



Seafloor geological survey in Estonian shelf area

Sten Suuroja, Kalle Suuroja and Aado Talpas

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Abstract The first investigations of seafloor in Estonian shelf area are related to hydrographic surveying carried on in 18th c., when the Russian Hydrographic Survey launched composing the charts of the Estonian coastal sea. For the first time the scheduled systematic sampling of bottom deposits was carried out at end of the 19th c. and beginning of the 20th c. After World War II, the geological investigations on the seafloor had been launched in late 1960s – mostly aerogeophysical investigations carried in connection with oil and gas explorations. Systematic investigations directly related to the seafloor research were launched in 1973 when the Institute of Geology of the Estonian Academy of Sciences purchased R/V Joldia. Medium-scale (1:200 000) integrated geological mapping of the Estonian shelf area supplemented with exploration works started in 1981, when the respective programme was compiled at the Geological Survey of Estonia and R/V Marina as well as equipment needed for seafloor investigations were purchased. The investigation results are stored at the Depository of Manuscript Works whereas the reports of investigations and the metadata are kept in a digital database of the Euroseismic. New impetus in seafloor geological investigations came when in 1995 during large-scale geological mapping the hypothesis of presence of an impact structure in NW Estonia in the area of Neugrund bank was assumed and the impact origin of the structure was proven by marine geological investigations. Beside these many applied investigations and coastal monitoring were carried out in cooperation with several local and foreign partners.

Keywords *Baltic Sea, Gulf of Finland, Estonian shelf, Neugrund impact structure, Neugrund Bank, seafloor, bottom deposits, geological mapping, geophysical investigations, seismoacoustic sounding, applied research.*

Sten Suuroja [s.suuroja@egk.ee], Kalle Suuroja [k.suuroja@egk.ee], Aado Talpas [a.talpas@egk.ee], all Geological Survey of Estonia, Kadaka tee 82, 12618 Tallinn, Estonia. Manuscript submitted 1 December 2007; accepted 9 December 2007.

INTRODUCTION

In connection with the planned Nord Stream gas pipeline, especially due to an idea to lay it across the economic zone of Estonia, it has been sometimes spoken that the Estonian shelf has not been investigated at all, or at least is extremely poorly investigated. The authors of this paper are the geologists who also carry out marine geological investigations and therefore wish to overrule the above misleading opinions. Maybe the Estonian shelf is not as thoroughly investigated as the seafloor bordering Finland or Sweden, but definitely it is not unexplored. Unfortunately, in 1993 R/V Marina was given away, which practically meant termination

of systematic seafloor geological investigations at the Geological Survey of Estonia. The investigation results are stored at the Depository of Manuscript Works whereas the reports of investigations and the metadata are kept in digital databases.

BEGINNING OF INVESTIGATIONS

The first investigations are related to hydrographic surveying of seafloor, because in the process of compiling marine charts the surveyors used to determine the composition of the top layer of bottom deposits in separate points. Thus, the beginning of seafloor investigations can be dated back to the 18th c., when

the Russian Hydrographic Survey launched composing the charts of the Estonian coastal sea. The first written notes about seafloor investigations are related to curative mud in the Rootsiküla Bay on the Saaremaa Island.

For the first time the scheduled systematic sampling of bottom deposits was carried out in 1883 during a marine expedition (Braun 1894). In 1900–1910, Russian scientists I. Knipovich and S. Popov performed a geological cross-section from Kotlin Island to Osmussaar Island. Approximately at the same time German research vessel Poseidon carried out expeditions reaching the western part of the Gulf of Finland, which included also investigations of bottom deposits (Kuppers 1906). The first notes about the distribution and composition of iron-manganese nodules in the Baltic Sea were provided by Russian investigators I. Samoilov and A. Titov (1922). Important information on the seafloor setting is also included in the Estonian pilot book issued by colonel lieutenant J. Mey in 1927. W. Twenhofel (1938) discusses, in his study, the seafloor geology in the area of the West–Estonian Archipelago. However, at that time the investigations were focused mostly on hydrographical issues.

After World War II, the Soviet Union launched systematic geological investigations of the seafloor only in late 1960s, and they were mostly aerogeophysical investigations carried in connection with oil

and gas exploration (Effendejeva 1967; Tugolesov et al. 1968).

Systematic investigations directly related to the seafloor research of the Estonia's territorial waters were launched in 1973 when the Institute of Geology of the Estonian Academy of Sciences purchased the research vessel Joldia (Orviku 1974). More detailed investigations (mapping) were carried out in Pärnu, Narva and Tallinn bays and the Sea of Straits (Väinameri) (Lutt 1983, 1985). However, the equipment at that time enabled to obtain the information only about the uppermost part of the seafloor (Raukas & Lutt 1993). More investigations were focussed on the processes occurring in the bays (Matsalu, Keibu,

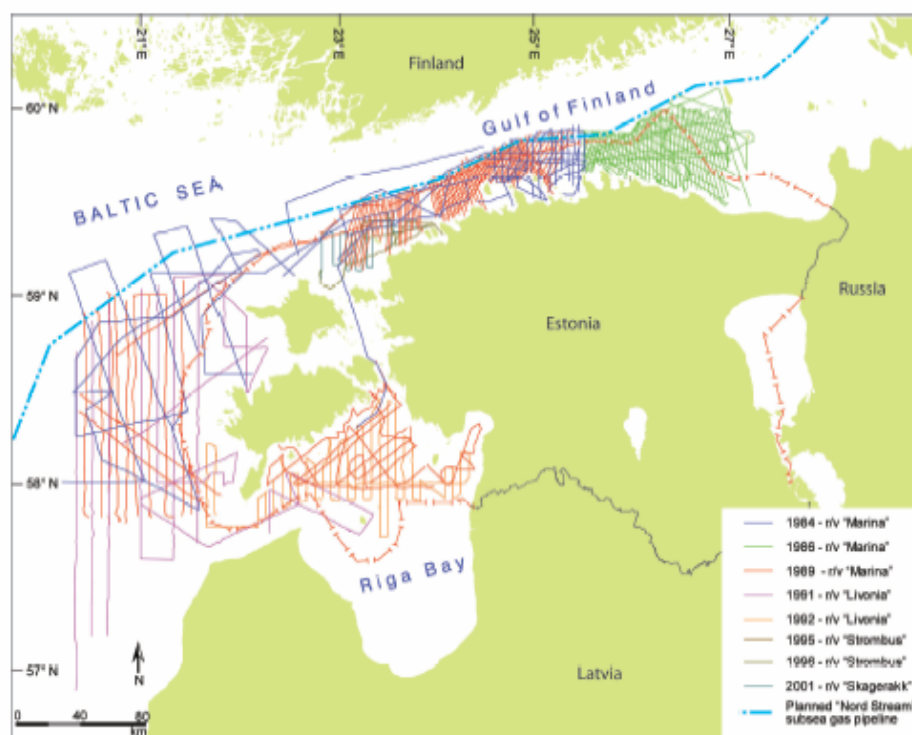


Fig. 1. Location of profiles of seismoacoustic sounding, carried out in participation of EGK.

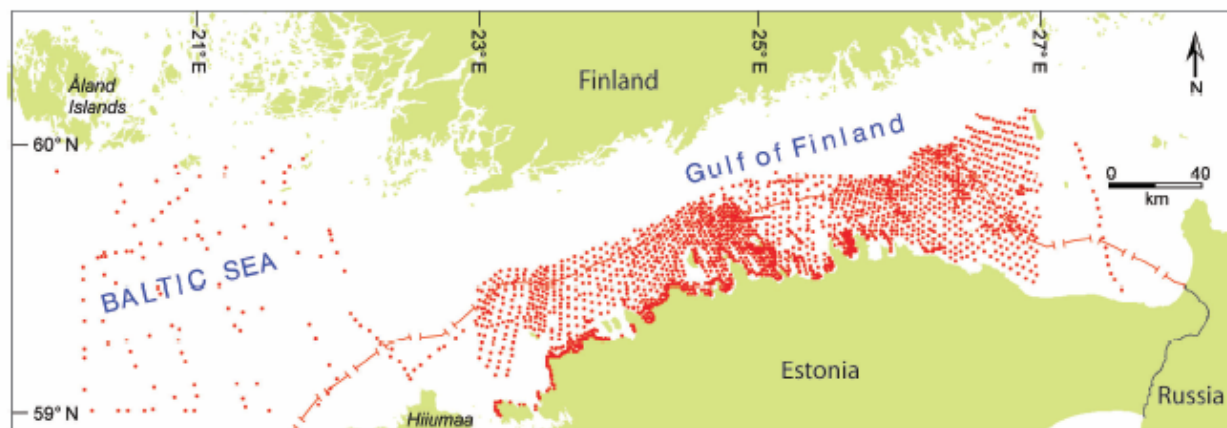


Fig. 2. Sampling points of bottom deposits in the Gulf of Finland.

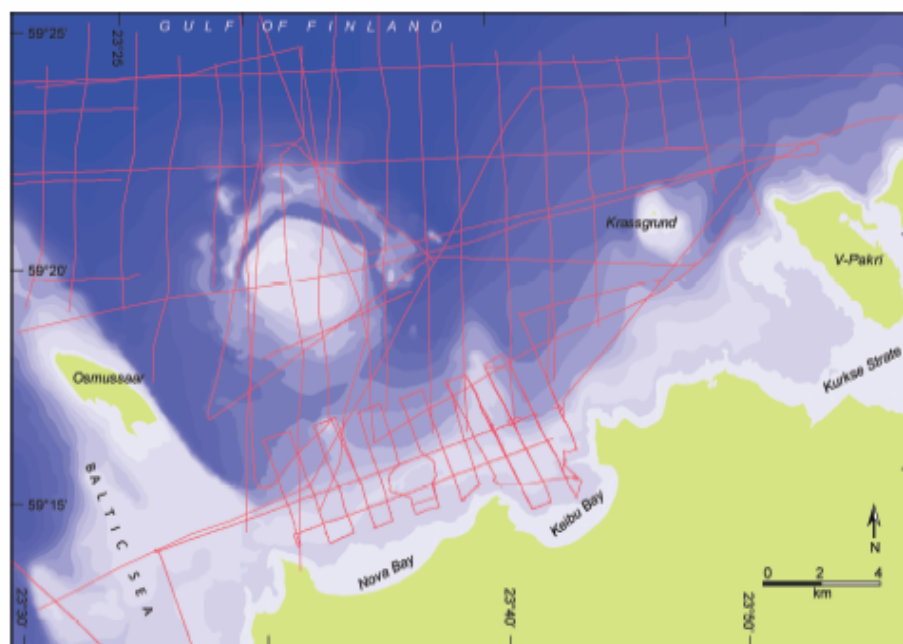


Fig. 3. Profiles of seismoacoustic sounding carried out in the area of the Neugrund crater.

Tagalaht, Küdema; Lutt & Kask 1980) and on the shore (Orviku et al. 1982).

In 1980-1985, during the expeditions arranged by the Institute of Oceanology of the USSR Academy of Sciences ca. 500 rock samples were collected by dredging from underwater escarpments (the formation of the sampled rocks was identified for 60 samples, and the Cambrian or Vendian was defined for 86 samples). These data considerably facilitated deciphering of the seismoacoustic sounding profiles (Kiipli et al. 1993).

SYSTEMATIC INVESTIGATIONS

Systematic seafloor investigations (geological mapping) were started in 1981, when the respective programme was compiled at the Geological Survey and research vessel *Marina* as well as equipment needed for Seafloor investigations were purchased (Malkov et al. 1983). The programme was aimed at a medium-scale (1:200 000) integrated geological mapping of the Estonian shelf and additional exploration works. As a result, seafloor maps were compiled, firstly, at a scale of 1:500 000 (Malkov et al. 1983), later at 1:200 000 (Malkov et al. 1986; Talpas et al. 1986; Talpas et al. 1993).

The mapping covered a major part of the Estonian territorial waters. It was agreed that the All-Union Geological Institute (VSEGEI) carried out mapping of the eastern Gulf of Finland (east-

ward of Aseri settlement). The data obtained during these investigations are still stored at VSEGEI and in spite of repeated attempts and former agreements we have failed to obtain these materials. The first set of maps (Malkov et al. 1983) included the maps of bottom deposits, Quaternary deposits, bedrock geological map and the map of seafloor topography.

Another map set covering the central Gulf of Finland (Talpas et al. 1989) was compiled based on seafloor investigations done by geophysical methods (mainly seismic sounding) and sampling of loose bottom deposits by gravity corer and grip scoop. Be-

sides, drillholes penetrating into the crystalline rocks were made on small islands of the Gulf of Finland (Põhja-Uhtju, Väike-Tütarsaar (2), Vaindloo). The above-mentioned mapping resulted in compilation of the following set of maps:

- map of seafloor topography;
- bedrock geological map;
- map of Quaternary deposits;
- geomorphological map;
- map of bedrock topography;
- map of mineral deposits;
- lithological map of the topmost part of bottom deposits;
- a set of geochemical maps;
- map of factual material of geophysical investigations;
- map of drillholes and sampling points.

The seafloor geological investigations are presently continued at the Geological Survey of Estonia (Eesti Geoloogiakeskus, EGK). In 1993 were compiled

Table 1. Geological mapping of the Estonian territorial waters and economic control zone at a scale of 1:500 000 and 1:200 000.

1981-1983	Regional geophysical investigations in Tallinn Bay at a scale of 1:200 000
	Regional geophysical investigations at a scale of 1:200 000 on Estonian shelf between Naissaar Island and Juminda Peninsula
	Geological mapping of Estonian shelf at a scale of 1:500 000
1986-1989	Geological mapping of Estonian shelf between Juminda Peninsula and Tütarsaar Island at a scale of 1:200 000
1989-1992	Geological mapping of Estonian shelf between Vormsi Island and Juminda Peninsula at a scale of 1:200 000

geological maps of the part of the Gulf of Riga within the Estonian territorial waters and in 1994 a set of maps covering the western Gulf of Finland came out. Within the later works almost 4000 km of seismoacoustic sounding was carried out, bottom deposits were sampled in 3884 points and on small islands (Aegna, Koipse, Rammu) were made drillholes reaching the crystalline basement. Besides, in cooperation with VSEGEI engineering–geological investigations were carried out within Tallinn Bay.

The main investigation method was seismoacoustic sounding carried out mostly by a profilograph operating at frequencies up to 450 Hz. Besides, high–frequency acoustic profilograph (24 kHz) and echo–sounder were used. The data were recorded on thermochemical paper. Seismoacoustic methods in some cases enabled to “penetrate” the complex of Quaternary deposits and sedimentary rocks down to the surface of crystalline basement. Besides, the bottom deposits were sampled by up to 18 m long gravity corer, grip–scoop and sometimes with vibrocorer. Maximum 14 m of drillcore was obtained by this method. At 1:200 000 geological mapping the distance between geophysical profiles as well as the distance between stations was 2 km. The drilling and sampling were carried out in locations selected on the grounds of seismoacoustic sounding results. In 1991–1992 by R/V Livonia were carried expeditions to the central Baltic Sea, during which by geophysical methods (seismoacoustic sounding at 250–500 Hz and 4 kHz and magnetometry) was investigated seafloor within the Estonian territorial waters and economic zone.

In 1993 R/V Marina was given away, which practically meant termination of systematic seafloor geological investigations at the Geological Survey of Estonia. The investigation results are stored at the Depository of Manuscript Works as reports of investigations and the metadata – in digital databases.

THE NEUGRUND IMPACT STRUCTURE

New impetus in seafloor geological investigations came when in 1995 during large–scale geological mapping the hypothesis of presence of an impact structure in NW Estonia in the area of Neugrund bank was erected, mainly on the grounds of composition and distribution of gneiss–breccia erratic boulders (Suuroja & Saadre 1995). In 1996 during Swedish–Estonian expedition the Neugrund Bank and its surroundings were investigated by seismoacoustic sounding from R/V Strombus and the presence of a crater–like structure was identified (Suuroja et al. 1997). Inspired by this discovery, the mapping of the newly discovered crater and its surroundings was launched in 1996 (Suuroja et al. 1999). In 1998 samples were taken from the crater wall during diving from R/V Mare and thus the impact

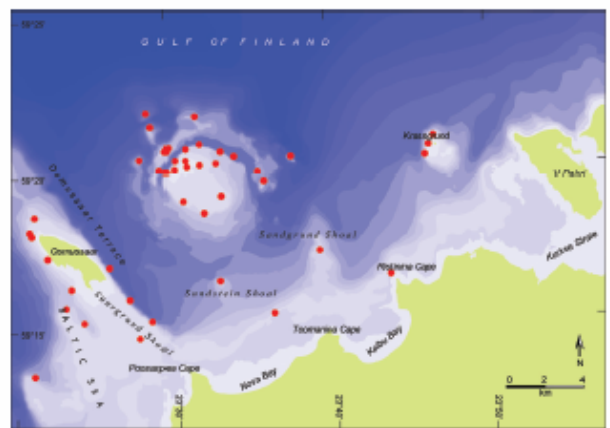


Fig. 4. Location of diving sites in the area of the Neugrund crater and surroundings.

origin of the structure was proven, as well as the source area of the gneiss breccia erratics in Western Estonia (Suuroja & Suuroja 1999, 2000). In 2000–2004 the crater structures were investigated by sidescan sonar and video robot (Suuroja & Suuroja 2004).

APPLIED RESEARCH

Although the systematic mapping was terminated, several applied investigations and coastal monitoring were carried out in cooperation with several local and foreign partners. Bottom deposits of the shallow coastal sea were investigated from German R/V Littorina (in 1995 and 1996) and Humboldt, firstly to obtain data for modelling the coastal processes. These investigations included seismoacoustic sounding (1–1.5 kHz), sidescan sonar profiling and vibrocoreing. In 1994–2001 several attempts were made to investigate the shallow coastal areas (Tagalaht, Paldiski, Eru, Pakri and Hara bays and sea area within Riguldi map sheet), but for several reasons these works were not accomplished.

Besides, contractual works have been carried out to investigate the waters and sample the bottom deposits of several small harbours (Haapsalu, Heltermaa, Kab-



Fig. 5. Sand investigation areas (blue polygons) and approved resources of subbottom sand (red polygons) in the surroundings of Tallinn.

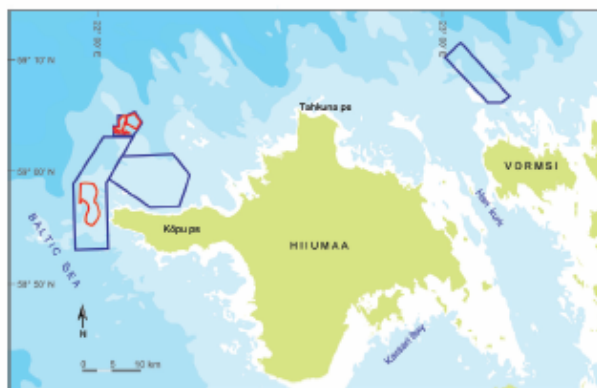


Fig. 6. Sand investigation areas (blue polygons) and approved resources of subbottom sand (red polygons) in surroundings of Hiiumaa Island.

erneeme, Munalau, Mõntu, Pärnu-Jaagupi, Rohuküla, Toila). Investigations have been carried out to obtain a general review of distribution of sand and gravel (A.

References

- Amantov, A., Hagenfeldt, S., Söderberg, P. 1995. The Mesoproterozoic to Lower Paleozoic sedimentary bedrock sequence in the northern Baltic Proper, Aland Sea, Gulf of Finland and Lake Ladoga. Proceedings of the third Marine Geological Conference "The Baltic", Prace Państwowe Instytutu Geologicznego 149, 19–25.
- Amantov, A. V., Spiridonov, M. A., Moskalenko, P. E. 1988. Geology of the pre-Quaternary formations along the margin of the Baltic Shield as an indicator of the evolution of the Gulf of Finland up to most recent stage. Geological Survey of Finland, Special Paper 6, 87–93.
- Braun, M. 1894. Physikalische und biologische Untersuchungen im westliche Teile des finnischen Meerbusens. Arch. Naturk. Liv-, Est- u. Kurl. Ser. II/X, 1–130.
- Effendjeva, M. A. 1967. The relief of the crystalline basement on Baltic Sea aquatory in magnetometrical regards. Sovetskaya geologiya 4. In Russian.
- Grindel, D. 1824. Über die Untersuchung eines Seeschlammes auf der Insel Oesel. Med.-pharm. Blätter I.
- Flodén, T., Puura, V., Söderberg, P., Tuuling, I., Suuroja, K. 1994. The Ordovician–Silurian transitional beds in the seafloor between Gotland and Hiiumaa islands, Baltic Proper. Proceedings of the Estonian Academy of Sciences 43 (1), 1–17.
- Kask, J., Suuroja, S. 1995. Gulf of Riga Project. Subproject 5d: Heavy metals. Chemistry and data compilation, Riga.
- Kiipli, T., Malkov, B., Pirrus, E., Põlma, L. 1993. Sedimentary cover. In J. Lutt and A. Raukas (eds.): Geology of the Estonian shelf. Estonian Geological Society, 53–75, Tallinn.
- Lutt, J. 1985. Väinamere põhjasetted. [Bottom deposits of the Väinameri]. Tallinn, 238 pp. In Estonian.
- Talpas), several perspective areas have been investigated in more detail (J. Kask). Curative mud deposits have studied in Haapsalu and on Hiiumaa and Vormsi islands (J. Kask). Geologists have participated also in several intensely discussed topical investigations: marine geological investigations along possible alignments of the bridge across Suur Väin and in the location of Undva Harbour. The impact of fast ferry traffic on the shore of Viimsi Peninsula and Aegna and Naissaar Island and the possibilities of mitigation their adverse impact have been examined as well. The content of pollutants and heavy metals in the bottom deposits of several harbours has been determined and several dredging works have been supervised.

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Lutt, J. 1993. Late- and postglacial deposits of the Estonian shelf. Diss. PhD, Tartu Univ., 140 pp.

Lutt, J. 1993. Geological survey. In J. Lutt and A. Raukas (eds.): Geology of the Estonian shelf. Estonian Geological Society, 5–9. Tallinn.

Lutt, J., Kask, J. 1980. Matsalu lahe põhjasetted. [Bottom deposits of the Matsalu Bay.] Loodusvaatlusi 1978 / I, Tallinn, Valgus, 167–178. In Estonian.

Malkov, B., Dulin, E., Kiipli, T., Talpas, A. 1983. Report of the mapping Baltic Sea shelf area jointed to Estonian territory in 1981–1983. Estonian Geological Fond 4014, Tallinn. In Russian.

Malkov, B., Kiipli, T., Rennel, G., Tammik, P., Dulin, J. 1986. The regional geological-geophysical investigation at a scale of 1:200 000 of Baltic Sea shelf area jointed to Estonian SSR territory in 1984–1985. Estonian Geological Fond 4188, Tallinn. In Russian.

Mey, J. 1927. Eesti Loots. Meresõidu ja lootsiasjanduse käsiraamat. [Estonian Pilotage Manual]. Tallinn.

Orviku, K. 1974. Estonian offshore. ETA Toimetised, Tallinn, 1–112. In Russian.

Orviku, K., Lutt, J., Kask, J., Veisson, M. 1982. Eesti nüüdisrannavööndi ja rannikumere kaitse geoloogilisi aspekte. [Geological aspects of protection Estonian shore and offshore.] In Eesti NSV rannikumere kaitse. Tallinn, Valgus, 28–35. In Estonian.

Puura, V. 1991. Origin of the Baltic Sea depression. In A. Grigelis (Ed.) Geology and Geomorphology of the Baltic Sea. Nedra, Leningrad, 267–290.

Puura, V., Floden, T. 1995. Crustal structure of the Baltic Sea basin. In The Baltic – The fourth Marine Geological Conference, Uppsala, Abstract Volume. Sveriges Geologiska Undersökning 68, 1–68.

Puura, V., Floden, T. 1997. The Baltic Sea drainage basin – a model of a Cenozoic morhostructure reflecting the early Precambrian crustal pattern. Sveriges Geologiska Undersökning 86, 131–137. Uppsala.

- Samoilov, I. V., Titov, A. G. 1922. Iron- and manganese concretions on bottom of Black Sea, Baltic Sea and Barents Sea. *Trudy Geol. Min. AN* 19/2. In Russian.
- Suuroja, K., Saadre, T. 1995. The gneiss-breccia erratic boulders from northwestern Estonia as witnesses of an unknown impact structure. *Bulletin of Geological Survey of Estonia* 5/1, 26–28.
- Suuroja, K., Suuroja, S. 1999. Neugrund Structure – a submarine meteorite crater at the entrance to the Gulf of Finland. *Estonia Maritima* 4, 161–189.
- Suuroja, K., Suuroja, S. 2000. Neugrund Structure – the newly discovered submarine early Cambrian impact crater. In I. Gilmour and C. Koeberl (eds.): *Impacts and the Early Earth*, Springer Verlag, Berlin–Heidelberg, *Lecture Notes in Earth Sciences* 91, 389–416.
- Suuroja, K., Suuroja, S., Puurmann, T. 1995. Neugrund Structure as an impact crater. *Bulletin of Estonian Geological Society* 2/96, 32–41.
- Suuroja, S., Suuroja, K. 2004. The Neugrund Marine Impact Structure (Gulf of Finland, Estonia). In H. Dypvik, M. Burchell, P. Claeys (eds.): *Cratering in Marine Environments and on Ice*, Springer Verlag, Berlin–Heidelberg, *Impact Studies* 75–95.
- Talpas, A., Kivisilla, J., Körvel, V., Mardla, A. 1989. The regional geological-geophysical mapping at a scale of 1:200 000: sheets O-35 II, O-35-III. Maps and explanatory note. *Estonian Geological Fond* 4339, Tallinn. In Russian.
- Talpas, A., Kask, J., Väling, P., Mardla, A., Sakson, M., Genno, E. 1994. Balti mere çelfiala geoloogiline kaardistamine lehtedel O-34-VI, O-34-XII, O-35-I ja II. Maps and explanatory note. *Estonian Geological Fond* 4860, Tallinn. In Estonian.
- Tavast, E. 1993. Bedrock topography In J. Lutt and A. Raukas (eds.): *Geology of the Estonian shelf*. *Estonian Geological Society*, 5–9. Tallinn.
- Tugolesov, D.A. 1968. The problems of prospecting oil and gas on Baltic Sea area. *Sovetskaya geologiya* 3. In Russian.
- Tuuling, I. 1998. Shipborne geophysical study of an Ordovician–Silurian carbonate platform, Farå–Hiiumaa area, northeastern Baltic Sea. *Meddelanden Stockholms Universitets för Geologi och Geokemi*, Thesis, Stockholm.
- Tuuling, I., Floden, T., Sjöberg. 1997. Seismic correlation of the Cambrian sequence between Gotland and Hiiumaa in the Baltic Sea. *GFF* 119, 45–54.
- Tuuling, I., Floden, T. 2001. The structure and relief of the bedrock sequence in the Gotland–Hiiumaa area, northern Baltic Sea. *GFF* 123, 35–49.
- Twenhofel, W. 1938. The Silurian and high Ordovician Strata of Estonia, Russia and their Faunas. *Bulletin Museum of Zoology* 56/4, Harvard, 289–354.
- Vaher, R. 1993. Tectonics. In J. Lutt and A. Raukas (eds.): *Geology of the Estonian shelf*. *Estonian Geological Society*, 39–48. Tallinn.