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Influence of sedimentological composition on OSL dating of glaciofluvial deposits: examples from Estonia

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We assess the suitability of luminescence (TL and OSL) dating techniques for establishing a precise Late Pleistocene chronology for the northern Baltic area, and show on the basis of the fine sand/coarse silt fraction of subaqueous deposits, how sedimentological composition influences the dates obtained. Turbidity, loading by fine suspended material, water depth, velocity of outwash streams and transport length, and also perhaps rapid night-time sedimentation and incorporation of older, unbleached particles are factors that variably influence the extent of bleaching of the luminescence signal, and thus, cause variability of dates obtained. Alongside reliable dates for "late-glacial" deposits between 11 000–15 000 OSL years BP, many entirely unreliable dates from 8 000 ± 300 to 114 000 ± 8 000 OSL years BP have been obtained. This means that the age determination of glaciofluvial deposits is extremely difficult in practice. This applies particularly to intermorainic sediments, the exact genesis of which is unknown. The paper is addressed to the investigators wishing to use luminescence dating techniques to establishing the Pleistocene chronostratigraphy of glaciofluvial deposits.

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INTRODUCTION

Several ice-marginal belts: Haanja, Otepää, Sakala, Pandivere and Palivere (Fig. 1), have been distinguished in Estonia, but their age and genesis remain in dispute. It seems that some parts of these belts formed in the marginal area of active ice, others being deposited under the influence of passive glaciers or even in dead ice. In most cases, the morphologically distinct ice-marginal deposits serve as indicators of the active glacier margin. However, the various ice lobes dependent on the subglacial topography and differences in glacier dynamics are not always and everywhere synchronous, and seldom contain organic matter usable for radiocarbon dating. Besides, older sediments and structures often occur in young morainic belts.

The lack of trustworthy absolute and even semi-absolute dates beyond the radiocarbon (^{14}C) dating range has been hampering the development of Pleistocene stratigraphic charts and the correlation of ice-marginal successions. Application of the radiocarbon method is also limited due to the lack of good interstadial sections for dating, redeposition of organic matter and contamination with young and ancient carbon. In Estonia, where a carbonate bedrock prevails, anomalously old ages have been obtained due to the "hard water" effect. Thus, new dating methods are needed.

In 1974, Galina Hütt founded a radiometrical dating laboratory in the Institute of Geology at the Tallinn University of Technology (formerly the Institute of Geology of the Estonian Academy of Sciences), which soon became internationally well known. Together with the first author of this paper she collected and analysed a great number of samples of glaciofluvial sediments from different parts of Estonia. Unfortunately, the untimely death of Galina Hütt did not allow us to complete the project. To check the reliability of the results obtained we set out to fill a few gaps and constrain some data of the more improbable at the Department of Radioisotopes of the Silesian University of Technology in Gliwice, Poland. This work was done in 2003–2004 as part of scientific cooperation between the Estonian and Polish Academies of Sciences. In the Tallinn laboratory mainly feldspars, and in Gliwice quartz was used for dating, hampering the comparison of results but allowing assessment of the suitability of TL and OSL dating for establishing an accurate Late Pleistocene chronology for glaciofluvial deposits of different genesis. The dating procedures in both laboratories have

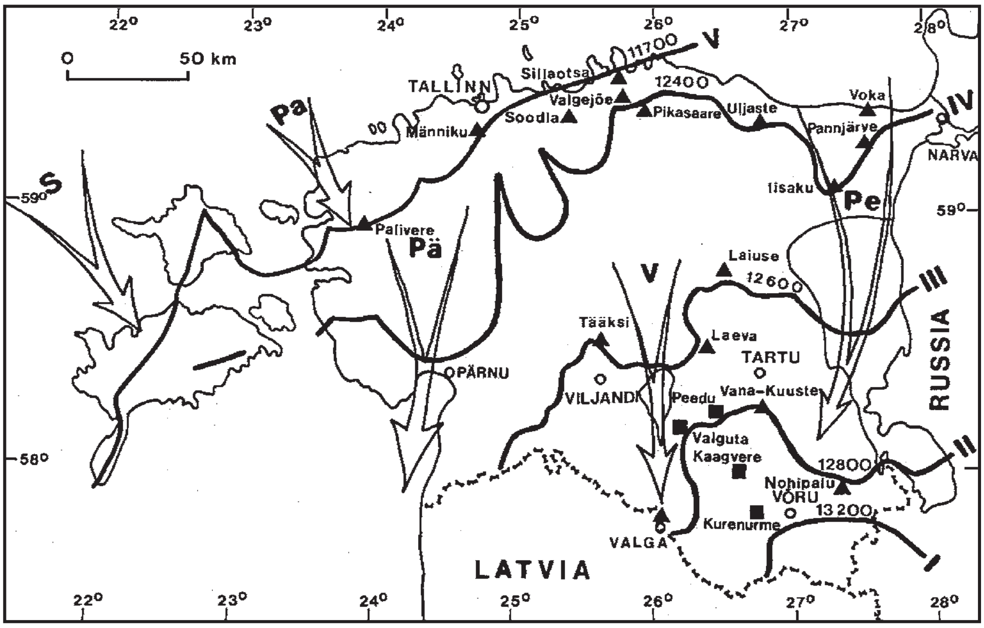

Fig. 1. Location of sites dated (black triangles) and probable age of ice-marginal zones

I — Haanja, II — Otepää, III — Sakala, IV — Pandivere, V — Palivere, ice streams: S — Saaremaa, Pa — Palivere, Pä — Pärnu, V — Võrtsjärv, Pe — Peipsi; black squares mark the location of dated interstadial sites mentioned in the text

been repeatedly published (Hütt and Smirnov, 1983; Bluszcz, 1986; Hütt *et al*., 1988; Bluszcz and Botter-Jensen, 1993; Hütt and Jaek, 1996*a*, *b*; Bluszcz, 2000; Bluszcz and Stypa, 2000) and will not be further repeated in this paper.

The error of the accumulated doses determined was calculated using the "jack-knifing method" following Grün and MacDonald (1989). It should be pointed out that this is an analytical error, the value of which was calculated by Hütt as follows: ±1 100–1 500 years for dates between 10 000–13 000 years, ±2 500–6 000 years for dates between 16 000–25 000 years and ±5 000–12 000 years for dates between 80 000–120 000 years. In both laboratories different aliquots were dated.

GEOLOGICAL SETTING

Estonia is located in the northwestern part of the East European Platform. Structurally, it lies for the most part on the southern slope of the Fennoscandian Shield with only its extreme southwestern and southern parts forming the wings of the Baltic Syneclise. Almost horizontal Vendian to Devonian sedimentary rocks cover the Proterozoic crystalline basement, dipping slightly southwards, at normally not more than 3–4 metres per km (or 15'). The Palaeozoic rocks are overlain by a Quaternary cover ranging to more than 200 metres in thickness.

The Quaternary cover consists mostly of Pleistocene deposits of glacial and fluvioglacial origin. Five till beds are generally recognised (Raukas, 1978). These tills are correlated with the Elsterian/South Polish, Saale/Middle Polish and Weichselian/North Polish/Vistulian glaciations in Central and Western Europe. In a few places, the till beds are separated from each other by deposits of Eemian (Prangli, Rõngu) or Holsteinian (Karuküla, Kõrveküla) interglacial or interstadial (Valguta) deposits (Raukas and Kajak, 1995). The thermoluminescense date of 62 400–66 500 years for the Valguta section (Kajak *et al*., 1981; Liivrand, 1991) is difficult to accept. The highly disputed Peedu intermorainic section (Liivrand *et al*., 1980; Kajak *et al*., 1981) above Eemian organic sediments has produced TL ages between about 90 000 and 100 000 years. However, there are also samples with a TL age of 40 000–65 000 years. Since radiocarbon (^{14}C) dates range from 30 000 to 40 000 years BP, the age of this section is still open to question.

At this point it is worth pointing out that the second author faced a similar situation in the Konin area where the ^{14}C and TL ages of sediments also proved to be very different (Stankowska and Stankowski, 1987; Bluszcz *et al*., 1999). There are also good examples in the literature of using TL dates to constrain long Pleistocene successions (Gaigalas and Fedorowicz, 2002).

In our opinion further improvement of the luminescence method is urgently needed. Morover, great caution is necessary in sediment selection and in the interpretation of dating results (Ber, 2001; Fedorowicz, 2003*a*, *b*).

The Upper Weichselian late-glacial deposits in Estonia are divided into Arctic (Bølling, Older Dryas) and Subarctic (Allerød, Younger Dryas) chronozones (Pirrus and Raukas, 1996). Traditionally, the beginning of the late-glacial interval in Estonia is placed at the time span when deposits of the Raunis Interstadial below the Haanja till started to accumulate in Central Latvia (dated by different laboratories as 13 390±500: Mo-196, 13 250±160: TA-177, 13 320±250: Ri-39 conventional ^{14}C ages; see Pirrus and Raukas, 1996). The majority of the ^{14}C dates obtained from submorainic and intermorainic sequences with organic remains in Estonia (Petruse, Viitka, *etc*.) are younger than one would expect on the basis of the conventional radiocarbon method (Raukas, 1986). The Kurenurme intermorainic section above the Haanja till (Fig. 1) gave OSL dates between 12 710±1800 (TL~OSL-1433) and –14 490±2060 (TL~OSL-1434) and the Kaagvere section gave dates of 14 130±790 (TL~OSL-1432) and 21 070±2330 (TL~OSL-1432) see Kalm (2005). ^{14}C dates for the Kurenurme section are 12 650±500 (TA-57) see Liiva *et al*. (1966) and 12 420±100 (Tln-35) see Punning *et al*. (1974), and for the Kaagvere section 15 150±575 (TA-50) see Liiva *et al*. (1966) and over 30 000 (TA-36) yr BP.

The deglaciation history in Estonia has been dated using the conventional ^{14}C method, varve chronology, thermoluminescence (TL), optically stimulated luminescence (OSL) and ^{10}B methods (Raukas, 2004; Raukas *et al*., 2004). The main conclusion is that Estonia became ice-free at about 13 500–11 000 ^{14}C years BP (Raukas, 1986; Pirrus and Raukas, 1996; Raukas and Kajak, 1997). In the light of pollen analytical interpretations, the retreat of the ice margin from the Haanja zone (the oldest in Estonia) began in the Bølling. Estonia was finally free of ice in the second half of the Allerød chronzone (Pirrus and Raukas, 1969, 1996). This means that the deglaciation process was fast. According to Kalm (2004), deglaciation of all of Estonia (average 130 m/yr) lasted 1650 ^{14}C or 1725 varve years only.

During the thinning of the ice sheet, the movement of its individual lobes was controlled by the subglacial topography (Tavast and Raukas, 1982). Ice-marginal positions are represented in the modern topography mainly by discontinuous chains of end moraines and glaciofluvial deposits (Raukas and Kajak, 1997) and the correlation of such chains is contentious. Five ice-marginal zones (in order of decreasing age: Haanja, Otepää, Sakala, Pandivere and Palivere; Fig. 1) are usually distinguished in Estonia (Raukas *et al*., 1971, 2004; Raukas and Karukäpp, 1979; Raukas, 1986). They were formed either as a result of standstills of the ice margin or, in some cases, as a result of readvances. At some sites where till-covered interstadial-type sediments occur, lithostratigraphical observations provide evidence for events of ice-front oscillations (Raukas and Rähni, 1966; Karukäpp and Miidel, 1972; Kajak *et al*., 1976; Raukas, 1986; Pirrus and Raukas, 1996). The Haanja, Otepää, Sakala and Palivere stadials are characterized by a dominant southeasterly ice movement direction, the Pandivere Stadial by a southerly or even southwesterly ice movement direction (Raukas, 1978, 1992; Raukas and Karukäpp, 1979; Raukas *et al*., 2004).

As for the Pleistocene intermorainic beds, very different and contradictionary TL dates have been obtained (Kajak *et al*., 1981; Liivrand, 1991). We therefore decided to check the reliability of the OSL method on the base of surficial glaciofluvial sediments whose age is more or less controlled by other dating methods. Part of the sites dated by us are located in the ice-marginal zone and some between zones of different ages (and so their absolute age must be a little different to them). In dead ice topography the melting out of sediments could happen hundreds of years later than in the ice-marginal zone.

DISTRIBUTION OF GLACIOFLUVIAL SEDIMENTS IN ESTONIA AND SAMPLING STRATEGY

Surficial glaciofluvial deposits cover 3.1% of Estonia's territory (Vares and Raukas, 1981) and are divided into englacial and periglacial genetical types with frequent transitions between them (Raukas, 1978). According to Gudelis (1963), marginal glacial successions may be divided into frontal, intramarginal and extramarginal ones. Deposits of radial eskers and fluviokames are conventionally regarded as englacial glaciofluvial deposits, and those of glaciofluvial deltas, outwash deltas (sandurs) and marginal eskers as periglacial ones. Glaciofluvial deposits also form kame terraces and often fill ancient valleys. In general, glaciofluvial deposits show great variations in granulometric composition and structure, and also in their lithological and mineral composition, everywhere closely connected with the composition of the adjacent till and bedrock. Therefore, one of our tasks was to sample genetically different glaciofluvial deposits and another task was to sample surficial glaciofluvial deposits of different ages, as needed for the establishment of a reliable deglaciation chronology.

Based on the palynological and varve data available as well as ^{14}C dates from both the study area and its neighbourhood, it may be concluded that the approximate age of the Haanja belt is about 13 200, of the Otepää belt *ca*. 12 800, of the Sakala belt 12 600, of the Pandivere belt *ca*. 12 400 and of the Palivere belt *ca*. 11 700 years BP (Raukas, 2004).

Most of the samples were collected from the ice-marginal zones of the Palivere and Pandivere stages to establish the time when the Estonian territory was finally freed from the ice cover. For comparison, two fine sand samples from the Serafiniskes sandur deposits near Trakai, Lithuania, close to the maximum distribution of the ice cover, were dated (Table 1).

Sandurs or outwash deltas are rare in Estonia but theoretically they are the most promising study objects. They were sampled by us in summer 2005 and we hope to receive results in the coming year. Glaciofluvial deltas are extensive the territory. They are most frequent on the northwestern and western slope of the Pandivere elevation and a little north of it at absolute heights of 55–65 m. There are also deltas at heights of 40–50 m (Nõmme, Männiku, Valgejõe), and less frequently above 65 or below 40 m. The area of deltas fluctuates from a few square km to several hundreds of square km.

The extent and shape of the deltas as well as the thickness of the deposits occurring within their boundaries depend essentially on the subglacial topography. The grain-size of the delta sediments decreases distally where deltas often turn into glaciolacustrine plains. Locally, the deposits of proglacial lakes occur under delta deposits (e.g. at Nõmme, Vaivara, Valgejõe), which evidently points to a temporary advance of the glacier. Delta deposits are dominated by gravel, rich in crystalline rocks, and coarse sand. The fine fractions (fine sand/coarse silt useful for luminescence dating) occur mainly as interlayers. Occasionally, carbonate rocks dominate among gravel and pebbles. In the mineral composition of the sand and silt fractions, quartz (80–90%) prevails, followed by feldspars (6–15%). The share of micas and carbonates is insignificant reaching seldom 20–30% (Raukas, 1978).

In delta deposits cross-lamination prevails. Less frequently, wavy or horizontal lamination dominates. The style of lamination correlates strongly with the granulometric composition of the deposits. The lamination characteristic, as well as other features (continuous transitions to glaciolacustrine deposits, very rare occurrence of glaciokarst forms and so on) suggest subaqueous deposition of these deposits. In this case the dates obtained will be less reliable than those obtained on sandur deposits which accumulated in streams open to sunlight. Glaciofluvial deltas of various ages at Männiku, Sillaotsa, Valgejõe, Soodla, Laeva and Valga were sampled (Fig. 1) and dated (Table 1). It is possible that those at Laeva and Valga are

Table 1

Results of dating

Sample index	Locality	Coordinates	Stadial	Lithology	Sample depth [m]	Age [ka]
1	2	3	4	5	6	7
Glaciofluvial deltas						
*R-31	Männiku	59°21'43''N 24°43'08''E	Palivere	medium and fine sand	2.0	10.2
*R-32	Männiku	59°21'43''N 24°43'08''E	Palivere	medium and fine sand	4.0	21.0
*R-33	Männiku	59°21'43''N 24°43'08''E	Palivere	medium and fine sand	6.0	12.3
**1166	Männiku	59°20'00.1''N 24°41'46.2''E	Palivere	medium and fine sand	2.2	80.5
**1167	Männiku	59°20'00.1''N 24°41'46.2''E	Palivere	medium and fine sand	6.5	39.8 (85.8)
*R-34	Sillaotsa	59°32'00.2''N 25°46'37.1''E	Palivere	fine sand	4.7	11.3
*R-35	Valgejõe	59°27'46''N 25°45'28''E	Palivere	medium sand	4.4	12.4
R-36	Valgejõe	59°27'46''N 25°45'28''E	Palivere	medium sand	4.4	12.2
*N-3	Valgejõe	59°27'46''N 25°45'28''E	Palivere	medium sand	7.0	59.0
*R-44	Soodla	59°23'39''N 25°23'00''E	Pandivere	medium and fine sand	3.5	81.0
*R-45	Soodla	59°23'39''N 25°23'00''E	Pandivere	medium and fine sand	3.5	94.0
*R-47	Laeva	58°28'16.5''N 26°21'36.6''E	Sakala	medium sand interlayer in gravel	7.8	13.8
*R-50	Valga	57°49'28''N 26°03'12''E	Otepää	fine sand interlayers in gravel	2.0	7.5
*R-51	Valga	57°49'28''N 26°03'12''E	Otepää	fine sand interlayers in gravel	2.0	13.2
*R-54	Valga	57°49'28''N 26°03'12''E	Otepää	fine sand interlayers in gravel	2.0	70.0
Marginal eskers						
*R-29	Palivere	58°58'12.6''N 23°55'43.2''E	Palivere	fine sand interlayers in gravel and cobble material	4.6	9.8
*R-30	Palivere	58°58'12.6''N 23°55'43.2''E	Palivere	fine sand interlayers in gravel and cobble material	4.6	10.9
Sandurs						
*R-52	Serafiniskes	54°37'08''N 24°59'50''E	Frankfurtian	fine sand interlayers in gravel	2.0	15.4
*R-53	Serafiniskes	54°37'08''N 24°59'50''E	Frankfurtian	fine sand interlayers in gravel	3.2	16.2
Kames						
*R-37	Pikasaare	59°26'16.8''N 25°51'22.1''E	Pandivere	fine sand interlayers in gravelly sand with pebbles and cobbles	3.2	13.7
*R-38	Pikasaare	59°26'16.8''N 25°51'22.1''E	Pandivere	fine sand interlayers in gravelly sand with pebbles and cobbles	6.4	23.0
*R-39	Pikasaare	59°26'16.8''N 25°51'22.1''E	Pandivere	fine sand interlayers in gravelly sand with pebbles and cobbles	8.2	16.2
**1161	Vana-Kuuste	58°16'28.5''N 26°52'45.2''E	Otepää	sand in gravel	9.7	19.0 (36.4)
**1162	Vana-Kuuste	58°16'28.5''N 26°52'45.2''E	Otepää	sand and silt	7.0	21.5 (95.1)
**1163	Vana-Kuuste	58°16'28.5''N 26°52'45.2''E	Otepää	medium and fine sand and silt	3.5	13.4 (46.4)
**1159	Nohipalu	57°57'49.1''N 27°22'06.4''E	Haanja	sand and silt	2.5	9.23 (12.5)
**1160	Nohipalu	57°57'47.5''N 27°22'05.1''E	Haanja	sand and silt	4.5	13.24 (18.6)

Tab. 1 continued

1	2	3	4	5	6	7
Ancient valley fillings						
*R-48	Tääksi	58°31'08.8''N 25°38'31.6''E	Sakala	medium and fine sand	6.2	54.0
*R-49	Tääksi	58°31'08.8''N 25°38'31.6''E	Sakala	medium and fine sand	6.2	62.0
*R-41	Pannjärve	59°16'40''N 27°34'00''E	Pandivere	coarse and medium sand with silt	8,0	9.8
*R-42	Pannjärve	59°16'40''N 27°34'00''E	Pandivere	coarse and medium sand with silt	8.0	11.5
*R-43	Pannjärve	59°16'40''N 27°34'00''E	Pandivere	coarse and medium sand with silt	15.0	13.4
*N-9	Pannjärve	59°16'40''N 27°34'00''E	Pandivere	coarse and medium sand with silt	5.0	72.0
*N-10	Pannjärve	59°16'40''N 27°34'00''E	Pandivere	coarse and medium sand with silt	5.0	75.0
**1168	Voka	59°24'51.0''N 27°35'56.3''E	Pandivere	sand with silt	5.5	12.53 (18.5)
**1169	Voka	59°24'51.0''N 27°35'56.3''E	Pandivere	sandy patches in silt	~12	25.0
Eskers						
*N-4	Uljaste	59°21'00''N 26°48'19''E	Pandivere	coarse and medium sand	2.2	96.0
*R-46	Iisaku	59°07'25''N 27°19'13''E	Pandivere	fine sand patches in gravel	3.0	11.6
*N-5	Iisaku	59°07'25''N 27°19'13''E	Pandivere	fine sand patches in gravel	5.0	114.0
Drumlins						
**1164	Laiuse	58°44'52.6''N 26°31'25.6''E	Sakala	medium and coarse sand below till	3.0	13.99 (26.2)
**1165	Laiuse	58°44'52.6''N 26°31'25.6''E	Sakala	the same 4 m deeper	7.0	13.11 (18.73)

* — dated in Tallinn by G. Hütt and published for the first time in Raukas (2004), ** — dated in Gliwice by A. Bluszcz

not glaciofluvial deltas, but rather outwashdeltas (sandurs). This question needs additional palaeogeographical investigation across a wider area.

Samples were also taken from a classical marginal esker near Palivere in northwestern Estonia (Fig. 1). According to Geer's classical theory (1897), marginal eskers of this kind were formed near the edge of the glacier as it descended into the basin.

In Estonia, especially in its northern part, radial eskers are extremely common. They fall into narrow (width/height ratio up to 7:1) and wide (over 7:1); straight-sloped, convex-sloped or concave-sloped; convex-rested, acute-crested or flat-crested types (Rähni, 1957). The longitudinal profile of the crests may be either straight or undulatory, the configuration of the base straight, curved or indistinct, and the transverse profile symmetrical or asymmetrical (Raukas *et al*., 1971). The variety of morphological types suggests that the eskers were formed in different ways: in dead ice as well as in active and passive glaciers. Some of them probably formed according to the delta theory proposed by Geer (1897). However, there are also eskers that conform the river-bed theory in open channels (e.g. at Aravete). At the same time, some eskers (at Neeruti, Kuusalu) were probably formed in subglacial tunnels. Since we do not know how exactly the study object was formed and what was the luminescence signal cleaning effectiveness, we dated only two eskers in NE Estonia, Uljaste near Kiviõli town and Iisaku (Fig. 1) — which hopefully were formed in open crevasses.

Sampling of kames (crevasse fill) seems also unpromising. In the study area both glaciofluvial and glaciolacustrine kames, as well as structurally complicated kames have been described. On top of the kames, the till cover is usually missing.

Morphologically, the kames of Estonia are represented by cupolas, hills, short ridges, terraces and oval plateaus, which within the limits of the kame field alternate with various negative forms, mainly of glaciokarst origin. There are kame fields (e.g. at Viitna), which are predominantly composed of hills and cupolas and accompanying glaciokarstic forms. But there are also kame fields (e.g. Kaiu, Selguse) where the positive forms are mostly ridge-like. The area of a kame field is mostly small, only seldom exceeding 10–20 km^2. The kames are often associated with eskers or represent transitional forms to the hilly topography. In each case only fine fractions were dated.

Several kame fields (Pikasaare, Nohipalu) and single kames (Vana-Kuuste) were investigated and dated (Figs. 1 and 2, Table 1). As kames mostly formed in dead ice and had limited possibilities for bleaching we are pessimistic about the results.

The bedrock surface in Estonia is strongly dissected by deep ancient valleys (Tavast and Raukas, 1982). According to their geological structure, they can be divided into valleys,

Fig. 2. Samples as a rule were taken from homogenous beds or interlayers, Nohipalu (photo by W. Stankowski)

filled mainly with subaqueous deposits of the last glaciation; valleys filled mainly with glaciolacustrine deposits of the last glaciation; valleys with one till horizon with underlying or covering subaqueous deposits; valleys of complex structure with more than one till horizon and accompanying subaqueous deposits. We took samples only from the first type of valleys, filled mainly with subaqueous deposits of the last glaciation at Voka (Fig. 3), Pannjärve and Tääksi (Fig. 1).

Two samples were taken from glaciofluvial deposits on top of the Laiuse drumlin (Laiuse, Figs.1 and 4).

RESULTS

The aims of this study were as follows: firstly, to establish a better constrained chronology for the deglaciation history of the Baltic States and, secondly, to establish the suitability of the OSL method for dating glaciofluvial deposits. Glaciofluvial deposits accumulated in widely different sedimentological conditions: in front of the ice margin, or on top, below or inside the ice cover. The resultant deposits vary strongly in their sedimentary characteristics, most of all in their grain-size composition. Nevertheless the fine fractions, transported in highly turbulent conditions, can potentially be bleached. At the same time the assumption that the luminescence of every grain was completely zeroed prior to final deposition is not only disputable but in many cases impossible. Incomplete bleaching gives higher ages and this phenomenon is evident in most of our results. The degree of bleaching of the luminescence signal during glaciofluvial transport remains a topic that deserves particular attention. In glacial outwash, the transport distances are short and the water muddy. It is difficult to establish the cycles of erosion and the deposition of mineral grains before final deposition. Moreover, transport and deposition of mineral grains likely took place partly at night.

Fig. 3. In the Baltic Klint Bay at Voka the Quaternary cover is about 30 m thick

The sampled upper 10 m of the section is represented by fine sand and silt (photo by T. Tubli)

It is clear that bleaching will mostly occur when, during day-time hours, the sediment grains in the moving medium are close to the water surface where the light intensity is greater and light spectrum is wider. An important factor is the muddiness of water, that in the transport of silty material was undoubtedly higher. This means that the results depend not only on the transport distance, but on many other factors, the role and relative importance of which difficult to establish.

In the Gliwice laboratory, three different aliquots were made for every sample. The measurements were repeated many times. The results obtained differ enormously. In the measured samples two groups of dates prevail: *ca*. 13.0 ka and *ca*. 18.8 ka. However, there are also dates older than 30 ka and even older than 80 ka. The youngest dates for a particular sample seem to be nearest to the latest grain transport and reflect almost complete bleaching.

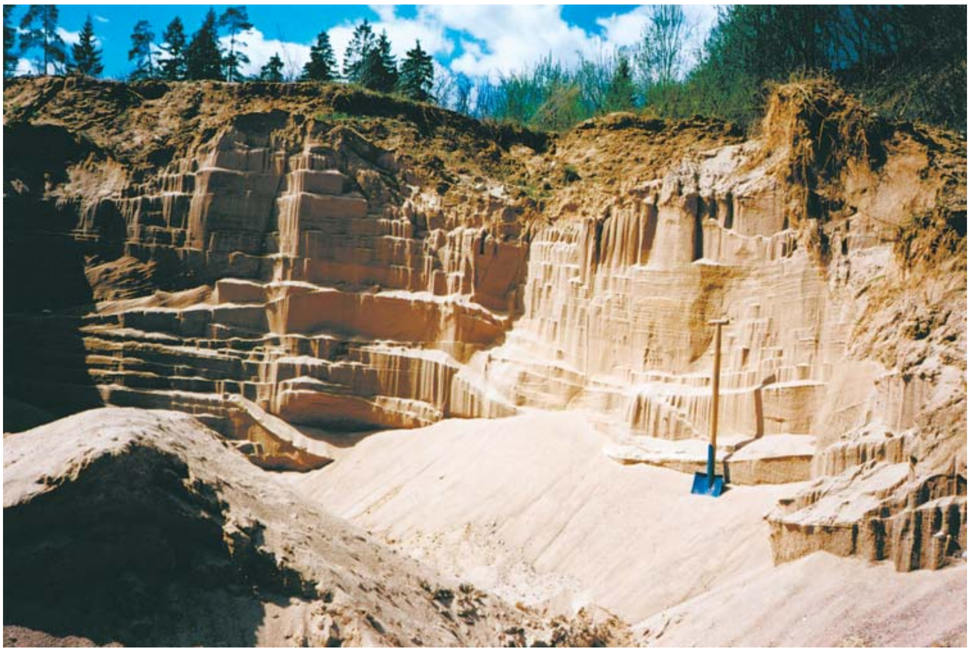

Fig. 4. Sand-grade beds were mostly sampled, Laiuse (photo by W. Stankowski)

CONCLUSIONS

The data obtained (Table 1) are extremely heterogeneous from a stratigraphical point of view. Less than half of the dates are more or less reliable. Some are completely unreliable. On the one hand this may be explained as resulting from a considerable admixture of unbleached mineral grains from older Quaternary deposits and from Palaeozoic rocks (e.g. at Tääksi); on the other hand, they may reflect a short duration of the moving medium under sunlight. In and below the ice, mineral grains were not exposed to light at all.

In applying OSL dating to fine fractions of subaqueous sediments, it is important to assess whether the light-sensitive trapped charge of every grain was bleached prior to final deposition. If such is the case, the age of the deposit can be obtained using OSL dating of any number of grains. If not, special care has to be taken to use only the OSL signal from those grains that had their charge bleached or, alternatively, the age obtained should be interpreted as a maximum age of the deposits (Bluszcz and Botter-Jensen, 1993; Bluszcz, 2000; Bluszcz and Stypa, 2000; Botter-Jensen *et al*., 2000; Gaigalas and Fedorowicz, 2002; Wallinga, 2002; Fedorowicz, 2003*a*).

Our study was based on a synthesis of deglaciation history, geomorphology, sedimentology and luminescence dates obtained in two laboratories: in Tallinn (performed by Galina Hütt) and Gliwice (made by Andrzej Bluszcz). The glaciofluvial assemblages studied (eskers, kames, glaciofluvial cones and deltas, ancient valley-fills) were deposited in various depositional settings including erosional and deformational events. This complicates the use of glaciofluvial deposits for chronostratigraphical purposes. The results obtained demonstrate that the OSL dating method could not improve the existing "late-glacial" stratigraphic chart of Estonia (Raukas and Kajak, 1995) nor the deglaciation chronology of the Northern Baltic area. Even the error-bars in OSL years are often larger than the duration of the entire deglaciation period of the Republic's territory.

We consider that inadequate light exposure in the glaciofluvial environment has commonly led to the OSL signal producing age overestimations.

Depending on different sediment concentrations, turbidity and depth of water, velocity of outwash streams and transport duration, incorporation of older unbleached particles, limited time of exposure to the sun in nonsummer time and other factors, the extent of bleaching of luminescence signal in the environments studied varies and is difficult to reconstruct in laboratory, so causing variability of dates. To our mind, this limits the use of the TL and OSL methods in solving the problems related to deglaciation history. It influences the dating of older intermorainic sediments even more, where most of the limiting factors are unknown. If the mechanism of formation of the deposits is unknown even the most accurate measurements of their TL properties will be meaningless. Each sample exhibits unique TL and dosimetric characteristics and, therefore, the dating technique cannot be routinely applied.

Clearly, much more research is needed to constrain the significance of OSL ages from glaciofluvial deposits. Further research should focus on comparing OSL ages with independent age control, which is easy to achieve for surficial sediments but very complicated for older intermorainic deposits, where the potential of the OSL method have clearly been overestimated.

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