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# Some remarks on distribution and genesis of palaeoincisions in the East Baltic area

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Until the recent time genesis of palaeoincisions is one of the debatable problems among the Quaternary investigators in the East Baltic area. Distribution of palaeoincisions in the East Baltic area is closely correlated with the pre-Quaternary bedrock lithology and permeability as well as with recently active faults. These regularities confirm the theory that most palaeoincisions in this area were formed as subglacial tunnel valleys during catastrophic discharge of meltwaters, due to high pressure conditions beneath the ice sheet.

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## INTRODUCTION

Speaking about palaeoincisions we usually mean buried valleys cut into the sub-Quaternary surface and filled with the Quaternary meltwater deposits or tills. They are sufficiently deep (to 300 m and more), relatively narrow (mostly 0.5–2 km wide), with steep slopes (to 40–45°) and their bottoms are generally located below the present sea level (100–300 m b.s.l.). Palaeoincisions are widespread in the East Baltic area (Estonia, Latvia, Lithuania, northwestern Russia and Belarus) as well as in other neighbouring territories that have been covered by the Pleistocene continental glaciations. The palaeoincisions are not only of great scientific interest in the Quaternary geology, but they are of a very important practical value in some areas too. First of all, some of the palaeoincisions are filled with meltwater deposits and serve as mineral resources or a good aquifer for water supply but, on the other hand, they are hydrogeological windows for salt groundwater migration from deep horizons or for a polluted water infiltration from land surface, etc. Thus, for a long time genesis, morphology, geological structure and regularities of distribution of palaeoincisions have been widely discussed among the Quaternary investigators of the East Baltic region. Special complex scientific studies to solve these problems have been carried out as well (A. Gaigalas *et al.*, 1976). On the basis of analysis of recent publications related to the palaeoincisions, we can make some more remarks concerning regularities in their distribution and origin.

## DISTRIBUTION OF PALAEOINCISIONS

An exhaustive analysis of publications related to genesis of palaeoincisions in the East Baltic area was carried out by D. B. Malachovsky (1988). There are two major points of view regarding the genesis of palaeoincisions. According to one of them, the palaeoincisions were eroded and pressed out by glaciers during the earliest glaciations of the Pleistocene. The palaeoincisions are also genetically related to zones of marginal accumulation and glaciotectonic dislocations. The role of meltwater hollowing, according to this hypothesis, was of secondary importance only. For a long time this point of view has been predominating among the Belarus investigators (G. I. Goretsky, 1980).

According to another point of view the palaeoincisions are the buried valleys of ancient rivers which existed during the pre-Pleistocene or the Pleistocene interglacials (L. Micas,

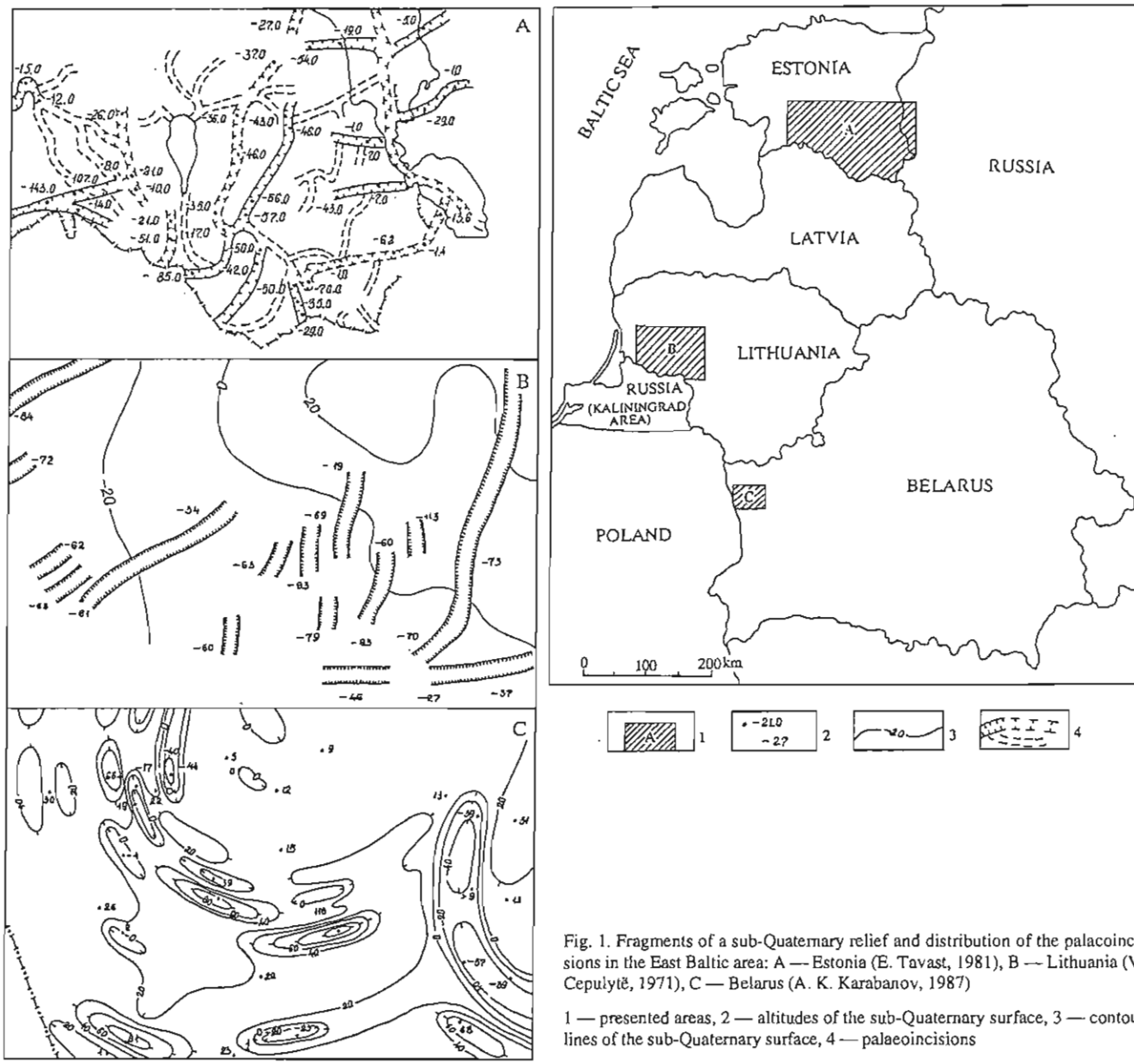


Fig. 1. Fragments of a sub-Quaternary relief and distribution of the palaeoincisions in the East Baltic area: A — Estonia (E. Tavast, 1981), B — Lithuania (V. Cepulytė, 1971), C — Belarus (A. K. Karabanov, 1987)

1 — presented areas, 2 — altitudes of the sub-Quaternary surface, 3 — contour lines of the sub-Quaternary surface, 4 — palaeoincisions

1974; A. Raukas, 1978; A. Šliaupa *et al.*, 1995; A. Šliaupa, 1997; V. Baltrúnas, 1997). Some investigators from this group consider these valleys to have been also deformed due to glacial erosion and flow of meltwaters. Besides, according to some investigators separate palaeoincisions appear to be of different genesis (A. Gaigalas *et al.*, 1976).

However, both major hypotheses or their modifications can not explain a number of peculiarities of the palaeoincisions. For example, V-shaped bottom profiles, very often observed in the palaeoincisions, are not characteristic of glacial erosion. Longitudinal profiles of the bottoms of the palaeoincisions are usually jumping up to some ten of metres and commonly, no distinct trend is observed — and these are not typical for a river erosion. Alluvial deposits in bottoms of the palaeoincisions are not detected. Another unsolved problem is: where was the basis of erosion, stipulated by such deep rivers penetrating into the bedrock?

Investigations of the palaeoincisions are generally based on data from single boreholes. Only in very limited and small areas, the paleoincisions are described on the basis of a group of boreholes or results of geophysical investigations: by gravimetry or magnitometry data on the land and of seismic reflection profiles in the sea. So, interpretation of morphology of the palaeoincisions and their extension depends on the subjective point of view of an interpreter and on available data. Different investigators in separate regions (or in the same region) are compiling quite different maps of the sub-Quaternary relief and a network of the palaeoincisions (Fig. 1).

Systematic investigations of the palaeoincisions enabled to establish a few regularities in their distribution in the East Baltic area. A few generations of the palaeoincisions were found and related to different glaciations. Their location is inherited and they are closely connected with a network of the

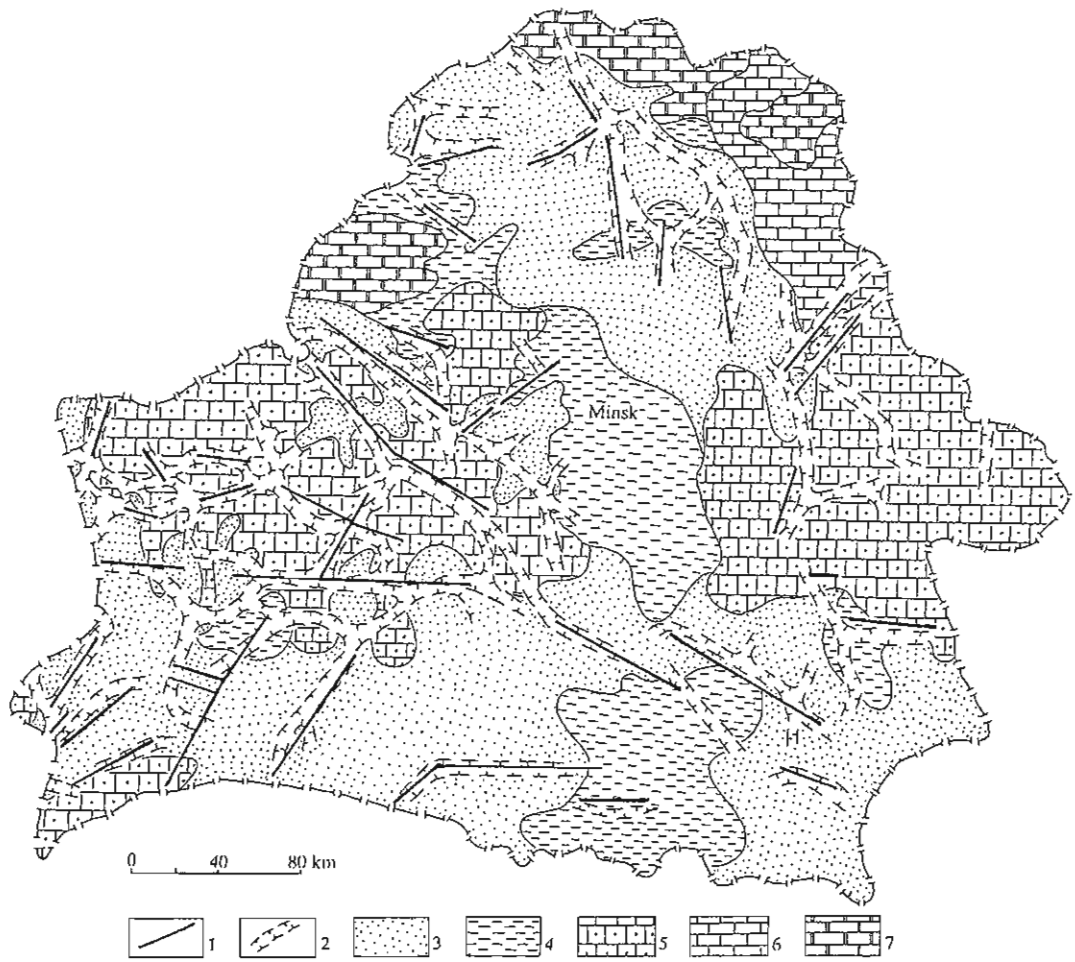


Fig. 2. Distribution of tectonic faults, palaeoincisions and lithology of the Quaternary bedrock in the territory of Belarus, compiled on the basis of the published data of L. A. Nechyporenko (1989)

1 — fault, 2 — palaeoincision, 3 — sands and sandstones, 4 — clays, 5 — chalk, 6 — limestones, 7 — dolomites

present river valleys (L. Micas, 1974). A number of authors have observed another very important regularity: the palaeoincisions (as well as the present river valleys) are closely connected with zones of the recently aetive faults. This connection is the most expressively evident in the scheme of distribution of the palaeoincisions and the tectonic faults in Belarus (Fig. 2), based on the published materials of L. A. Nechyporenko (1989). However, there is also another regularity: a network of the palaeoincisions in the territory of Belarus is unequaly dense. Correlation between the palaeoincisions and the pre-Quaternary bedrock is also quite evident. The palaeoincisions are concentrated in the areas where the sub-Quaternary bedrock is composed of sands, weakly cemented sandstones, marls or chalk (soft and high permeable sedimentary rocks), but they are absent in the areas where dolomites or limestones prevail. The same phenomenon is also typical for a distribution of the palaeoincisions and the Quaternary bedrock in the neighbouring territory of the Baltic States and the adjacent Baltic Sea area (Fig. 3). The greatest density of the palaeoincisions is common in the areas where the pre-Quaternary high permeable beds (porous deposits as sands, weakly cemented sandstones or fractured bedrock: marl and chalk) as well as aquicludes (soft sedimentary rocks as silt and clay) are observed directly under the Quaternary deposits. The palaeoincisions are absent in the areas where the aquicluds composed of hard sedimentary rocks (dolomites, limestones, dolomitic clays) predominate in top of a bedrock. Single palaeoincisions in this areas are usually closely linked with tectonic faults where hard sedimentary deposits are crushed and permeability increases some tens of times (M. Dobkevicius *et al.*, 1992).

## FINAL REMARKS

Recently the majority of investigators in North America and West Europe explain development of the palaeoincisions by the meltwater flow beneath an ice sheet. Thus, they have been formed as subglacial tunnel valleys during catastrophic discharge of subglacial meltwater in high pressure conditions (H. E. Wright Jr., 1973; G. S. Boulton, C. A. Hindmarsh, 1987; G. S. Boulton *et al.*, 1993, 1995; J. A. Piotrowski, 1994,

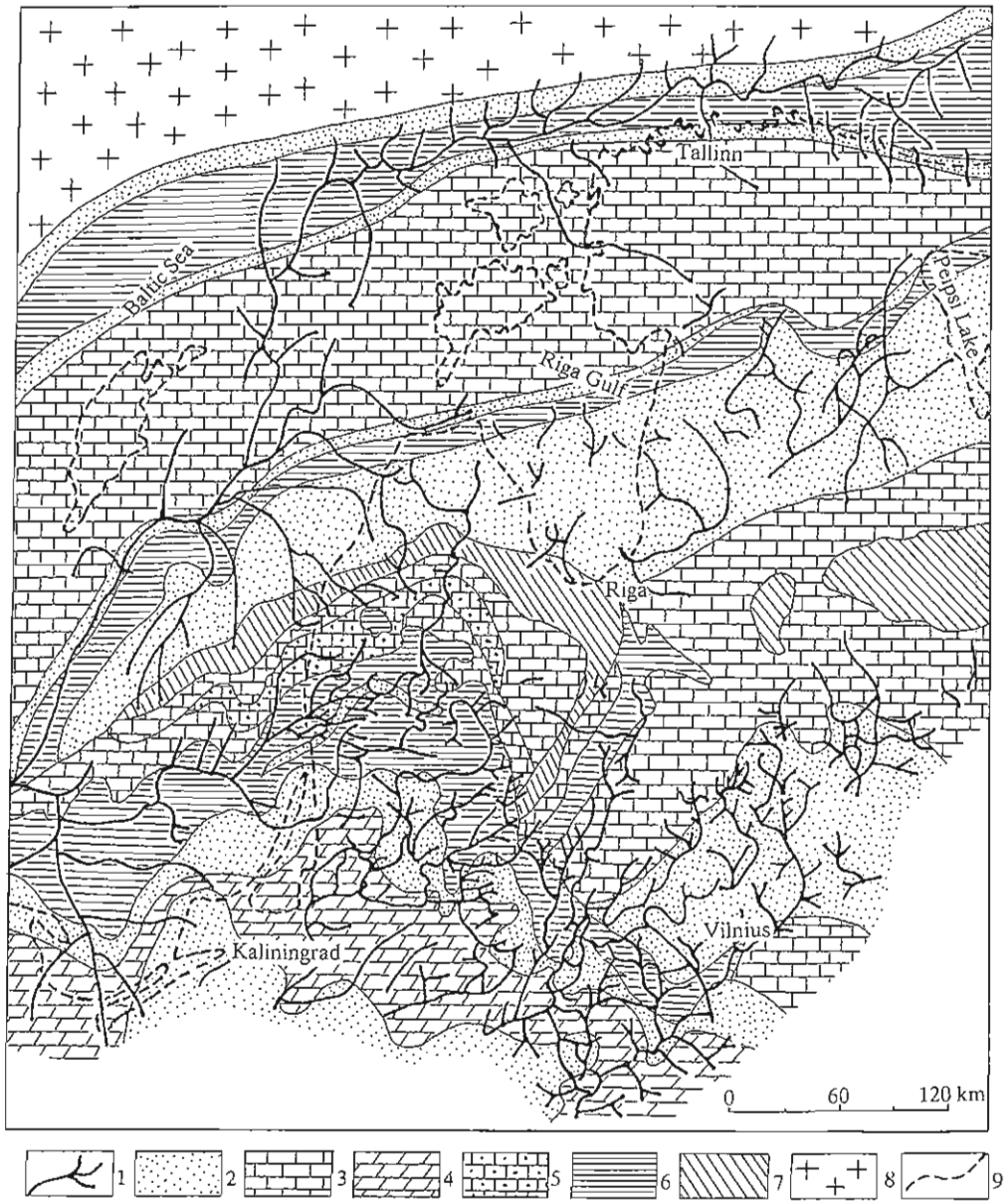


Fig. 3. Distribution of palaeoincisions and hydrogeological properties of the Quaternary bedrock in the territory of the Baltic States and the adjacent Baltic Sea area, compiled according on the basis of data of V. Juodkazis (1979) and A. Šliaupa *et al.* (1995)

1 — palaeoincisions; 2 — pore water medium aquifer (sands, weakly cemented sandstones); pore water medium and fractured aquifers: 3 — limestones and dolomites, 4 — chalk and marls, 5 — stratification of sandstones, marls, limestones and dolomites; 6 — aquiclude (clays, clayey-carbonate rocks); 7 — semipervious rocks with groundwater lenses; 8 — crystalline rocks; 9 — coastline of the Baltic Sea and the Peipsi Lake

1997, and others). In the authors view, regular distribution of the palaeoincisions in the East Baltic Region is the most convincingly explained by this theory. Meltwater flow under the ice sheet occurred in the areas where hard sedimentary rocks (generally aquicluds with relatively low permeability) prevailed in the top of the pre-Quaternary bedrock (e.g. in northern Estonia, southern Latvia and northern Lithuania). Meltwater discharge in tunnel valleys occurred extremely occasionally. It could be possible only in the tectonically active zones where permeability was much more higher due to a crushed bedrock. The palaeoincisions do not occur or they are relatively rare in the areas where aquifers with high permeability predominate in the top of the bedrock (e.g. area from the Peipsi Lake to western Latvia, Kaliningrad area). In this case meltwater flow took place radically through the subglacial aquifers. Transmissivity of aquifers was high enough to evacuate almost the whole water produced beneath an ice sheet. Tunnel valleys were formed only in exceptionally. The most dense network of the palaeoincisions occurs in the areas where relatively soft fractured middle-permeable aquifers or soft tectonically disintegrated aquicludes predominated beneath the ice sheet (e.g. western and southwestern Lithuania). In such conditions the tunnel valleys served as the main way for a discharge of meltwaters.

It is impossible to disclaim the opinion that a network of rivers existed during the pre-Pleistocene or during the Pleistocene interglacials. However, erosion of rivers has not resulted in development of the deepest palaeoincisions. Perhaps only a small part of the shallow palaeoincisions could be possibly attributed to the ancient river system. It was only later that glacial erosion (in a number of cases rather significantly) transformed a morphology of these river valleys.

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## UWAGI O ROZMIESZCZENIU I GENEZIE GŁĘBOKICH DEPRESJI W PODŁOŻU CZWARTORZĘDU W REJONIE WSCHODNIOBAŁTYCKIM


Streszczenie

W ostatnich latach geneza głębokich depresji w podłożu czwartorzędu stanowi jeden z najżywiej dyskutowanych problemów wśród badaczy czwartorzędu z państw wschodniobaltyckich (fig. 1). Rozmieszczenie tych głębokich obniżeń jest ściśle związane z litologią i przepuszczalnością skał podłoża, jak również z występowaniem czynnych uskoków w tym rejonie (fig. 2, 3). Te zależności potwierdzają przypuszczenie, że powstanie większości depresji w podłożu czwartorzędu jest związane z rynnowym przepływem subglacjalnym podczas katastrofalnego odpływu wód roztopowych w warunkach wysokiego ciśnienia panującego pod lądolodem.