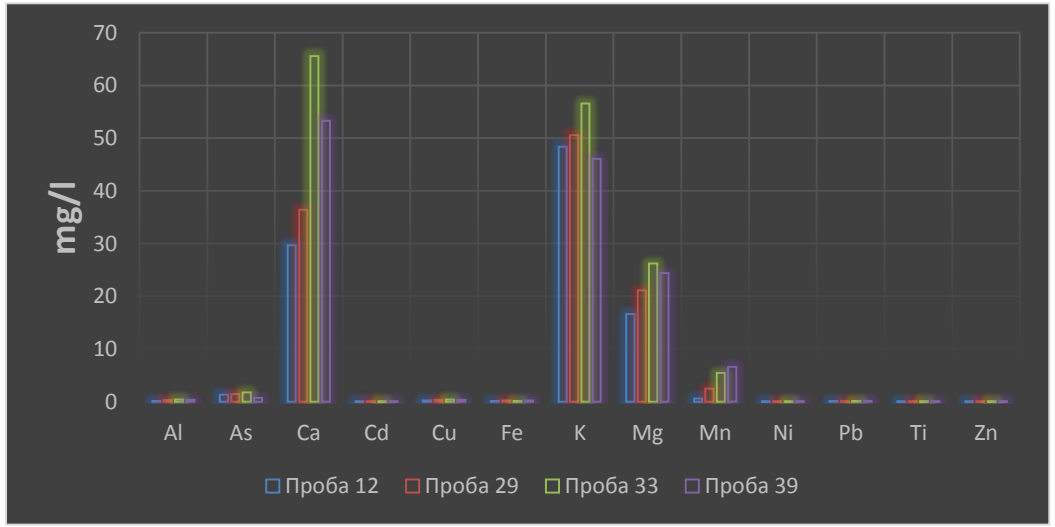


Eh reduction





reduced oxygen



CONCLUSIONS

1. Full concretionary layer is preserved only at sites outside the trenches left by mining vessels;

2. Regeneration of concretions within the trenches was not observed;

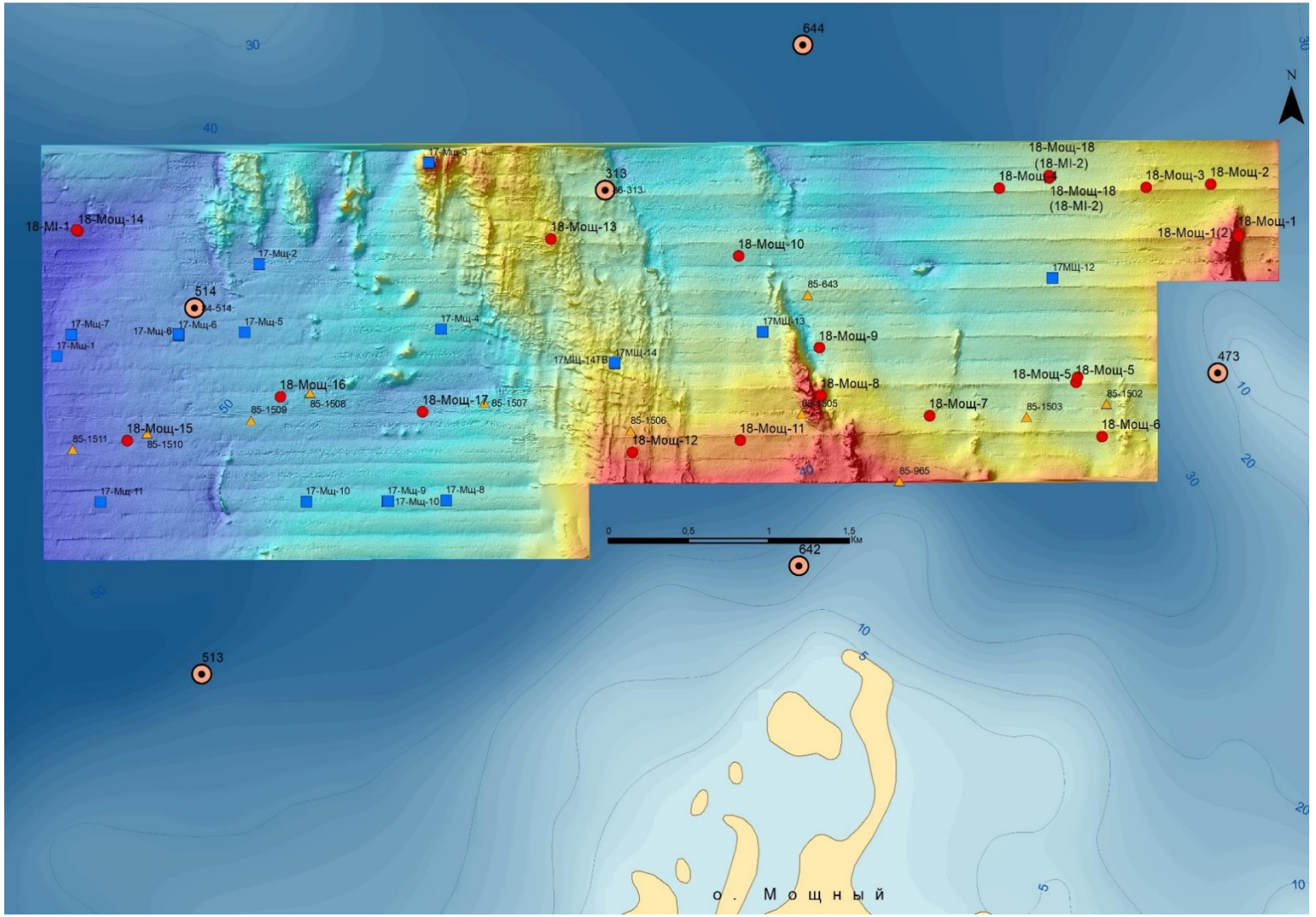
3. Within the trenches, active accumulation of silty-clay mud is now observed with an abnormally high rate of sedimentation;

4. A geochemical structure of concretions sampled within the area of under water extraction differs from normal geochemical structure of growing concretions from undisturbed areas. It is markedly violated, probably as a result of selective removal of elements from dissolving concretions;

5. The concretions remaining after under-water extraction as a result of change of sedimentation conditions become a secondary source of contamination of bottom sediments.

FUTURE RESEARCH

Research on the new areas of the island «Moshniy»




Tänan teid tähelepanu eest
Kiitos huomionne!
Thank you for Attention!