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Where was the outlet of the ice-dammed Lake Komi, Northern Russia?

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Abstract

When ice-sheets on the continental shelves of the Barents and Kara seas expanded onto the Russian mainland, north-flowing rivers were blocked. The last proglacial lake in European Russia dammed between the ice-sheet in the north and the drainage divide in the south was Lake Komi, which has been dated to the Early Weichselian, 80–100 ka. The lake was about 1400 km long with a water level of about 100 m a.s.l. In the present paper, we discuss four alternative outlets: (1) Across the drainage divide towards the Volga River, leading the water southwards into the Caspian Sea; (2) across the Polar Urals towards West Siberia; (3) between the Barents Ice Sheet and the northern slope of the Kola Peninsula, leading the water northwestwards into the Norwegian Sea; and (4) across the drainage divide between the White Sea and the Baltic Sea catchment areas. Based on present knowledge, we consider the first three options unlikely. Across the divide to the Baltic Sea, a buried channel is mapped where the threshold altitude is lower than the Lake Komi level. We conclude that the outlet of Lake Komi probably followed this valley towards the Baltic Sea. However, the Scandinavian Ice Sheet overran this drainage divide during the Late Weichselian and therefore a younger till and other sediments cover the channel.

Keywords: ice-dammed lake; Lake Komi; spillway; Early Weichselian; Northern Russia

1. Introduction

Large proglacial lakes must have developed on the northern Russian lowlands every time Pleistocene ice sheets expanded from the Barents and Kara seas onto the mainland and blocked the northward flowing rivers. The existence of ice-dammed lakes has indeed for long been recognised both in West Siberia and European Russia, partly based on postulated altitudes of outlet thresholds (Lavrov, 1968, 1975; Kvasov, 1979; Arslanov et al., 1987; Volkov et al., 1978; Grosswald, 1980), although some of these reconstructions have subsequently been shown to be erroneous (Astakhov, 1989, 1992).

In this paper we will only discuss possible outlet channels of former connecting ice-dammed lakes of European Russia (Fig. 1). A huge lake, called Lake Komi, was inferred from its strandlines mapped by

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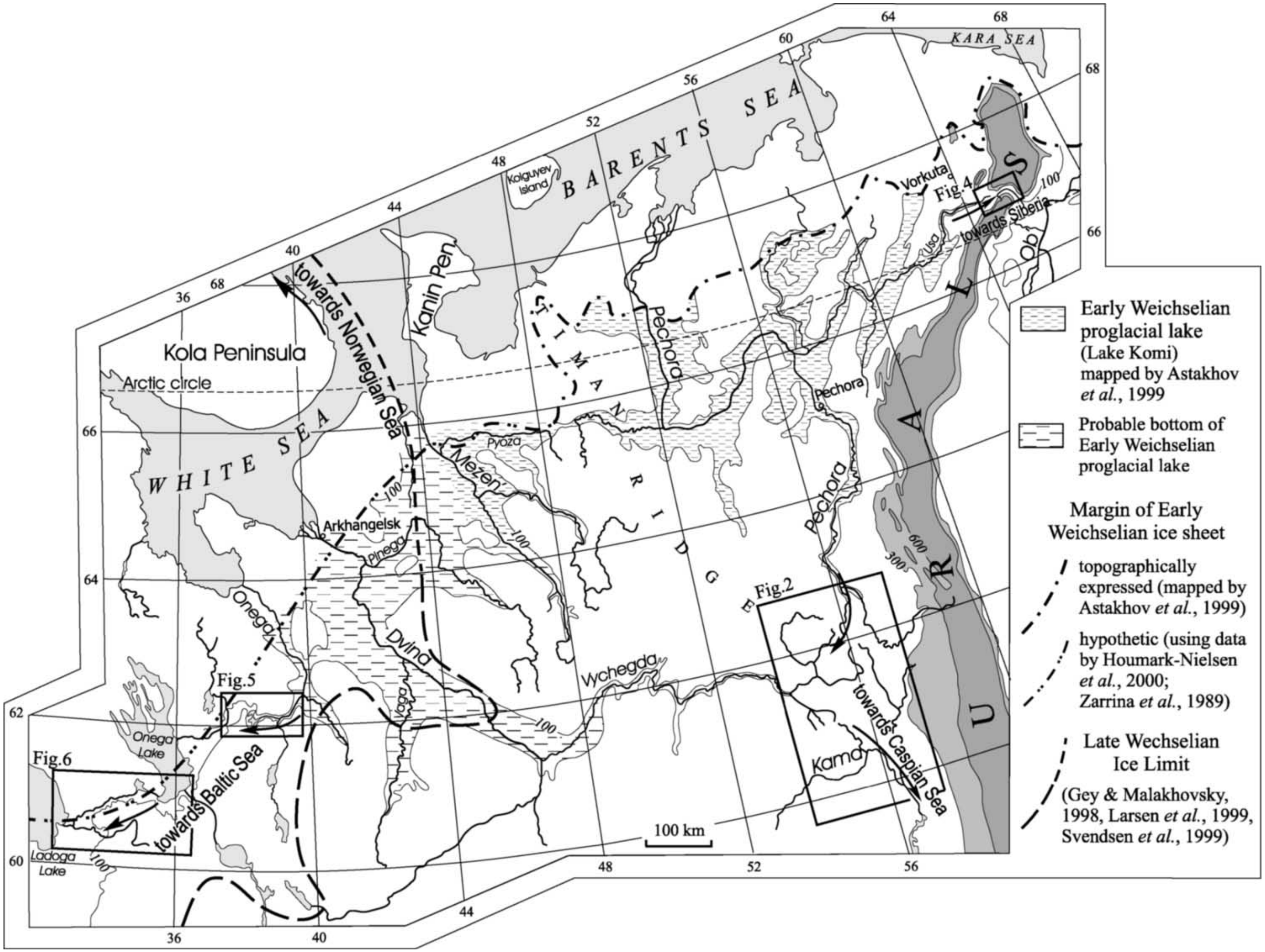

Fig. 1. Four possible outlets from the Lake Komi system are marked with arrows. In the text, we conclude that the outlet was probably towards the Baltic Sea. Rectangles with numbers indicate more detailed figures in the text. The western extension of Lake Komi is hypothetical and delimited by the Early Weichselian ice margins mapped by Astakhov et al. (1999) and inferred by us from data by Houmark-Nielsen et al. (2001) and Zarrina et al. (1989). Late Weichselian Ice Limit as described by Gey and Malakhovsky (1998), Larsen et al. (1999) and Svendsen et al. (1999).

air photos, satellite images and field observations in the Pechora lowland (Astakhov et al., 1999; Mangerud et al., 1999). Its shorelines were also traced across the Timan Ridge into the Mezen and Severnaya Dvina catchment areas (Astakhov et al., 1999), demonstrating that the Barents–Kara Ice Sheet also blocked the mouth of the White Sea at that time. The present altitudes of the shoreline are about 90 m a.s.l. in the southern part of the Pechora drainage basin, rising to 100–110 m in the northern part. Beach sediments of Lake Komi have been dated to the Early Weichselian, 80–100 ka, by means of optically stimulated luminescence (OSL) dating (Mangerud et al., 2001). Lake Komi is considered to have been the last ice-dammed lake in the Pechora lowland, at least the last one with shorelines as high as about 100 m a.s.l. (Astakhov et al., 1999; Mangerud et al., 1999).

Even though the configuration of Lake Komi is fairly well known in the eastern areas, its outlet has not yet been identified. In this paper we discuss four possible alternatives (Fig. 1), mainly based on earlier Russian publications and mapping reports: (1) An outlet across the southern drainage divide, to the Kama River, a tributary to the Volga River running to the Caspian Sea; (2) an outlet through the Ural Mountains to West Siberia; (3) an outlet channel between the Barents Ice Sheet and the northern slope of the Kola Peninsula, leading the water northwest into the Norwegian Sea; and (4) An outlet across the drainage divide between the White Sea and Lake Onega in Russian Karelia, leading the water to the Baltic Sea.

The final emptying of the reservoir, when the ice-dam broke, had to occur through the Pechora Valley and the White Sea, but will not be discussed in this paper.

2. The southern drainage divide

The divides between the three major continental drainage basins of Pechora, Dvina and Volga are presently at less than 140 m a.s.l. (Fig. 2). The divides are dissected by a system of sediment-filled through valleys (shaded in Fig. 2) where all bedrock thresholds in fact are lower than 70 m a.s.l., i.e. considerably lower than the Lake Komi level. These buried valleys are most often referred to as spillways of ice-dammed lakes in the Pechora and Dvina catchment areas (Krasnov, 1948; Kvasov, 1979; Lavrov, 1968, 1975, Arslanov et al., 1987). They have been discovered and studied extensively by geotechnical profiling since the 1930s (Krasnov, 1948; Yakovlev, 1956; Ryabkov, 1967). The valleys are topographically well expressed, with gentle slopes and 3–5-km-wide, boggy floors. Altitudes of the present drainage divides are 140 m a.s.l. in the Mylva valley, connecting the Pechora and Vychegda–Dvina catchment areas, and 132 m a.s.l. in the Keltma valley, connecting the Vychegda–Dvina and Kama–Volga catchment areas (Figs. 2 and 3).

The valleys are filled with up to 100 m of terrestrial sediments (Fig. 3), which according to published interpretations, range in age from Late Pliocene to Holocene (Krasnov, 1948; Yakovlev, 1956; Ryabkov, 1967). Three horizons of Pleistocene tills interbedded with fluvial gravel, sand and silt are recognised. The top of the uppermost till was recorded at 100–104 m a.s.l. (Fig. 3a,b). This level may be considered a candidate for outlet levels of Weichselian ice-dammed lakes. The till is overlain by lacustrine and fluvial sand and silt (Yakovlev, 1956; Ryabkov, 1967). In the Keltma valley, there is also an up to 2.5 m thick sedge-moss peat about 120 m a.s.l. (Fig. 3b). It contains pollen of *Salix*, *Betula*, *Pinus*, *Picea* and scarce pollen of deciduous trees. The peat was originally considered to be of Middle Pleistocene interglacial age (Yakovlev, 1956), and, showing a full interglacial vegetation, is certainly of Eemian or older age.

We agree that ice-dammed lakes in the Pechora–Dvina river basins probably have drained through the Mylva–Keltma valleys several times during the Pleistocene. However, the surface of the Middle Pleistocene till (104 m a.s.l.) is well above the Lake Komi shoreline (90 m a.s.l.) in the southern end of the lake. Accepting that the thick buried peat (about 120 m a.s.l.) in the Keltma valley (Fig. 3b) is of pre-Weichselian age, it proves that Lake Komi did not spill over this pass. We have studied satellite images of the Upper Pechora basin and aerial photographs of the Pechora–Vychegda–Kama interfluve. Only normal fluvial terraces sloping downstream have been found, but no lake strandlines south of the 64th parallel. We therefore find it

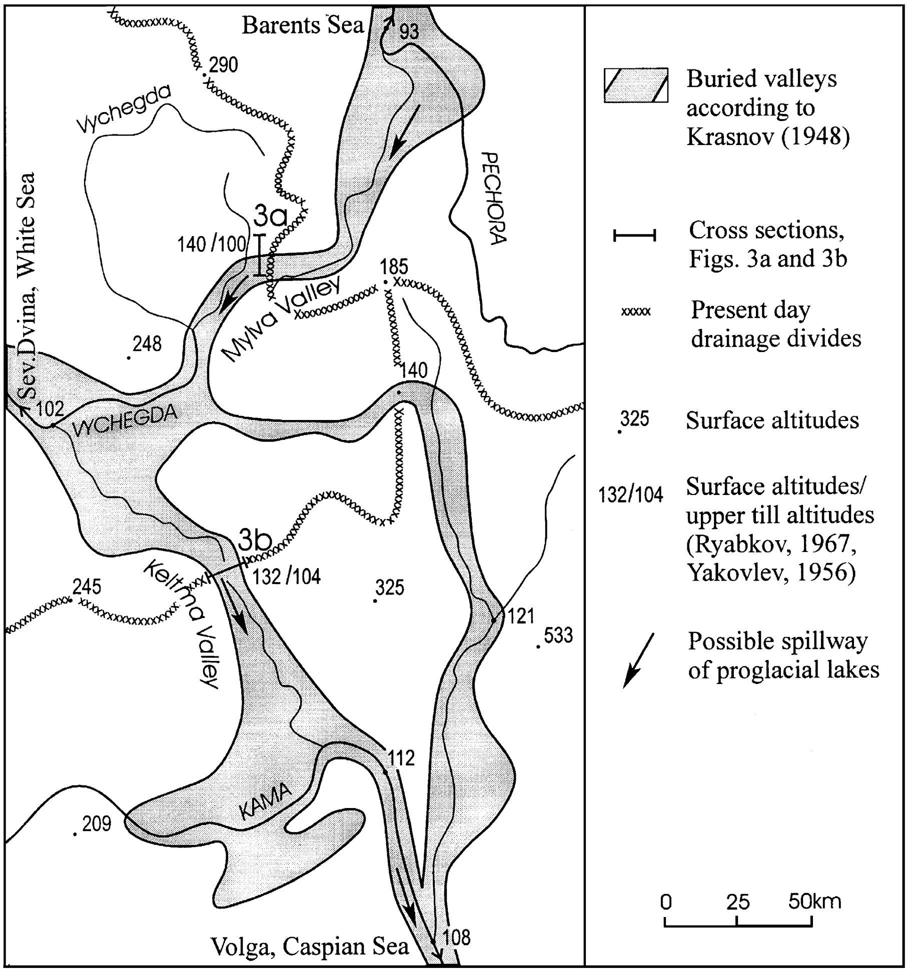

Fig. 2. The geomorphology around the drainage divides between the Pechora, Vychegda–Dvina and Kama–Volga rivers.

unlikely that the outlet of Lake Komi was across the drainage divide to the Volga.

3. Drainage across the Urals

In West Siberia, the last ice-dammed lake existed during the Early Weichselian (Astakhov, 1989). The lake, which did not exceed 70 m a.s.l., drained to the Aral Sea via the Turgai Valley with a bedrock threshold at 40 m a.s.l. (Astakhov, 1992). Theoretically, Lake Komi could have drained into this low-level Siberian lake. This option requires a pass point in the northern Urals that was lower than about 110 m a.s.l., which is the shoreline level in the northern part of Lake Komi.

The lowest and widest valley crossing the Polar Urals is along the Yelets and Sob rivers (Fig. 4), used by the Moscow–Labytnangi railway. The Yelets flows into the Usa River, a tributary of the Pechora, and the Sob is a tributary to the Ob River on the Siberian side. The present drainage divide is on the surface of a moraine at 154 m a.s.l. (Fig. 4). The altitude of the underlying bedrock is unknown both at this site and along the valley. The moraine was probably deposited by alpine glaciers, which existed contemporaneously with the ice sheet damming Lake

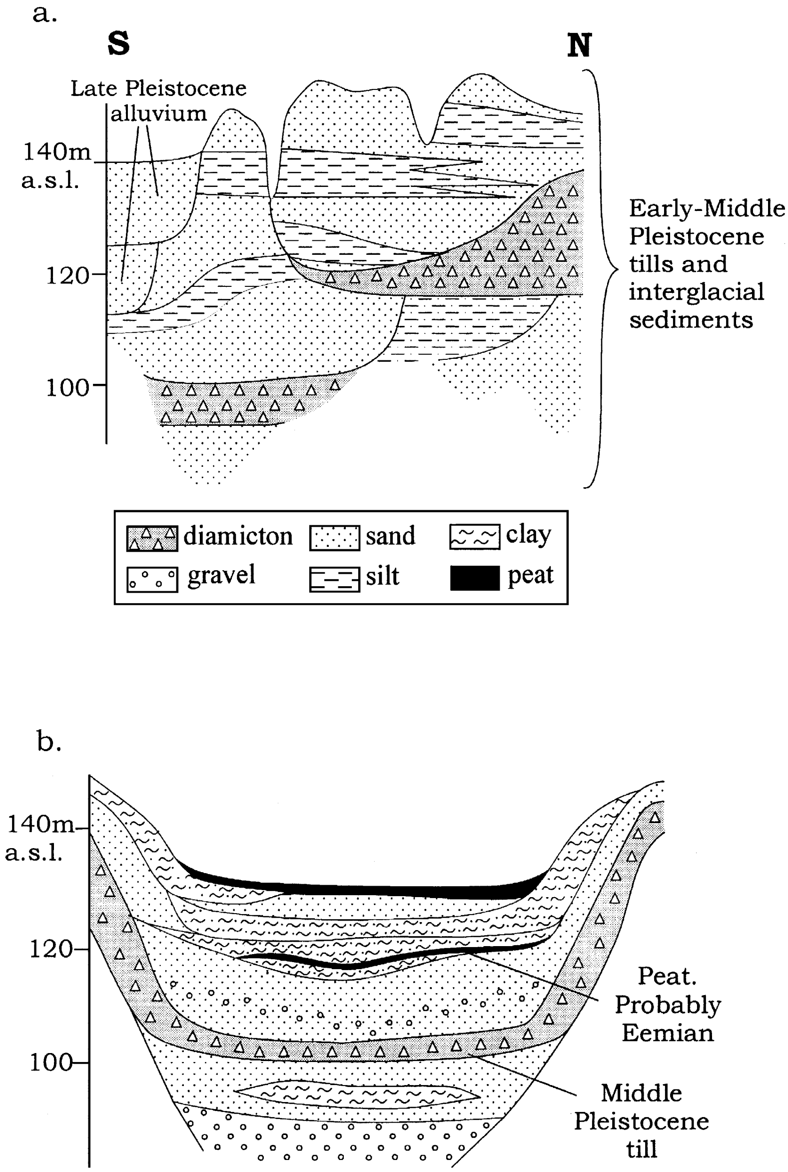

Fig. 3. Cross-sections of (a) the Mylva (simplified from Ryabkov, 1967) and (b) Keltma (simplified from Yakovlev, 1956) through valleys.

Komi, as indicated by morainic aprons along the foot of the Polar Urals at 150–400 m a.s.l. (Astakhov et al., 1999). Furthermore, Lake Komi shorelines ended well west of the present-day drainage divide, according to our photogeological mapping. Along the upper reaches of the Yelets River, only alluvial terraces were seen. From the available evidence, we therefore conclude that Lake Komi did not drain through this valley.

4. Possible outlet towards the Norwegian Sea

During the Late Weichselian, the Scandinavian Ice Sheet overran the western part of the area that

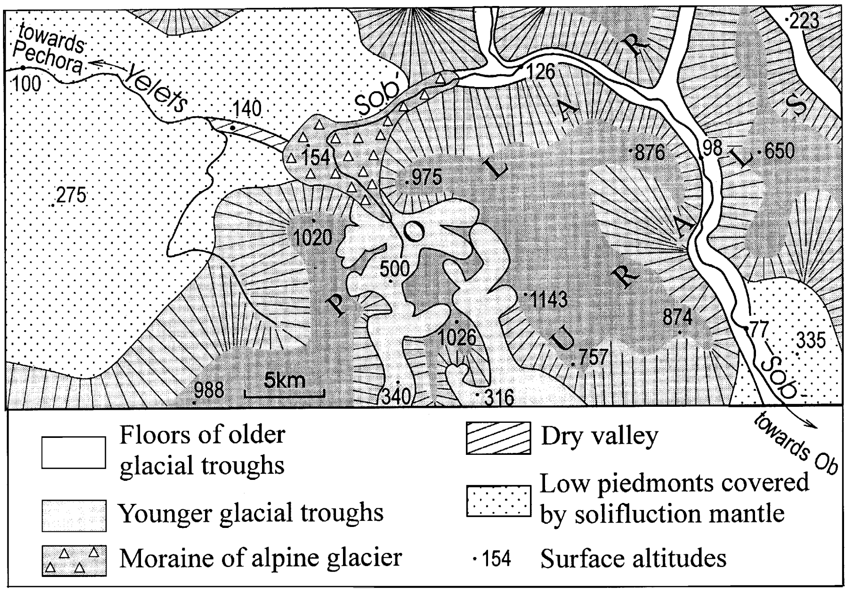

Fig. 4. The geomorphology around the drainage divide in the Sob pass, Polar Urals.

was flooded by the Lake Komi system, and thus obscured the lake deposits. The configurations of the ice sheets and ice-dammed lakes during the Early Weichselian are therefore poorly known in the western areas. We cannot rule out the possibility that the northern extension of the Scandinavian Ice Sheet was restricted during the Early Weichselian, and that there was an outlet for Lake Komi along the southern flank of the Barents Ice Sheet, across the northern tip of Kola Peninsula. However, such an outlet would require a very specific ice sheet configuration that we find unlikely, and, even more important, that hypothesis cannot presently be tested, and is therefore disregarded.

5. Southwestwards into the Baltic Sea

Shorelines of Lake Komi have been traced by satellite imagery into the Mezen Basin (Fig. 1) (Astakhov et al., 1999). Farther southwestwards, the flatlands at altitudes of about 100 m a.s.l. are truncated by the Late Weichselian moraines of the Scandinavian Ice Sheet (Larsen et al., 1999), and the older topography is therefore unknown. However, the present-day wide valleys along the major rivers —Severnaya Dvina, Pinega, Vaga, Vychegda—are situated well below 100 m a.s.l., suggesting that the Lake Komi system continued westwards into the area later covered by the Late Weichselian Scandinavian Ice Sheet (Fig. 1).

Presently, the lowest pass across the drainage divide between the White Sea and the Baltic Sea basins is located NE of Lake Onega, between Lake Kenozero and the Vodla River (Figs. 1 and 5). The divide is here about 98 m a.s.l., with bedrock close to the surface (Fig. 5, Kalberg et al., 1970; Kapishnikova et al., 1994). Therefore, even with the present-day topography, which is formed by the Late Weichselian moraines, an Early Weichselian lake at 100 m a.s.l. could have spilled over this water divide and drained to Lake Onega and further southwestwards to the Baltic Sea. However, according to Kalberg et al. (1970) and Kapishnikova et al. (1994), the Kena and Onega rivers, running NE-wards from Lake Kenozero, follow a 3–6-km-wide buried valley (shaded in Fig. 5), cutting through the Carboniferous bedrock plateau of about 200 m a.s.l. (Fig. 5; Nalivkin, 1983). The buried valley proceeds SW-wards along the plateau escarpment, through the present drainage divide and into the Lake Onega depression. The bedrock floor along the entire buried valley is below 40 m a.s.l. Sediment cores revealed the following stratigraphy in the buried valley (Kalberg et

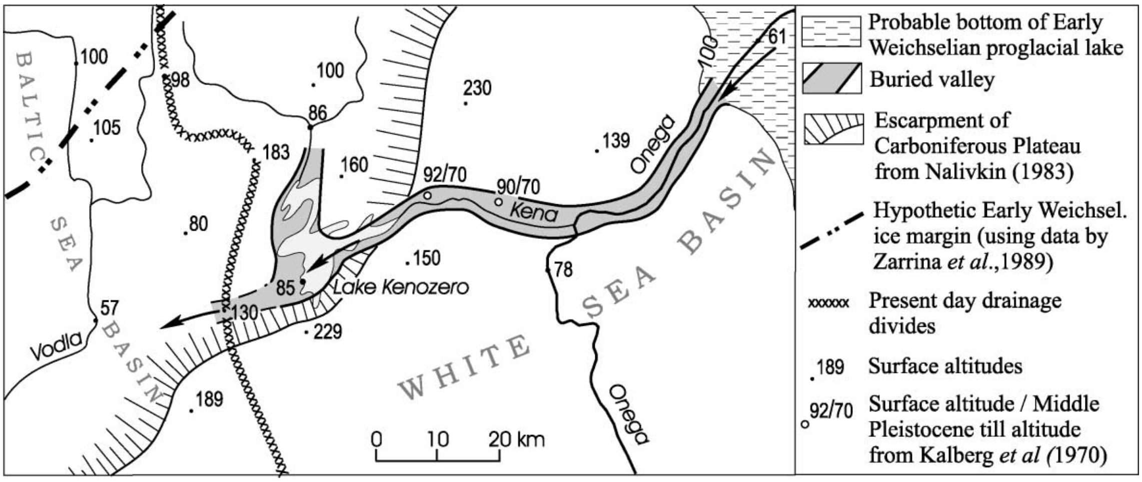

Fig. 5. The geomorphology around the White Sea–Baltic Sea drainage divide. Arrows show a possible spillway for Lake Komi water through the buried valley along Kena–Onega rivers and across the drainage divide to Lake Onega (and on to the Baltic Sea). The buried valley mapped by Kalberg et al. (1970) and Kapishnikova et al. (1994).

al., 1970). Middle Pleistocene tills reaching up to 70 m a.s.l. are overlain by a lacustrine formation up to 90 m a.s.l. The latter consists of finely laminated clay with sporadic lenses of sand and well-rounded pebbles, changing upwards to sand with rare, well-rounded pebbles. A Late Weichselian till, followed by glaciofluvial sand and gravel, cap the lacustrine sequence.

We find it likely that the outlet of the Lake Komi system was along this buried valley. This feature was previously proposed by Kvasov (1979) as a spillway for an ice-dammed lake with water table at 110 m a.s.l., which he thought existed in the White Sea–Mezen–Severnaya Dvina–Vychegda catchment area during the Younger Dryas. A Younger Dryas age is impossible according to the glaciation history known today (Saarnisto et al., 1995), but Kvasov's reconstructed lake and outlet pattern may be valid for Lake Komi. The altitude of the pre-Weichselian till is only about 70 m a.s.l., and therefore the till does not represent an obstacle for overflow from Lake Komi. In fact, the top of the till is so low that there

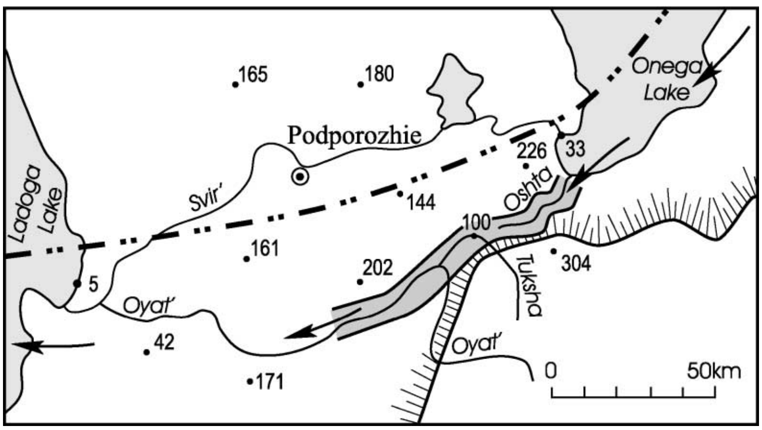

Fig. 6. The geomorphology on the Onega–Ladoga isthmus. For symbols, see Fig. 5. Buried valley mapped by Malakhovsky et al. (1995). Circle with dot indicates the location of the Podporozhie borehole where an Early Weichselian till is described (Zarrina et al., 1989). Arrows show possible spillway of the Lake Komi system towards the Baltic Sea.

is a possibility that the lake continued through the valley, and that the outlet threshold was even farther south.

From the drainage divide west of Lake Kenozero (Fig. 5), the rivers presently run towards the lakes Onega (33 m a.s.l.) and Ladoga (5 m a.s.l.), and farther towards the Baltic Sea. However, if the Lake Komi system continued south of Lake Kenozero, the Scandinavian Ice Sheet must have blocked this low terrain. Such an ice sheet extent is indeed compatible with the data by Zarrina et al. (1989) (Figs. 1 and 6). Two diamicton beds separated by lacustrine sand were found above Eemian deposits in a borehole along the river Svir, near the town Podporozhie (Fig. 6). The lacustrine sequence was interpreted as Middle Weichselian interstadial sediments sandwiched between Early and Late Weichselian tills (Zarrina et al., 1989). If the age of the older till is correct, an Early Weichselian ice sheet advanced as far south as the river Svir, blocking a possible spillway along the river (Fig. 6). Present altitudes south and east of Svir exceed 100 m a.s.l., reaching up to 300 m a.s.l. on the Carboniferous Plateau (Fig. 6). However, here deep buried valleys connect the depressions of Ladoga and Onega (Malakhovsky et al., 1995). The valley along the Carboniferous escarpment (shaded in Fig. 6), located along a regional lineament and marked by the rivers Oyat, Tuksha and Oshta, is the most spectacular. The bedrock surface in places along the valley floor drops below sea level. Although no data about the age of the sediments filling the valley have been reported so far, this valley is a potential spillway.

We emphasize that Houmark-Nielsen et al. (2001) and Lyså et al. (2001) concluded that the mouth of the White Sea was not blocked by glacial ice during the Early Weichselian, implying that Lake Komi could not extend into that basin and thus that the discussed outlet candidate should be rejected. However, after re-examination of air photos we still maintain that the strandlines can be traced across the Timan Ridge into the White Sea Basin.

6. Conclusion

The outlet of the Lake Komi system was probably located in Russian Karelia, with the water draining into the Baltic Sea. The outlet followed deep bedrock channels across the drainage divide between the White Sea and the Baltic Sea basins. The channels subsequently were buried by till and other sediments deposited by the Late Weichselian Scandinavian Ice Sheet, so further investigations are needed to confirm this hypothesis.

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