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Transformation of natural sedimentation and geochemical conditions in the area of underwater extraction of ferromanganese concretions in the Gulf of Finland (Baltic Sea).

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Due to specific environmental conditions, ferromanganese concretions in the eastern Gulf of Finland are characterized by highest levels of abundance found in shallow-water environments. In some areas at sea depths of 20-100 m, the productivity of Mn-rich spheroidal concretions layer exceeds 60 kg/m^2 (wet weight). According the recent data, total weight of concretions in the eastern Gulf of Finland is calculated to be about 10 million tonnes. The thickness of the concretion layer rarely exceeds 15 cm (up to a maximum of 50 cm). In 2006-2008, "Petrotrans ltd" carried out an experimental underwater extraction of ferromanganese concretions using a "Lauer" mining ship within the area of several square kilometres. Totally, it was extracted about 60 000 tonnes of concretions.

The area of underwater mining was investigated in 2012-2015 using side scan sonar and multibeam echosounding profiling, as well as underwater video-observations and sediment sampling in the framework of TOPCONs and Monitoring of Geological Environment State projects. Areas of definitive disturbance of environment with new specific forms of bottom relief and remnants of undisturbed bottom surface were mapped.

Within the trenches (0.5-1.0 meter depth) left by mining vessel, conditions of sedimentation were markedly changed. Former slow or almost zero clastic sediment accumulation accompanied by concretions growth within this area gave way to silty-clayey mud accumulation. The thickness of silty-clayey mud surface layer suggests abnormally high (up to 1-1.5 cm/year) recent sedimentation rate. Spheroidal concretions (up to 1 cm in diameter) and their debris are rare and mainly found buried in the sediments at a depth of 5-10 cm. Lack of microconcretions and smoothed surface of buried concretions indicate that the concretions at present do not grow. Concretions are conserved or, more likely, are being dissolved.

Comparison of the geochemical structure of concretions sampled within the area of underwater mining and outside it allowed the authors to identify their noticeable difference. Studying correlation coefficients of compositional data for concretions collected in undisturbed areas (80 samples) demonstrates the occurrence of four associations of elements: a Mn-group (Mn-Mg-Mo-Ni-Zn), a Fe-group (Fe-P-Y-P), a terrigenous group (Si-Al-Ti-Na-K) and possibly a biogenic group (Ba-Sr-Ca).

The structure of factor loadings distribution for concretions sampled within the area of underwater mining is significantly different. In particular, correlation relationship within Mn and Fe associations is very low. These associations are almost aligned. P_2O_5, usually closely associated with Fe-oxides, in this case is associated with Mn. Mo, usually closely associated with Mn, is out of Mn association. It can be assumed that the geochemical structure of concretions sampled within the area of underwater mining

was probably deformed as a result of selective removal of elements from dissolving concretions. Thus, the concretions remaining after underwater mining as a result of change of sedimentation conditions have become a secondary source of contamination of bottom sediments. It is possible to predict further dissolution of concretions buried in the sediment and their subsequent formation at the periphery of the areas of modern silty-clay mud accumulation after the trenches left by the dredger will be filled by sediments and sedimentation equilibrium will be restored as it was before concretions mining. Analysis of different forms of chemical elements in concretions also showed essential transformation in their distribution.