Postglacial Incision-Widening-Infill Cycles at the Borisoglebsk Upland: Correlations Between Interfluve Headwaters and Fluvial Network

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1 Introduction

Postglacial fluvial network history of the central Russian Plain is complex and heterogeneous regarding both temporal framework and leading development agents. Modern valley systems inherit many relic features including excessively large width inconsistent with present runoff conditions, highly elevated terraces (both depositional and erosional), thick bottom sedimentary infills partly incised by modern gullies, inactive headwaters almost infilled and disconnected from the presently active fluvial network, etc. Such distinct footprints can be related to much higher intensities of fluvial and other associated processes in the past. For the Upper Volga region located within the last Middle Pleistocene (Moscow – Saalian) glaciation marginal zone (Astakhov et al. 2016), the phase of uninterrupted fluvial network evolution is limited to the later glacial-interglacial climatic cycle. More than 20 sections of Quaternary deposits have been thoroughly described in the area forming the stratigraphic framework for reconstructing postglacial landscape evolution (Moskvitin 1976; Sudakova 2008; Velichko 2012 etc.). Geomorphological events with prominent stratigraphic representations are concentrated largely within the fluvial network. Hence, most of the landscape development reconstructions were strongly biased towards understanding fluvial sediment sequences, landforms and network evolution, and corresponding incision-widening-infill cycles. Unfortunately, until the present, such reconstructions remained controversial and unsupported by reliable absolute dating and chronological correlations with simultaneous processes in the upper reaches and headwaters through the major landscape shifts.

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2 Methods

The Borisoglebsk Upland case study area belongs to the long-existing Nero Lake basin. The latter remained local base level since the Moscow ice cover decay. Local fluvial network evolution was largely controlled by the Late Pleistocene – Holocene lake level fluctuations. In an attempt to reconstruct the past extent, density, and distribution of fluvial systems and to correlate the incision-widening-infill cycles between their presently dynamic and inactive parts, an interdisciplinary research of the present and buried topography, lithology and pedogenic properties of surface deposits have been carried out. Several independent approaches were combined: detailed geomorphic descriptions and DGPS profiling, remote sensing data interpretation, description of geological sections and cores followed by comprehensive analysis of grainsize, chemical and organic contents, pedogenic features on macro, meso- and micromorphological levels, and absolute ^{14}C dating of organic-rich layers (Garankina et al. 2018).

3 Results and Discussion

Morphologic differences (cross-section profiles, clearness of the carcass landscape lines, slope inclinations, width, depth, terraces, and bottom patterns) allow distinguishing three main types of linear depressions (Table 1).

Table 1. Types of small linear depressions and its morphologic patterns.

Types	1	2	3
Cross-section profile	V- and U-shaped	V- and U-shaped	V-shaped
Carcass lines	Sharp clear	Smooth clear	Smooth unclear
Sides slope inclination	15°–45°	20°–40°	12°–30°
Width	25–70 m	4–30 m	39–55 m
Depth	8–10 m	3, 5–13 m	10–12 m
Terraces	+	+	+
Embryonal floodplain	+	+	–

Based on the analysis of morphologic and structural patterns of meltwater (Garankina et al. 2018) and fluvial networks and the comparison of postglacial sedimentary archives both exposed by the actual erosion and buried in the inactive upper chains of Late Moscow fluvial net we distinguish several major incision-infill cycles at the Eastern Borisoglebsk Upland over the last 150 ka. The first stage of fluvial incision occurred in still severe periglacial conditions at the end of the Late Moscow. Probably, it was triggered by the final degradation of glacial ice in the Nero Lake Basin leading to rapid base-level decrease and formation of the high lake terrace (130 m a.s.l.). The following stage during most of the Mikulino interglacial was associated with general landscape stabilization. Middle parts of the Late Moscow valleys, after a short-time pedogenesis, in places were almost fully infilled during the Mikulino interglacial

(Moskvitin 1976). Small isolated lakes appeared to form in the locally dammed Late Moscow incisions caused probably by the intensive slope (landslides and thaw slumps) or zoogenic processes. The existence of much greater lake basin (Kvasov 1975) is inconsistent with regional paleogeographic reconstructions showing a low level of the receiving Nero Lake during Mikulino interglacial.

Second erosion stage is related to the uncertain Early-Middle Valdai time. At the interfluve postglacial sequences, that incision reached 5–7 m in depth and is marked by distinct erosive contact found in two out of three drill cores (Fig. 1). All incisions in upper reaches were filled by alluvial, in middle – both by alluvial and colluvial sediments most likely in Early Valdai time. Third incision cycle allocates by numerous morphologic and geologic evidences in the middle reaches of the actual fluvial network

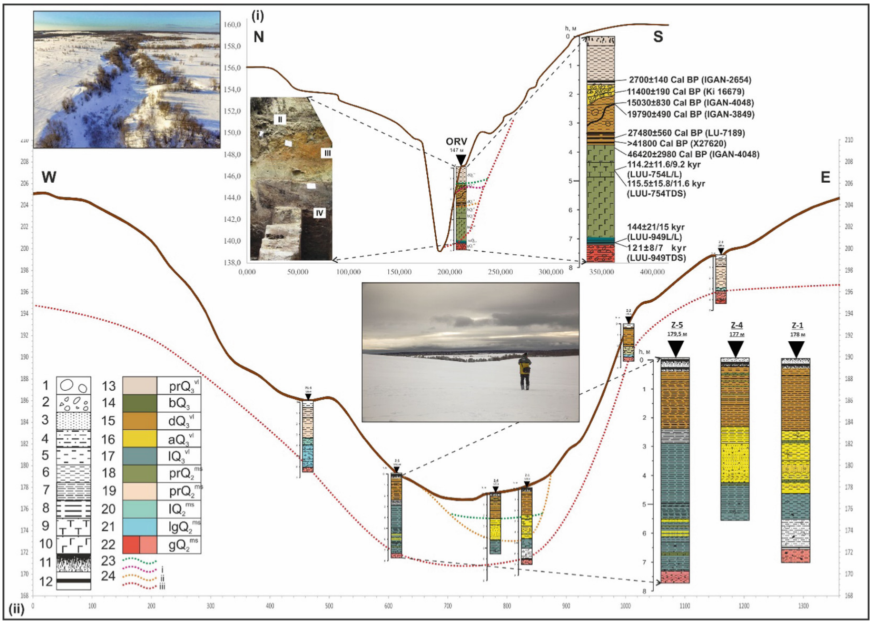

Fig. 1. Geological structure of the Late Pleistocene valley infills: (i) Cross-sections of the Cheremoshnik gully at the reference section Cheremoshnik (^{14}C and U-Th dates after Rusakov et al. 2015, 2018; Sedov et al. 2016); (ii) Cross-sections of the meridional depression at the key site area (between Lomy and Antciferovo villages). *Lithologic features* 1—boulders, 2—gravels, 3—sands, 4—loamy sands, 5—sandy loams, 6—loams, 7—clayey loams, 8—silts, 9—peat, 10—gyttja, 11—soil horizons, 12—paleosols. *Genetic and stratigraphic interpretation* 13—Late Valdai (Weichselian) cover deposits (MIS2), 14—Valdai peat deposits, 15—Late Valdai colluvial and cover deposits (MIS2), 16—Valdai alluvial sediments (MIS3), 17—Valdai lacustrine sediments (MIS4?), 18—Early Mikulino lacustrine and peat sediments (MIS5e), 19—Late Moscow cover sediments (MIS6), 20—Late Moscow lacustrine sediments (MIS6), 21—Late Moscow (MIS6) glaciolacustrine sediments, 22—(i) Moscow glacial till (MIS6) (ii) partially reworked by Late Moscow meltwaters (ii). *Incision-widening-infill cycles in the fluvial network* 23—Middle-Late Valdai infills (MIS2–MIS3), 24—erosion incisions: (i) Late Valdai (MIS2), (ii) Middle (?) Valdai (MIS3), (iii) Late Moscow (MIS6).

(Moskvitin 1976; Rusakov et al. 2018) and is non-found in the interfluves postglacial sedimentary cover. The main phase of the incision has determined the general appearance of the actual fluvial network. It resulted in deep erosion cuts and clearly shows in the landscape due to distinct rims and steep ledges of both depositional and erosive terraces 5 up to 10 m high above the floor of Puzhbol Gully and Shugor Valley. Most possibly, these indicate the actual amplitude of the Late Valdai incision probably triggered by drastic water table decrease of the Nero Lake Basin and formation of second lake terrace (100–105 m). All incisions in middle reaches were filled by alluvial sediments. It was followed by significant cover loams accumulation both at the interfluves (0.8–1.2 – more than 2.5 m) and relatively stable surfaces at the valleys (at least up to 1.5 m) leading to an essential infilling of the depressions. The latest stage of the major incision is marked by fragments of low gully terraces and knickpoints in the longitudinal gully profiles (0.5–1.5 m relative). The probable cause was due to the late major Nero Lake water table decrease (to 95–98 m) and formation of the first lake terrace in the Late Holocene. Numerous small buried superimposed cuts exposed on the sides of the Puzhbol gully show the probable influence of wildfires and increased number of extreme climatic manifestations at the second half of the Holocene and/or anthropogenic impact related to agriculturally initiated erosion.

4 Conclusions

Late Moscow glaciofluvial and Valdai fluvial systems were much denser and had greater extents than the present-day fluvial network. The latter often inherits their lower parts. However, it does not penetrate as far into the most elevated parts of interfluves and infilled headwaters where no signs of modern fluvial activity are observed (except for small steep gullies on hillslopes disconnected from the main network). That suggests much higher surface runoff discharges during the late glacial and some postglacial stages. It can be explained, respectively, by the excess glacial meltwater discharges and the Nero Lake Late Pleistocene fluctuations. Small-amplitude local incisions were widespread in the postglacial period throughout the area and probably did not have a direct connection to the regional base level (especially in the interfluve depressions disconnected from the main fluvial chains). They could have been triggered by widespread permafrost causing a substantial increase of surface runoff coefficient, wildfires, increased number of extreme climatic manifestations and/or anthropogenic impact.

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Foreword

The book collects research papers presented during the Second International Young Scientists Forum on Soil and Water Conservation and ICCE symposium 2018 "Climate Change Impacts on Sediment Dynamics: Measurement, Modelling and Management" held at Moscow from 27 to 31 August 2018. This conference was organized by World Association of Soil and Water Conservation (WASWAC) and Lomonosov Moscow State University in cooperation with the International Commission on Continental Erosion of the International Association of Hydrological Sciences and World Large Rivers Initiative.

Preface

This proceeding volume gathers together communications about theoretical and applied aspects of sediment transport monitoring and modelling with a special focus on the relationships between climate and land use changes and river systems' sediment load and quality.

Papers presented in the book deal with consequences of climate change on erosion and sediment transport in various environments of Russia, China, Italy, Iran, Ukraine and Ethiopia. The important aspect of the book is to close the gap in the field of fluvial geomorphology for the territory of Russia which covers nearly one-sixth the land surface of the Earth. In this book, we tried to rectify this with a special focus on presenting the results of the novel studies done in the field of sediment transport in Russia. There are also studies presenting diverse methods for estimating the amount of sediments, its variability in time and uncertainty of the existed monitoring programmes.

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