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Surface paleosols of the loess island within Moscow glacial limits: Vladimir Opolie

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ABSTRACT

Vladimir Opolie is a typical loess island with soil pattern that differs strikingly from that of adjacent territories. Soils are characterized by a controversial set of features. They have common features with other loess islands located in various environmental zones (similar dependence on microtopography with second humus horizons in soils within depressions and accumulation of carbonates in soils on the main surfaces). On the other hand they differ from soils of loess islands formed on typical loess due to specific features of sediments: mantle loams, and a northern variety of loess. A pedostratigraphic approach to the study of soils of Vladimir Opolye reveals that constitution of the upper loess strata depends on paleocryogenic microtopography and that relict soil features (second humus horizon, pattern of carbonates distribution) are syngenetic with the final stages of loess sedimentation. The abundance of relict features indicates that the soils of Vladimir Opolie are surface paleosols.

1. Introduction

Loess sediments of the Russian Plain are a part of the East European loess province (Velichko, 1990; Velichko et al., 2006). Loess sediments in Russia that are included within loess formations are subdivided on typical silty loesses and loess-like sediments (Moskvitin, 1940; Obruchev, 1948; Berg, 1960; Bolikhovskaya, 1995; Trofimov, 2001). Within the ice-sheet limits of the Moscow (Saalian III, MIS6) stage, loess sediments are mainly mantle loams that have characteristic features of loess: uniform thickness on uplands and slopes, vertical walls in exposures, and predominance of coarse silt in granulometric composition. Compared to typical loess, mantle loams are more compact, less porous, less water permeable, and not subsiding. They have well expressed prismatic blocky structure and asepic plasma with high birefringence. Because of the high clay content (sometimes more than 30%), they could be regarded as clay loess (Fink et al., 1977).

The territory of the Russian Plain was influenced by at least six Pleistocene ice sheets (Rychagov, 2006; Velichko et al., 2006, Fig. 1). Among them, two ice-sheets formed glacial and periglacial sediments that are the parent material for surface soils. As in Northern Europe, the middle Pleistocene Moscow (Saale III, Warthe, MIS 6, 180 (150) - 130 (115) ka) ice-sheet was more extensive than the most recent Valdai (Weichselian) ice sheet (Velichko et al., 2006). The pattern of surface glacial and periglacial sediments follows three conspicuous belts: the area south of Moscow ice-sheet limits is characterized by extensive loess mantles of the East-European loess belt. An area within Moscow glacial limits is characterized by a diverse set of sediments (separate bodies of mantle loams, glacial till, fluvioglacial sand) as a result of complex glacio-dynamic structure and extensive dissection of relief. Within Valdai ice-sheet limits, flooding prevented extensive loess accumulation. Soils here inherited specific layering of sediments (laminated clays, fluvioglacial sands and glacial till with veneer of fluvial sand, cover sand, some loess).

Within the Moscow ice-sheet limits on the northern periphery of East European loess province, loess sediments are represented by mantle loams. Separate mantles of these sediments cover high flat uplands that are isolated by moraine plains and fluvioglacial lowlands and dissected by river valleys. Dokuchaev (1948) called such high uplands “loess islands”. Loess islands follow a wide arch trending southwest to northeast from Northern Ukraine and Southern Belarus to southwest and central European Russia and to the Ural Mountains. The common feature of loess islands is that they were a part of the vast Late Pleistocene cryolithozone, with the

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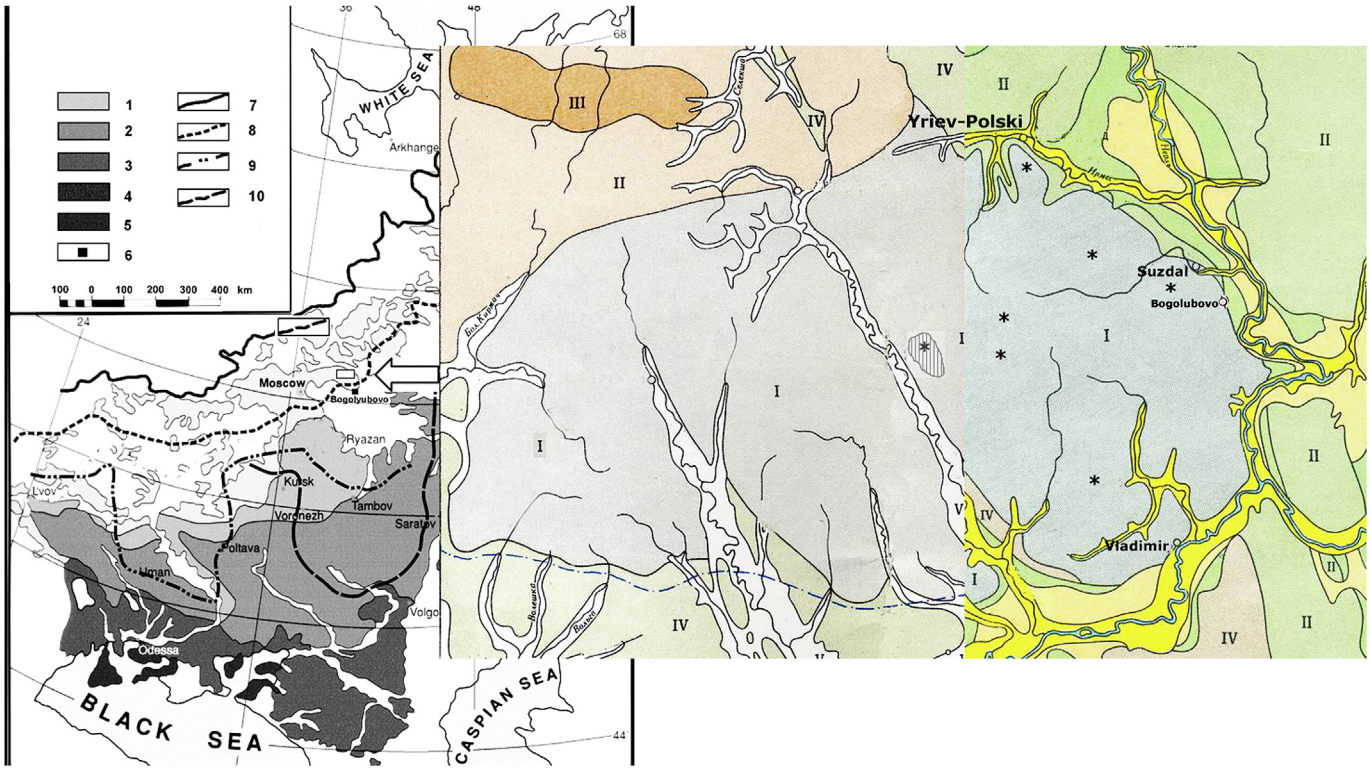

Fig. 1. Study site location. Left. Location of Vladimir Opolie in the East European loess region on the southern border of Moscow glacial limits (simplified from Velichko et al., 2006). 1—Upper Pleistocene loess, 2—Upper and Middle Pleistocene loess, 3— Upper, Middle and Lower Pleistocene loess, 4—Middle and Lower Pleistocene loess, 5—Submerged Pleistocene loess, 6—Bogolyubovo section on the periphery of Vladimir Opolie; 7–10—ice sheets limits: 7—Valdai, 8—Moscow, 9—Dnieper, 10—Don. Right. Ancient denudation plateau of Vladimir Opolie (I) surrounded by moraine (II) and end-moraine (III) plains and fluvioglacial lowlands (IV) and dissected by river valleys (V). Key sites are marked with *. Shaded area -watershed with bipartite sediments – thin veneer of loess on top of glacial till (Fig. 10).

southern boundary to 46–48° N. So, they were deeply influenced by periglacial environments (Velichko, 1965; Velichko and Morozova, 1975; Morozova and Nechaev, 2002; Makeev, 2009). As a result, the surface of the loess islands is complicated by rounded depressions 0.5–1 m deep and 20–50 m wide that occupy 20–30% of the terrain, forming a regular network.

Vladimir Opolie (from the Russian word *polie*—field) is one such loess island, with soils that amazed scientists in the 19th century. Dokuchaev (1884) called these soils, formed deep in the forest zone, Vladimir or Yuriev Chernozems because of the dark-colored humus horizons. Like other loess islands, Vladimir Opolie differs in all landscape components (parent rocks, vegetation, and soil cover) from the surrounding moraine plains and fluvioglacial lowlands. The soils of Vladimir Opolye are characterized by a set of common features typical for loess islands located in various environmental zones (southern taiga, forest-steppe and steppe) within and beyond the Moscow ice-sheet limits (Makeev, 2009, 2012).

During more than a century of study, a set of controversial hypothesis on the genesis of soils of Vladimir Opolye has been developed. Hypothesis have related soil genesis to the dominance of steppe vegetation in the past (Nikitin, 1885; Tanfil'ev, 1902; Obruchev, 1948; Kostychev, 1949), or to the high content of carbonates in the soil-forming rocks and the shallow table of hard ground water (Krasyuk, 1925; Kasatkin, 1931; Yakushevskaya, 1959). It was noticed that the soil pattern is determined by specific microtopography (Dolgova, 1964; Tyuryukanov and Bystritskaya, 1971; Rubtsova, 1974; Simakova, 1984; Makeev and Dubrovina, 1990; Alifanov, 1995; Alifanov et al., 2010). It was also noticed that soils of Vladimir Opolie retain numerous relict features, related to the mid-Holocene (Alexandrovsky, 1983; Velichko et al., 1996) or Late Pleistocene (Makeev and Dubrovina, 1990; Alifanov, 1995; Makeev, 2012). Until the present, the genesis of soils and sediments of Vladimir Opolie have been disputed.

2. Study area

Vladimir Opolie is located about 200 km east of Moscow (Fig. 1). It is a part of an ancient denudation plateau 50–60 km in diameter, with watersheds elevated 180–230 m above sea level. Vladimir

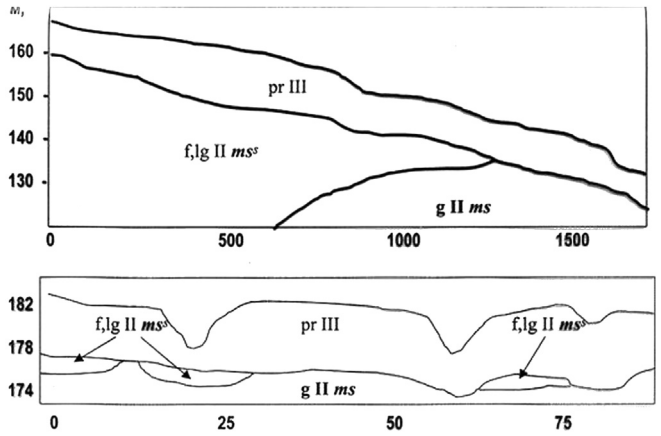

Fig. 2. Mantle loams on top of base till of Moscow glaciation (gII*ms*) and fluvio- and limnoglacial sands of Moscow glacial retreat (f,lg II ms^5). Archive of Centrgeologia geological survey, Moscow.