

Subfossil mollusc shells of the Baltic Sea and the possibilities of their usage in the stratigraphy and correlation of the Baltic Sea sediments

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Abstract: Subfossil mollusc shells in Estonia are widely spread both in contemporary and ancient sediments and for a long time they have served successfully for stratigraphical, palaeogeographical and archaeological purposes. There are extremely good conditions for the investigation of the subfossil mollusc fauna in Estonia. The bedrock in coastal area consists here mainly of limestones and dolomites, which are covered with carbonaceous till and aqueoglacial deposits. In Estonian nearshore environs molluscs had suitable living conditions and enough material to build up the shells. They are better preserved than in neighbouring countries. The molluscs can give precise information about the conditions of palaeobasins. This is primarily due to their good preservation and a large number of species. Their history began in the Palaeozoic Era and they are spread nearly in all biotopes. The molluscs are rather susceptible to the environment they inhabit and can therefore give information about the water depth, salinity, temperature and isotopic composition of water. Malacological method will give a great help in the correlation of the on- and offshore deposits and landforms and this method is well developed in Estonia.

Key words: mollusc fauna, environment, biostratigraphy, correlation.

Introduction

The investigation of the subfossil mollusc shells has a long history in Estonia. The first data was published by Eichwald (1852). The Estonian scholar

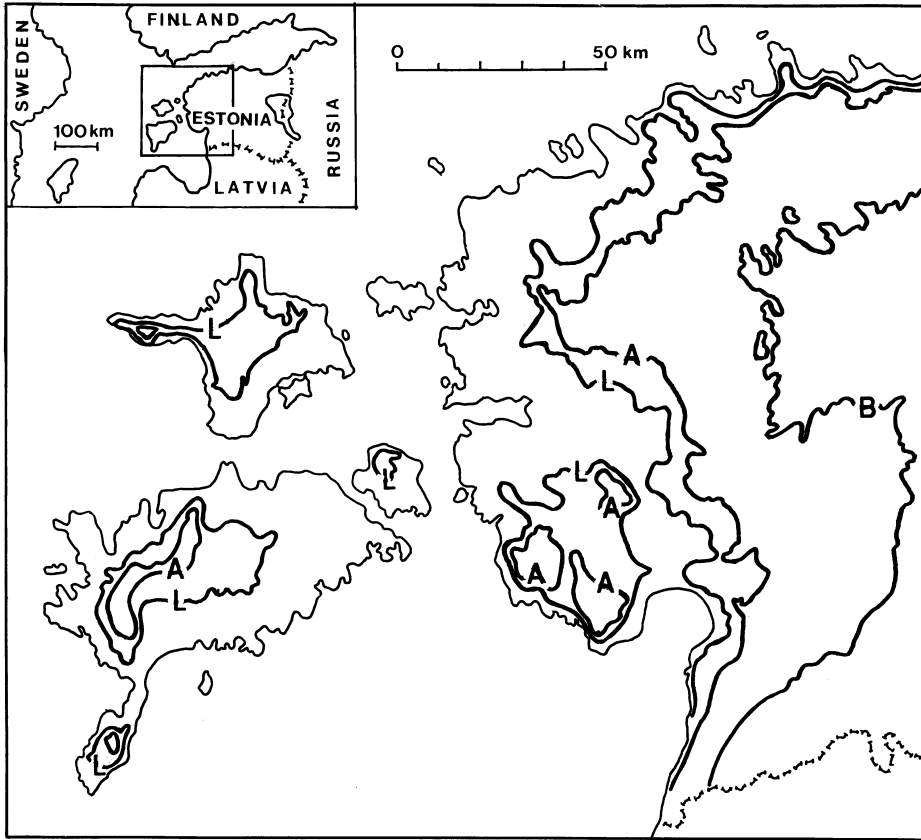


Fig. 1. Location of the study area showing the displacement of the ancient shorelines of the Baltic Sea in Estonia after Helgi Kessel.

B – Baltic Ice Lake, **A** – Ancylus transgression shoreline and **L** – shoreline at the end of the Litorina Stage.

Fr. Schmidt was the first in the Baltic Sea area to find in 1864 the subfossil freshwater *Ancylus fluviatilis* shells in beach deposits of western Estonia (Schmidt 1865). Before World War II, Orviku (1934) and later Jaanusson (1944) studied the subfossil mollusc fauna in West Estonia. Since the fifties the main researcher in the eastern Baltic was the late Helgi Kessel (1958, 1965).

The current hydrological conditions reveal marked variations in the salinity and temperature conditions within the Baltic Sea. The situation was much the same in the geological past and therefore direct stratigraphical correlations on the basis of molluscs are rather complicated to perform. But the investigations in the different parts of the Baltic basin (Sauramo 1958; Lundqvist 1963; Kliewe & Janke 1982) have shown the same trends in the vertical distribution of subfossil molluscs all over the basin. We have collected and analysed subfossil mollusc shells from many sites in Estonia, which allow new conclusions to be drawn.

As is well known, in the postglacial development of the Baltic Sea the stages of slightly brackishwater Yoldia Sea, the freshwater Ancylus Lake, the brackish-water Litorina and Limnea seas are distinguished. The displacement of the ancient shorelines in Estonia is shown on figure 1. The conditions of nearshore deposition in the ancient bodies of water deviated little from those at present, although there were differences during the all above-mentioned stages and changes from regressive to transgressive mode in the shore displacement (Hyvärinen & Raukas 1992). The coastal relief forms and sediments of the Ancylus Lake, Litorina and Limnea seas are well presented in Estonia, but the evolution of the Yoldia Sea is rather unclear (Raukas 1994). The subfossil molluscs occur in the sediments of all Baltic Sea stages, except the Yoldia Sea deposits. The characteristic for the Yoldia Sea mollusc *Portlandia (Yoldia) arctica* Gray has been found in varved clays near Stockholm and Söderstälje in eastern Sweden. In glacial and aqueoglacial sediments of Latvia they have been redeposited from the older marine sediments (Dreimanis 1970; Molodkov *et al.* 1988) and it is not excluded that they are not *in situ* in Sweden either.

Study area and methods

The mollusc shells have been collected from the whole coastal area of Estonia, but to show the effectiveness of the method, we give three examples only from Hiiumaa Island. In Late-glacial and Early Holocene Hiiumaa was a small open sea islet washed by strong wave action during heavy storms. As a result, it displays a great variety of ancient and contemporary shore types (Raukas *et al.* 1994).

In the northern part of the island the rich mollusc fauna was found in the Partsi (Fig. 2) gravel pit where a long section of inclined-bedded sandy gravels, shingles and cobbles exposes (Fig. 3). This coarse-grained bed and underlying sands at an absolute height of 9–15 m contain freshwater molluscs but covering sands in the uppermost part of the section at an absolute height of 15.6–19.8 m contain brackishwater molluscs (Raukas *et al.* 1996). The first ones belong to the Ancylus Stage, the latter ones to the Litorina Stage. This suggests “innormal” bedding conditions in the mentioned section, because in the neotectonically lifting areas the younger sediments must be at lower altitudes.

Several physical methods (^{14}C , ESR) have been applied to the age determination of molluscs. The isotopic composition of oxygen and carbon in the subfossil mollusc shells of the Baltic Sea was used for establishing the palaeosalinity and -temperature (Punning *et al.* 1988).

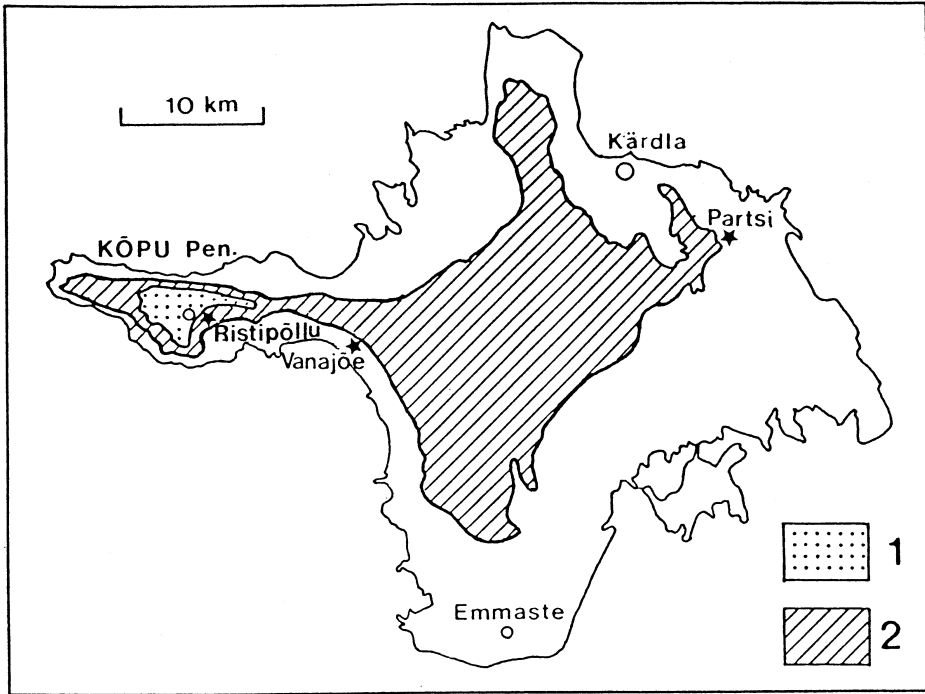


Fig. 2. Location of the investigated sections on the Island of Hiiumaa.
1 – *Ancylus* transgression shoreline and 2 – the shoreline at the end of the Litorina Stage.

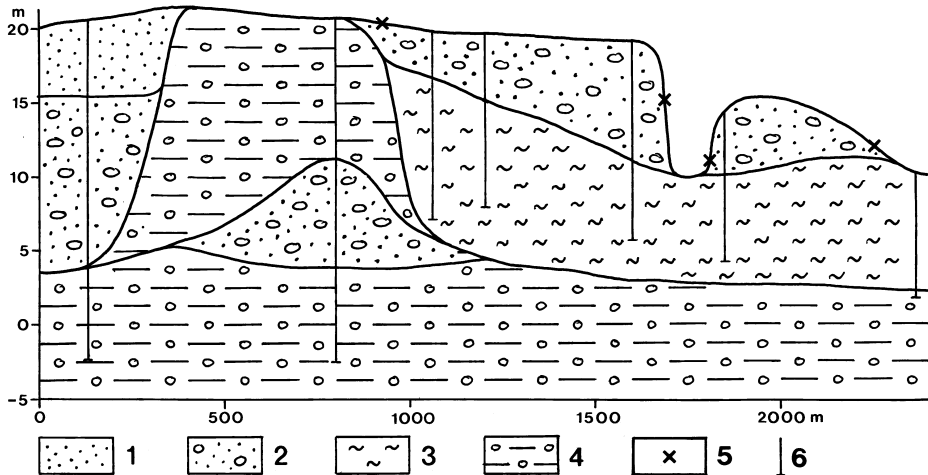


Fig. 3. Geological cross-section at Partsi gravelpit after G. Eltermann with the complements.

1 – sand, 2 – sandy gravel and pebbles, 3 – varved clay, 4 – till, 5 – sampling points, 6 – borehole.

Results

Among the 163 shells, found in the Partsi gravel pit at the height of about 12 m in the medium-grained sand in the lowermost part of *Ancylus* sediments the author has identified *Lymnaea baltica* and *Bithynia tentaculata* as dominants (90%), with the accompanying species being *Valvata piscinalis*, *Ancylus fluviatilis* and *Sphaerium nitidum* (Fig. 4). In the gravelly facies up to 10–15 m above the present sea level they often were only hardly identifiable broken species. Shells have preserved well only in the interlayers of fine-grained sediments or in sandy “pockets”. In total of 117 well preserved mollusc shells collected from the gravelly facies the following species prevailed: *Lymnaea baltica* (80%), *Ancylus fluviatilis* and *Bithynia tentaculata*. Only some tiny shells of *Lymnaea stagnalis*, *Valvata piscinalis*, *V. cristata* and *Sphaerium nitidum* were identified. The similar composition of malacofauna in both layers of *Ancylus* Lake sediments shows, that the palaeoecological situation in the Partsi area



Fig. 4. Typical *Ancylus* Lake subfossil mollusc shells from the sediments of the Partsi gravel pit:

1 – *Lymnaea baltica*, 2 – *Bithynia tentaculata*, 3 – *Ancylus fluviatilis*, 4 – *Valvata cristata*, 5 – *Sphaerium nitidum*.

was rather stable over the long span of time. During the slightly brackishwater Mastogloia Sea, which was the transitional stage between the Ancyclus Lake and Litorina Sea, the composition of fauna began to change. Besides freshwater molluscs *Bithynia tentaculata*, *Lymnaea baltica*, *Pisidium amnicum* also slightly brackishwater species *Theodoxus fluviatilis* and *Macoma baltica* have been found. According to Kessel and Raukas (1967), at the end of the Ancyclus Lake the water-level lowered about 20–25 m before the following Litorina transgression.

In the beginning of the Litorina Stage, only very tiny and thin-walled forms existed, as the size and thickness of the mollusc shells depends directly on the mineral content in the water they inhabit. In the Partsi gravel pit, at a height of 15.6–17.8 m in the Litorina sands already typical, rather thick-walled brackish-water molluscs, mainly *Cerastoderma glaucum* (80%) with some addition of *Macoma baltica*, *Hydrobia ulvae* and *Littorina littorea* were found (Fig. 5). The limits of the salinity of *Hydrobia ulvae* are very broad. They can inhabit water with the salinity higher than 20‰ (Petersen 1993) but tolerate also the salinity

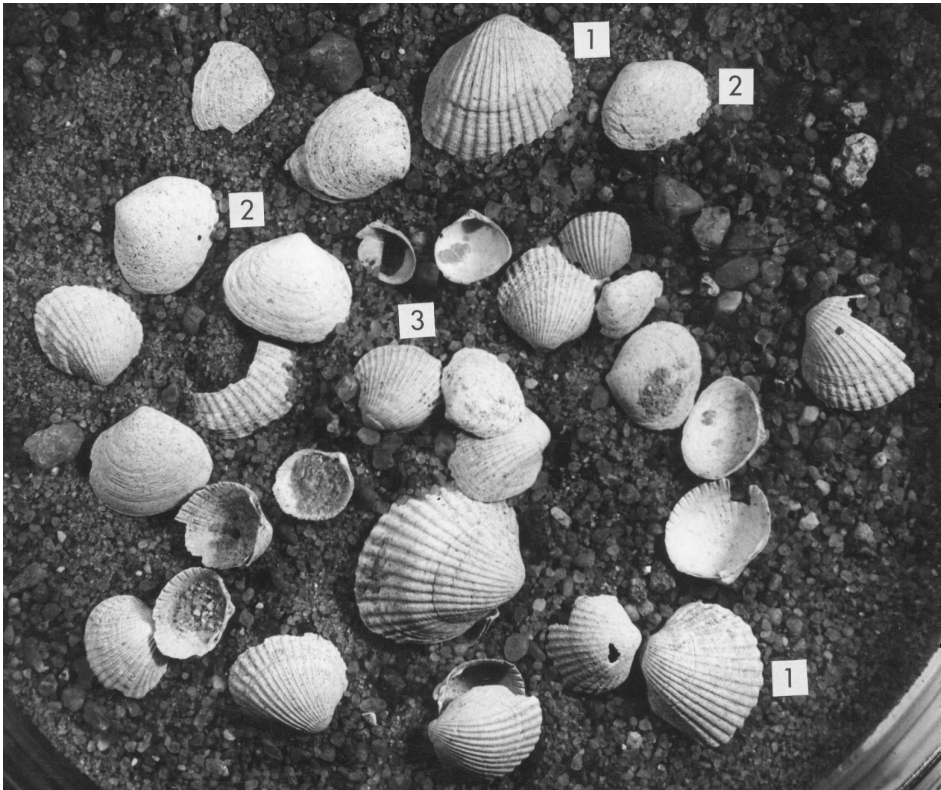


Fig. 5. Typical Litorina Sea subfossil mollusc shells from the sediments of the Partsi gravel pit:

1 – *Cerastoderma glaucum*, 2 – *Macoma baltica*, 3 – *Cerastoderma edule*.

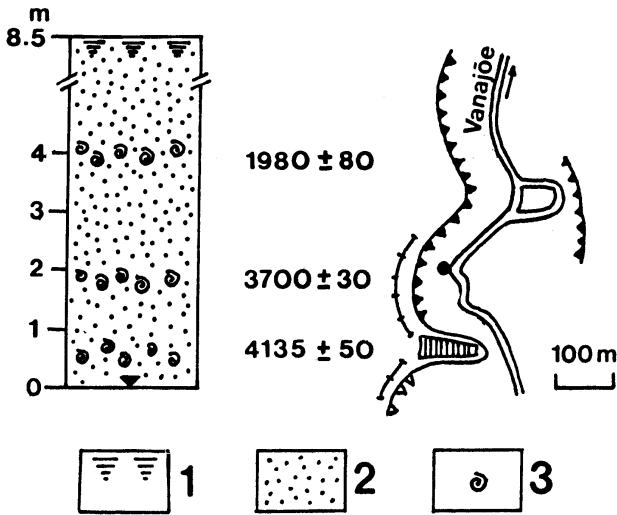


Fig. 6. Vanajõe section and the ESR age of the subfossil molluscs (Molodkov & Raukas 1996).

1 – soil, 2 – sand, 3 – shell.

around 7‰ as is nowadays in the Middle Baltic. *Littorina littorea* does not live at salinities lower than 8‰ and *Macoma baltica* can not stand the salinities over 11‰. It means that the salinity of the Litorina Sea nearshore waters during the phase L_1 in the northern part of Hiiumaa was 8–10‰. This data of salinity coincide with the earlier data of the isotopic investigation of salinity (Punning *et al.* 1988). The composition of malacofauna suggests shallow-water conditions, however, the water was deeper than during the preceding Ancyclus and Mastogloia stages. The evidence derived from the Partsi site supports the theory of Kessel and Raukas (1967) about the catastrophic lowering of the water level at the end of the Ancyclus stage and shows a rise of the water-level by several metres during the Litorina transgression. This gives new ideas for the correlation of shorelines.

Shell material from the Partsi section was dated by Molodkov (1996) with the electron-spin-resonance (ESR) method. A *Lymnaea baltica* shell sample from Ancyclus sediments has yielded an ESR calendar age of 8850 ± 700 yr BP. A *Cerastoderma glaucum* shell sample from the Litorina sediments gave an ESR age of 6310 ± 720 calendar years PB or about 5500 ^{14}C yr BP. Similar results were received by ^{14}C method in Tallinn and Uppsala laboratories: Ancyclus shells 8680 ± 90 yr BP (Ua – 10905) and Litorina shells 5515 ± 85 (Ua – 10906) and 5474 ± 47 yr BP (Tln – 2060, Raukas *et al.* 1996).

In the western part of the island, Litorina subfossil mollusc shells were collected during archaeological excavations on the Early Neolithic settlement at Ristipõllu (Fig. 2), near the Kõpu Peninsula. The mollusc fauna was found in

sand and gravel at the absolute height of 26 m. The main forms were *Cerastoderma glaucum*, *Hydrobia ulvae*, *Littorina littorea* and *Scrobicularia plana*. The content of *Littorina littorea* (10%) and the existence *Scrobicularia plana* is indicative of somewhat higher water salinity here than in the Partsi area. But both beds are synchronous because also in the recent sea in the western part of the island the molluscs suggest a bit higher salinity than in the eastern part of the island. *Littorina* fauna suggests that people lived at this site already in the beginning of the Atlantic time about 7000 years ago.

About 4000 years ago the ocean water level started to lower (Fairbridge 1961) and due to the neotectonic uplift in the Danish Straits the inflow of salty ocean water into the Baltic Sea decreased. The gradual change of the mollusc fauna composition can be traced in Hiiumaa Island in the Vanajõe section in the western part of the island (Fig. 2). An about 8 m high bluff with sand and gravel contains several layers of subfossil mollusc fauna. The thickness of the mollusc-bearing layers ranges from 5 to 10 cm. The brackishwater species *Hydrobia ventrosa*, *Cerastoderma glaucum* and *Hydrobia ulvae* were determined in the lower part of the section. The central layer at an absolute height of 12.7 m contains *Cerastoderma glaucum*, *Macoma baltica*, *Mytilus edulis*, *Hydrobia ulvae*, *H. ventrosa* and some *Littorina littorea* shells. In the uppermost layer (13.5 m absolute height) besides mesohalobous molluscs *Cerastoderma glaucum*, *Hydrobia ulvae* and *Mytilus edulis* also oligohalobous mollusc *Theodoxus fluviatilis* and more or less freshwater mollusc *Lymnaea baltica* were found. The composition of mollusc fauna suggests that the salinity of water was higher at the time of formation of the lower layers with *Littorina littorea* shells.

In the beginning of the Limnea Sea, the freshwater mollusc *Lymnaea baltica* proceeded to the Hiiumaa area. About 2500 years ago, the water of the Limnea Sea was so fresh that the oligohalobous mollusc *Lymnaea stagnalis* appeared. The third oligohalobous mollusc *Bithynia tentaculata* appeared 1700 years ago when the salinity of water couldn't be more than 6–7‰ because *Bithynia tentaculata* does not inhabit waters with a higher salinity (Järvekülg 1979). Such rather clear changes in the mollusc fauna composition allow to use mollusc complexes in the stratigraphical subdivision of sediments.

Conclusions

On the basis of the investigation of subfossil mollusc shells the following conclusions can be drawn:

- The freshwater *Ancylus* fauna was found below brackishwater *Littorina* fauna in the Partsi gravel pit in Hiiumaa. This phenomena speaks about a severe lowering of the *Ancylus* Lake before the *Littorina* Sea transgression.
- The investigation of molluscs imparts essential information about the

palaeoecological conditions during the different stages of the Baltic Sea, allowing to date the age of sediments and contributes to the stratigraphical subdivision of Holocene sediments.

– Principally, among the Holocene deposits the representatives of two ecological groups of malacofauna have preserved: freshwater molluscs in the Preboreal and Boreal sediments, and brackishwater molluscs since the Atlantic. The reduction of the salinity of water has resulted in the clear changes in the species composition of the malacofauna since the Subboreal.

– Between the *Ancylus* and *Litorina* stages there was the transitional Mastogloia Sea. Besides freshwater (*Bithynia tentaculata*, *Lymnaea baltica*, *Pisidium amnicum*) shells also slightly brackishwater species (*Theodoxus fluviatilis*, *Macomoma baltica*) have been found. The Mastogloia stage is closely related to A_{VI} level by Kessel and Raukas (1967). The malacological method can be used not only for the stratigraphical and palaeogeographical purposes but it can also help the archaeologists to determine the age of the ancient settlements, as it was demonstrated on the base of the Early Neolithic settlement at Ristipõllu on Hiiumaa Island.

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References

- DREIMANIS A., 1970: Are marine fossils in the Quaternary deposits a sufficient evidence for marine deposition? *Baltica*, 4: 313–322.
- EICHWALD E., 1852: Dritter Nachtrag zur Infusorienkunde Russlands. *Bulletan Soc. Nat. Moscou*, XXV, No. 11: 388–536.
- FAIRBRIDGE R. W., 1961: Eustatic changes in sea level. [In:] *Physics and Chemistry of the Earth*. New York – London, No. 4: 99–185.
- HYVÄRINEN H. & RAUKAS A., 1992: Principles of subdivision of the Baltic Sea History. [In:] A. Raukas and H. Hyvärinen eds.: *Geology of the Gulf of Finland*. *Valgus*. Tallinn: 239–246 [in Russian, Engl. sum.].
- JAANUSSON V., 1944: Über die postglaziale Entwicklung der Insel Vormsi in Estland. *Bulletan Commission Geologie Finlande*, No. 132: 86–90.
- JÄRVEKÜLG A., 1979: The bottom sediments of the eastern part of the Baltic Sea. *Valgus*. Tallinn, 382 p. (in Russian).
- KESSEL H., 1958: Neue Angaben über die Fauna subfossiler und recenter Mollusken der Esthnischen SSR. *Geoloogia Instituudi Uurimused*, III: 253–268 [in Russian, German sum.].
- 1965: History of the study of the *Limnea* and *Mya* stages of the Baltic and the stratigraphy of the *Limnea* Stage on the territory of the Estonian S.S.R. *Baltica*, 2: 21–45 [in Russian, Engl. sum.].

- KESSEL H. & RAUKAS A., 1967: The deposits of the Ancylus Lake and Litorina Sea in Estonia. *Valgus*. Tallinn, 134 p. [in Russian, Engl. sum.].
- KLIEWE H. & JANKE W., 1982: Der holozäne Wasserspiegelanstieg der Ostsee im nordöstlichen Küstengebiet. *Petermanns Geographische Mitteilungen*, H. 2: 65–74.
- LUNDQWIST G., 1963: Beskriving till jordartskarta över Gävleborgs län. *Sveriges Geologiska Undersökning*. C No. 42: 181 pp.
- MOLODKOV A., 1996: ESR Dating of *Lymnaea baltica* and *Cerastoderma glaucum* from Low Ancylus Level and Transgressive Litorina Sea Deposits. *Applied Radiation and Isotopes*, 47, 11/12: 1427–1432.
- MOLODKOV A., DREIMANIS A., ĀBOLTINŠ O. & RAUKAS A., 1988: The ESR age of *Portlandia arctica* shells from glacial deposits of Central Latvia: an answer to a controversy on the age and genesis of their enclosing sediments. *Quaternary Geochronology*, 17: 1077–1094.
- MOLODKOV A. & RAUKAS A., 1996: ESR dating of subfossil mollusc shells of the Limnea Sea. *Baltica*, 9: 29–35.
- ORVIKU K., 1934: Loodus ja inimene. Tartu, *Eesti Kirjastuse Selts*, 59 pp.
- PETERSEN K. S., 1993: Environmental changes recorded in the Holocene molluscan faunas from Djursland, Denmark. *Scripta Geologi, Special Issue*, 2: 359–369.
- PUNNING J.-M., MARTMA T., KESSEL H. & VAIKMÄE R., 1988: The isotopic composition of oxygen and carbon in the subfossil mollusc shells of the Baltic Sea as an indication of palaeosalinity. *Boreas*, 17: 27–31.
- RAUKAS A., 1994: Yoldia Stage – the least clear interval in the Baltic Sea history. *Baltica*, 8: 5–14.
- RAUKAS A., BIRD E. & ORVIKU K., 1994: The provenance of beaches on the Estonian islands of Hiiumaa and Saaremaa. *Proceedings of the Estonian Academy of Sciences. Geology*, 43, 2: 81–92.
- RAUKAS A., TAVAST E. & MOLODKOV A., 1996: Partsi – a new promising area for the investigation of Late Boreal and Early Atlantic water level changes of the Baltic Sea. *Proceedings of the Estonian Academy of Sciences. Geology*, 46, 2: 92–101.
- SAURAMO M., 1958: Die Geschichte der Ostsee. *Annales Academiae Scientiarum Fennicae*, A III, Geologica – Geographica No. 51: 522 s.
- SCHMIDT F., 1865: Untersuchungen über die Erscheinungen der Glacialformation in Estland und auf Oesel. *Bulletan Academy Science St.-Petersburg*, 6: 207–248.