Quaternary Glaciations – Extent and Chronology
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On the age and extent of the maximum Late Pleistocene ice advance along the Baltic-Caspian watershed

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In northwestern European Russia glacial limits are determined using both geomorphological (e.g., marginal features, drainage network density) and stratigraphical (the presence or absence of till overlying interglacial and interstadial sequences) criteria. Since Markov's work (1940) the stratigraphic approach has increasingly been gaining prevalence. Other parameters, such as distribution of periglacial loess-like silts, lithology of erratics, sub-till topography, proglacial reservoirs, soil thickness and lake density have also been taken into account. The area of the last Scandinavian ice sheet has traditionally been associated with the lake country fringed from the southeast by the wide belt of diverse glacial accumulations on the interfluvial Valdai Upland running between St. Petersburg and Moscow.

Until the late 1940s there was general agreement that a single Valdaian glaciation had followed the single Late Pleistocene interglacial (the Mikulinian). However, in 1950 Moskvitin suggested that a Mologa-Sheksna interglacial divided the large, Valdaian ice age into two glaciations – the Kalinin and Ostashkov (Moskvitin, 1950). This concept was adopted by Yakovlev (1956), Apukhtin & Krasnov (1967), Punning *et al.* (1969), Breslav (1971) and Zarrina (1991). Other investigators maintained that the Valdai glaciation was interrupted only by climatic ameliorations of inter-stadial rank. According to Malakhovsky and Markov (1969), Chebotareva (1974) and Arslanov (1987) the longest, Middle Valdaian interstadial is the equivalent of the so-called `Mologa-Sheksna Interglacial`.

Another long-standing controversy concerns the extent of the two ice advances, namely, which ice sheet, Early or Late Valdaian, was larger and where the major ice limit was located. Vozniachuk (1973) and Chebotareva & Makarycheva (1974) defended an ice-free Early Valdaian, whilst Velichko (1993) suggested the time-transgressive Late Valdai ice limit. In various publications the Valdaian glacial maximum was attributed either to the time around 20 ka BP, or to a period beyond 50 ka ago, and its position in the Upper Volga catchment area varied by 200-300 km (cf. maps by Krasnov, 1971 and Aseyev, 1981).

These disputes largely stemmed from the controversy concerning the origin of the sediments overlying the Mikulino (Eemian) interglacial sequences. Authors advocating an Early Valdaian glacial maximum tend to interpret all superficial diamictons as basal tills. For instance, Sudakova *et al.*, (1997) maintain that the 1-2 m thick diamicton, in places overlying Mikulino interglacial sediments distal to the main belt of terminal moraines, is an Early Valdaian-age basal till. This interpretation implies that the Late Pleistocene ice reached as far as only 20 km north of Moscow, i.e. 230 km southeast from the Late Valdai limit shown in the present digital map. However, Kozlov (1972) and other geologists have repeatedly demonstrated that the known interglacial sequences south of the main belt of Late Valdai end moraines are often overlain by a thin, soft, weathered diamicton instead of the normal glacigenic sedimentary complex. This diamictic layer pinches out upslope and has weak, slope-dependent bedding and fabrics, i.e. it bears signs of redeposition by slopewash or solifluction. Such sites are interspersed with interglacial sequences that lack any Pleistocene sediment cover.

In standard maps of the Geological Survey the thin discontinuous diamictic mantle is usually not regarded as a reliable signature of an ice advance (Auslender, 1989), the attitude shared by the present authors. In the digital map such sequences of Mikulino and Valdai interstadial sediments are also shown as not overlain by till. Accordingly, the limit of the maximum Late Pleistocene ice advance is located distally but close to the main marginal belt comprising diverse hummocky glacigenic accumulations (Gey & Malakhovsky, 1998). However, the geomorphological evidence is not straightforward everywhere. The most well-expressed push moraines, such as the Vepsa and Krestsy stadial formations, are often situated proximally to the maximum ice limit (Chebotareva, 1977). Moreover, in the flat lowland along the Suda river, in the Babayevo-Vesyegonsk area, the till is obscured by glaciolacustrine sediments. Two options for the ice limit in this area are shown on the digital map. Recent data indicate that the proximal option is more correct (Lunkka *et al.*, 2001).

Recently, the stratigraphic knowledge has improved significantly. The `Mologa-Sheksna interglacial` in its type

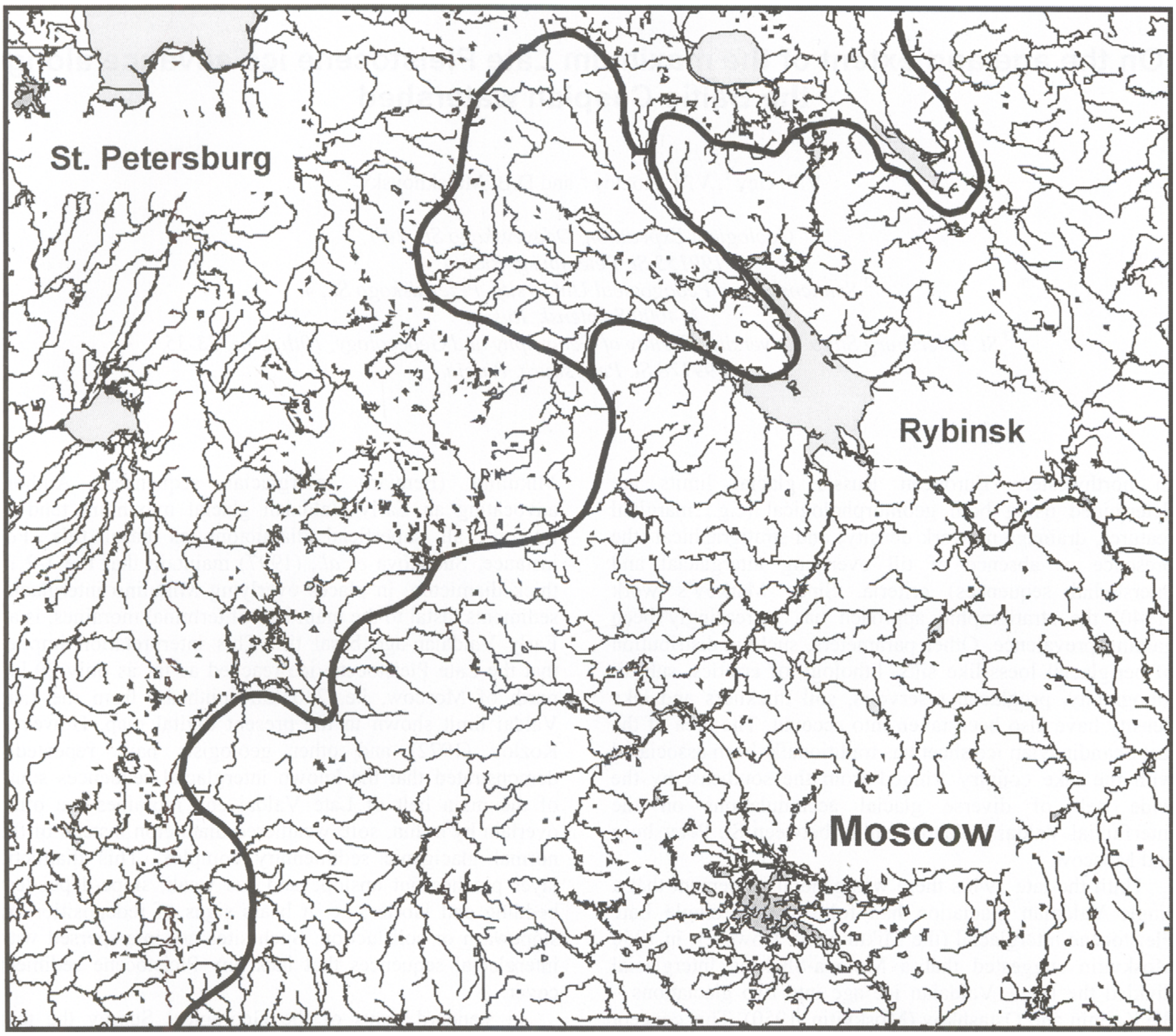

Fig. 1. Position of the maximum LGM in the Baltic-Caspian watershed region.

sections proved actually to represent the Mikulinian (Eemian) interglacial stage and was therefore deleted from the regional stratigraphical scale. Instead an interstadial sequence with the palaeoclimatic characteristics colder than those at present and radiocarbon dates ranging from 25 to 50 ka BP, was chosen as stratotypic for the Middle Valdai (Krasnov & Zarrina, 1986; Velichko & Faustova, 1986). The main climatic phases of the Mikulinian and Valdaian Stages are now more reliably distinguished on the basis of pollen analysis. Therefore, not only sites with interglacial sediments, but also those including Late, Middle and Early Valdaian interstadial sequences, can be used for locating the ice margin, depending on whether they are covered or not by Valdaian-age tills.

The most complete Upper Pleistocene stratigraphical sequence has been described from a borehole which penetrated 90 m of lacustrine sediments overlying Middle Pleistocene tills near the city of Dmitrov at the 1st May Factory, 56°N. The coldest and driest phase, indicated by pollen and diatom assemblages, is found in the interval between 30 and 12 ^{14}C ky BP. However, no Valdaian tills occur in this succession (Semenenko *et al.*, 1981). As to the Early Valdaian time, pollen assemblages in sections from the periglacial zone (e.g., 1st May Factory, Rogachovo, Shestikhino) show unmistakable signs of cooling suggesting a possible glaciation elsewhere. How-ever, basal till lying between the Mikulinian and Middle Valdaian formations has only been found in the very far north of the region (Podporozhye, Petrozavodsk and other sites north of 61°N).

The post-Eemian glacial maximum in northwestern European Russia, according to many works (Vigdorchik *et al.,* 1971; Auslender, 1989; Faustova, 1995; Gey & Malakhovsky, 1998;. Gey *et al.*, 2001), occurred 18-20 ^{14}C ky BP. This estimate, based on conventional radiocarbon dating, has lately been refined by the Russio-Finnish team who applied combined modern techniques of optically stimulated luminescence and AMS radiocarbon methods. They found that the maximum ice advance in the Vologda Region occurred *c.* 18 cal ky BP (Lunkka *et al.*, 2001).

Younger standstills of the retreating ice margin based largely on geomorphological evidence, are more controversial (Vigdorchik *et al.,* 1971). The age brackets for the main retreat stadials the Vepsa-Krestsy, Luga and Neva are determined mainly from evidence obtained from the adjacent Baltic states (Velichko & Faustova, 1986). Data available in the region under discussion suggest that these short-lived readvances occurred during the interval 17 - 13 ka BP. Recently, Saarnisto & Saarinen (2001), using varve chronology, palaeomagnetic events and AMS radiocarbon dating, concluded that the Luga Stadial, in the south of Lake Onega, took place slightly earlier than 14,250 cal yr BP, and the Neva Stadial occurred *c.* 13,300 cal yr BP, i.e. just before the Allerød interstadial.

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