

A brief outline of the Quaternary of Lithuania and the history of its investigation

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Quaternary sediments underlie all of Lithuania. The thickness of the Quaternary sediments varies from 2-10 m in northern Lithuania, up to 250-300 m in the highlands and the buried valleys. The sediments of no less than 6 glacial and 8 interglacial periods have been identified in the country (Gaigalas, 1995; Satkūnas, 1997). The correlation of the Lithuanian Quaternary stratigraphical scheme to that of the European Quaternary Time Scale is shown in Table 1. The scheme is based on comprehensive mapping, on litho- and biostratigraphical investigations and on physical (isotopic) dating of the sediments. All stratotype sections or stratotype areas have been documented (Kondratienė *et al.*, 1993). The scheme presented here is conventional and simplified in the case of the Late Nemunas subdivision. A more detailed stratigraphic subdivision of the Upper Pleistocene was recently proposed by Satkūnas (1999).

Detailed geomorphological investigations of the land surface of Lithuania, carried out by Basalykas in the 1950s, originally served as the basis for the stratigraphical subdivision of the Nemunas (Weichselian) glaciation. His geomorphological map, which has been modified several times, is still useful today (Basalykas, 1959, 1981). The map represents a very detailed analysis of landforms, their origin and relative ages, based on high-precision field observations. However, even though the ice-marginal complexes and their comparative age are shown in detail, these maps include no glacial limits. The first attempt at drawing the positions of glacial limits in the country and to correlate them with the stadials of the Last Glaciation then used in Poland and Germany, was undertaken by Gudelis (1955, 1958). The first Quaternary stratigraphical scheme for Lithuania appeared in 1957 (Gudelis, 1957).

By 1962 a Frankfurt (Žiogeliai) Stage of the Last Glaciation had been established and outlined in the southeast (Vaitiekūnas, 1962; Vaitonis & Vaitiekūnas, 1981) (Fig. 1). In the published stratigraphical scheme the Late Nemunas has been subdivided into three stadials, i.e. the Grūda, Žiogeliai and Aukštaitija, which are correlated with the Brandenburg, Frankfurt and Pomeranian stages respectively (Vaitiekūnas, 1962, 1965, 1968, 1969). Furthermore, the Antaviliai and Ūla interstadials, discovered in outcrops at Ūla, Antaviliai, Zervynos and elsewhere, were tentatively placed between the Grūda, Žiogeliai and Aukštaitija Stadials (Vaitiekūnas, 1965, 1969). However, later investigations have forced a revision of the stratigraphical positions of these interstadials, some being younger

(Blažauskas *et al.*, 1997) and others being older than the phases mentioned above (Satkūnas & Hütt, 1999). Gaigalas (1988, 1995), however, still considers the Pavytė Interstadial to occur between the Žiogeliai and the Baltija stadials.

Recently, much effort has been spent on the investigation of the interstadials and oscillations of the Late Nemunas glaciation. The best conditions for the accumulation of deposits from these events might have been close to the margin of the last ice sheet, where glaciolacustrine sediments are frequently deposited (Satkūnas, 1993). Over 300 boreholes have been drilled with the purpose of identifying such deposits, but without positive results. However, in the course of those investigations additional Early and Middle Nemunas interstadial sites have been found (Satkūnas *et al.*, 1997) and the stratigraphy of the sites known already has been revised (Satkūnas, 1993; Satkūnas & Grigienė, 1996, 1997a, 1997c).

Following revision of the Quaternary geological and Geomorphological maps at a scale of 1:200,000 (Guobytė, 1998, 2000), the number of Last Glaciation ice-marginal moraine ridges has been reduced because their presence could not be confirmed by field investigations. No geomorphological evidence of the existence of the Žiogeliai (Frankfurt) stadial have been so far found. Furthermore, the boundary of the South Lithuanian phase is not well established in the northeastern and western (coastal area) of Lithuania. Only geomorphologically and geologically well-established marginal ridges are interpreted as Last Glaciation stadial or phase limits.

Last Glaciation stadial and phase limits

The Last Glaciation in Lithuania is referred to as the Nemunas Glaciation (Gudelis, 1957). Its maximum extent was first drawn by Halicki (1934) in southeastern Lithuania. This line was later corrected and presented in small-scale sketches by Gudelis (1955, 1958, 1964), Vaitiekūnas (1962, 1968, 1969), Kudaba (1983), and others. Gudelis correlated the outermost boundary of the Last Glaciation with the Brandenburg stadial, and the onset of the Last Glaciation was estimated at *c.* 30,000 B.P. (Gudelis, 1964).

According to Gaigalas (1988, 1995), the last glacial period in Lithuania began at *c.* 22,000 B.P. More probably,

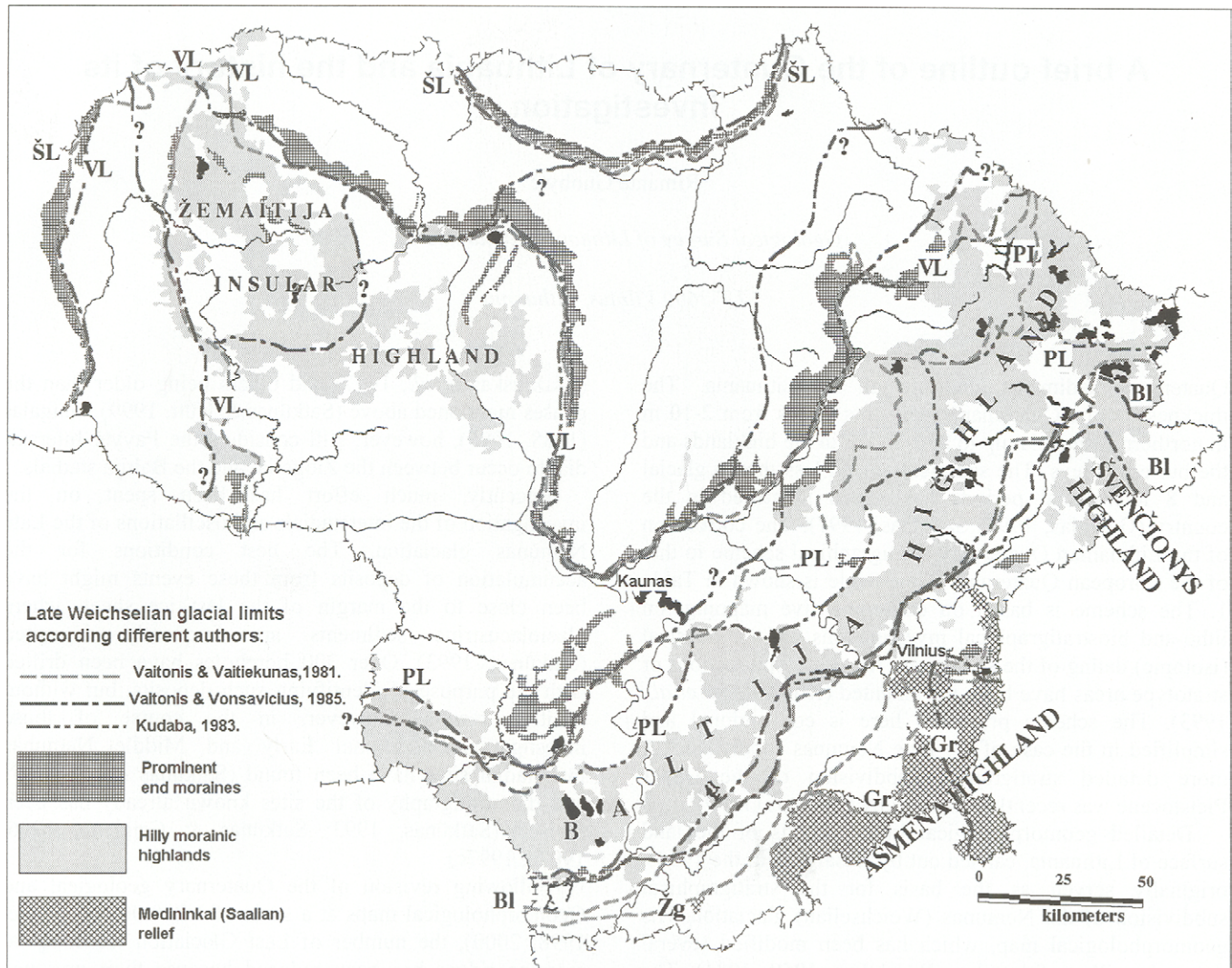


Fig. 1. Late Weichselian ice sheet marginal positions in Lithuania from different published maps. Gr – Grūda Stage, Žg – Žiogeliai Stage, BI – Baltija Stage, PL – South Lithuanian Phase, VL – Middle Lithuanian Phase, ŠL – North Lithuanian Phase, Pj – Pajūris Phase, ? – the oscillations of the Baltija Stage.

the last ice sheet invaded the Lithuanian landmass at c. 25,000 B.P. (Satkūnas, 1993, 1997). The maximum extent of the Last Glaciation corresponds to the Grūda (Brandenburg) stadial.

The existence of the outermost limit of the Last Glaciation in SE Lithuania has been challenged by some researchers who were of the opinion that the whole of Lithuania was covered by the last ice sheet (e.g. Baltrūnas *et al.*, 1984). This opinion was originally presented in the published Quaternary geological maps of Lithuania (Vonsavičius, 1980; Vaitonis & Vonsavičius, 1985).

Eventually the Saalian age of the Medininkai highland had been demonstrated by detailed geological mapping in 1986-1991 (scale 1:50,000) in the vicinity of Vilnius (Satkūnas *et al.* 1991, geological report in preparation; Guobytė, 1996). The maximal position of the Last (Late Nemunas) Glaciation has been established at the foot of the Ašmena highland in southern Lithuania. There is a clear contrast between the 'fresh-looking' landforms of the Late Nemunas

Glaciation and the more monotonous 'mature' old morainic landscape beyond its limit. Eemian interglacial and Weichselian interstadial deposits have been identified and dated from several marshy depressions in the Medininkai highland (Kondratienė *et al.*, 1986; Kondratienė & Vonsavičiūtė, 1986; Satkūnas & Kondratienė, 1998). They are not overlain by till.

Baltija Stadial

The name Baltija (BI) Stage (originally: Baltija Stage) was introduced by Kondratienė *et al.* (1964). According to Gaigalas (1988, 1995), its age is c. 17,000 B.P. Originally, a glacial limit running along the outer margin of the Baltija Highland was called the 'Main Pomeranian Stage'. From correlation with the Danish 'Bælthav Stage', Gudelis (1955, 1958) estimated its age to be c. 18,500-15,750 B.P. Later this phase was renamed the 'Aukštaičiai Stage', and its age

Fig. 2. Aerial view of the ice contact slope between hummocky morainal feature (A) and outwash fan (B) to the east of Merkinė. The slope margin is traditionally considered to be a limit of the Baltija Stage of the Last Glaciation. Aerial photograph (1952), approximate scale 1:17 000 (Archives of the Geological Survey of Lithuania).



corrected to *c.* 17,340±840 – 11,630±120 B.P. (Vaitiekūnas, 1969). Since 1974, the Baltija glacial limit has also been referred to as the East Lithuanian Phase (Kudaba, 1974).

Mortensen (1924) was the first who described and showed the Baltija Highland's moraine on a map. Detailed geomorphological investigations in the Baltija Highlands were carried out by Kudaba (1974, 1983). Traditionally, the boundary of the Baltija Stage is drawn along the distal (southern) margin of the Baltija Highland (Fig.2).

South Lithuanian (Pietų Lietuvos) Phase

The South Lithuanian (PL) Phase was named by Gudelis (1955) and correlated with the 'Bæltthav Phase'. The age of this phase is unknown. A fragment of a ridge, which is assigned to the PL Phase, was first mentioned by Hausen (1913).

The South Lithuanian Phase limit is correlated with some poorly-developed fragments of marginal ridges in southern Lithuania. In the eastern part of the Baltija Highland no continuous marginal ridges are observed.

These marginal ridges have been formed more likely by oscillation of the Baltija (Pomeranian) Stage glacier.

Middle Lithuanian (Vidurio Lietuvos) Phase

The Middle Lithuanian (VL) Phase was also named by Gudelis (1955) and is undated. He correlated it with the Danish 'Langeland Stage' (1955, 1958). A relict of the Middle Lithuanian marginal moraine ridge was first described by Mortensen (1924).

Overall, it is a prominent moraine ridge occupying an area between Seda, in the west, to Rokiškis, in the east. The ice-pushed ridge up to 8 km wide consists of small, low hills. Small outwash plains are related to the ridge near Šiauliai and Anykščiai. The Middle Lithuanian phase limit is drawn along the distal slope of the ridge. The boundary, however, is less-clearly expressed to the northeast of Rokiškis and to the northwest of Seda because of the generally more hilly glacial landscape around the ridge. Some investigators (e.g. Gaigalas & Kazakauskas, 1997) consider the extensive glaciolacustrine basins situated to the south of the ridge as being formed by



Fig. 3. Distal slope of the Linkuva marginal ridge representing the limit of the North Lithuanian Phase. (Photograph: V. Mikulėnas, 1999).

melting of the Middle Lithuanian phase glacier. However, on the basis of the morphology, the basins must have been formed before the VL Phase.

North Lithuanian (Šiaurės Lietuvos) Phase

The North Lithuanian (ŠL) Phase was named by Gudelis (1955). Its age has been determined at c. 13,000-14,000 BP (Gudelis, 1955, 1958; Vaitiekūnas, 1969; Gaigalas, 1988). Gudelis (1955, 1958) correlated it with the 'North Rügen Stage'. The ridge was first mentioned by Doss (1910).

The North Lithuanian Phase is represented by an arcuate ridge that bends towards the south, which is about 10 m high and 2 km wide. It is well expressed in the present landscape and is known as the Linkuva Ridge (Fig. 3). This ridge is considered to represent the limit of the North Lithuanian Phase in maps and publications (Fig. 1).

Pajūris Phase

The Pajūris (Pj) Phase was introduced by Vonsavičius (1980), but has not been dated. The phase is represented by a subdued, low ridge along the Baltic Sea coast.

In the vicinity of Klaipėda, a fragment of the ridge was erroneously described by Wichdorf (1911) as a drumlin landscape. It is a correlative of the Linkuva ridge, and thus belongs to the ŠL Phase, according to some of the Lithuanian investigators (e.g. Gudelis, 1955; Basalykas, 1959; Straume, 1982). Kudaba (1983) assigns it to the VL Phase (Fig. 1). The ridge is shown to be younger than the North Lithuanian Phase in the Quaternary geological map of the Baltic States (scale 1:500,000), and in the revised Quaternary geological and Geomorphological maps of Lithuania at a scale of 1:200,000 (Vonsavičius, 1980; Guobytė, 1998, 2000). It might have been formed during an oscillation of the North Lithuanian Phase of the last glaciation.

Discussion and conclusions

The reconstruction of the Late Weichselian glacial limits is based on geomorphological evidence combined with geological data. The maximum extension of the Last Glaciation has been established in southeastern Lithuania. Here the outermost Late Nemunas glaciation boundary has been traced to the foot of the Medininkai Highland. In general, it corresponds to the boundary between different glacial landscape types. The precise position of the Last Glacial maximum is unknown.

The Late Nemunas ice advance is considered to comprise two parts, the Grūda Stadial (the older) and the Baltija Stadial. However, they can only be distinguished using lithostratigraphic criteria. The Late Nemunas maximum, i.e. the Grūda Stadial, is dated approximately to 25,000-22,000 B.P. (Gaigalas, 1995; Satkūnas, 1997). The Baltija Stadial is correlated with Pomeranian Stage and its age is c. 17,000 B.P. according to Gaigalas (1995). The major part of the present topography of Lithuania was formed during this Baltija Stadial. There are several marginal morainic complexes north-west of the Baltija Highland, which may indicate three or even four additional ice front phases (South-Lithuanian, Mid-Lithuanian, North-Lithuanian and Pajūris) of the retreating Pomeranian ice sheet. These limits have been traced on the basis of various geomorphological criteria. As phase limits, mostly have been interpreted ice-marginal moraine ridges. In Lithuania there are no dates available for these stillstands, represented in recent correlation schemes (Andersen & Borns, 1994; Raukas *et al.*, 1995). No sites with Late Nemunas inter-phase deposits have been discovered in Lithuania.

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